



ISClass

INTERNATIONAL SHIP CLASSIFICATION

**RULES FOR THE SURVEY AND CLASSIFICATION
OF STEEL VESSELS 2025**

EXPLANATION

The **Rules for the Survey and Classification of Steel Vessels** serve as the fundamental framework of IS CLASS for providing classification services to sea-going ships engaged in international voyages. The Rules define the conditions, scope, and supporting technical requirements of classification, covering areas such as ship construction, hull structure, machinery and electrical systems, fire safety, and environmental protection. They also establish survey and testing requirements, along with provisions for maintaining ships in proper condition. Collectively, these standards are intended to ensure the safety, quality, and reliability of ships, while securing broad recognition within the maritime industry.

The Rules apply to classed sea-going ships of 20 meters in length and above. Unless expressly stated otherwise, they do not extend to military ships, wooden ships, non-commercial yachts, high-speed craft, small waterplane area craft, or sailing ships.

The 2025 edition of the Rules incorporates the 2025 amendments to the *IS CLASS Rules for Conditions of Classification 2024 Rev.2*. Upon its entry into force, the 2025 edition supersedes the 2024 Rev.2 version.

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OF STEEL VESSELS 2025**

PART B – HULL SURVEYS

TABLE OF CONTENTS

CHAPTER 1	GENERAL	1
SECTION 1	GENERAL PROVISIONS	1
SECTION 2	HULL STRUCTURAL MEMBERS	4
SECTION 3	MATERIALS	14
SECTION 4	WELD DESIGN FOR HULL STRUCTURES	23
SECTION 5	DIRECT STRENGTH CALCULATIONS	34
SECTION 6	CORROSION CONTROL FOR HULL STRUCTURES	53
SECTION 7	FORE DECK FITTINGS	55
SECTION 8	TANK SLOSHING	61
SECTION 9	INTACT STABILITY	63
SECTION 10	DAMAGE STABILITY	67
SECTION 11	LOAD LINE MARKS AND MARKING	68
SECTION 12	STRUCTURAL ARRANGEMENT	71
SECTION 13	MARKING OF OPERATING DRAFT OF WORKING SHIPS	81
 CHAPTER 2	 HULL STRUCTURES	 86
SECTION 1	GENERAL PROVISIONS	86
SECTION 2	LONGITUDINAL STRENGTH	89
SECTION 3	SHELL PLATING	109
SECTION 4	DECKS	115
SECTION 5	SINGLE BOTTOMS	119
SECTION 6	DOUBLE BOTTOMS	124
SECTION 7	SIDE FRAMING	134
SECTION 8	DECK FRAMING	141
SECTION 9	CANTILEVERS	151
SECTION 10	PILLARS	156
SECTION 11	NON-WATERTIGHT PILLAR BULKHEADS	158
SECTION 12	WATERTIGHT BULKHEADS	158
SECTION 13	DEEP TANKS	164
SECTION 14	STEMS, STERN FRAMES, BULBOUS BOWS AND PROPELLER SHAFT BRACKETS	171
SECTION 15	STRENGTHENING AT ENDS OF SHIP	176
SECTION 16	ENGINE SEATINGS AND SHAFT TUNNELS	183
SECTION 17	SUPERSTRUCTURES AND DECKHOUSES	185
SECTION 18	HELICOPTER DECKS	195
SECTION 19	BULWARKS AND GUARDRAILS	198
SECTION 20	HATCHWAYS AND HATCH COVERS	199
SECTION 21	VEHICLE DECKS	237
SECTION 22	STRENGTHENED FOR HEAVY CARGOES	241
SECTION 23	STRENGTHENING FOR GRABS	242
SECTION 24	ANALYSIS OF TEMPERATURE FIELD AND THERMAL STRESS OF CARGO TANK STRUCTURE	243
SECTION 25	STRUCTURAL STRENGTHENING LOADED BY STEEL COILS ON A WOODEN SUPPORT	248
APPENDIX 1	LOADING INSTRUMENTS	346

APPENDIX 2	IACS UR L5COMPUTER SOFTWARE FOR ONBOARD STABILITY CALCULATIONS	359
APPENDIX 3	GUIDELINES FOR UR S11.2.1.3 FOR BALLAST LOADING CONDITIONS OF CARGO VESSELS INVOLVING PARTIALLY FILLED BALLAST TANKS	369
APPENDIX 4	SLAMMING STRENGTH ASSESSMENT OF BOW BOTTOM STRUCTURES	385
CHAPTER 3	EQUIPMENT AND OUTFITS	392
SECTION 1	RUDDERS	392
SECTION 2	ANCHORING AND MOORING EQUIPMENT	417
SECTION 3	CEILINGS AND CARGO BATTENS	429
SECTION 4	MASTS OR DERRICK POSTS	431
SECTION 5	EMERGENCY TOWING ARRANGEMENTS	431
SECTION 6	SHIPBOARD FITTINGS AND SUPPORTING HULL STRUCTURES ASSOCIATED WITH TOWING AND MOORING ON CONVENTIONAL VESSELS	435
SECTION 7	SUPPORT STRUCTURE FOR DECK EQUIPMENT	443
SECTION 8	ENERGY-SAVING APPENDAGES IN FRONT OF PROPELLERS	449
APPENDIX 1	GUIDELINES FOR CALCULATION OF BENDING MOMENT AND SHEAR FORCE DISTRIBUTION	452
APPENDIX 2	DIRECT MOORING ANALYSES	460
CHAPTER 4	DOUBLE HULL OIL TANKERS	463
SECTION 1	GENERAL PROVISIONS	463
SECTION 2	SHELL PLATING	468
SECTION 3	DECKS	471
SECTION 4	DOUBLE BOTTOM STRUCTURE	472
SECTION 5	DOUBLE HULL CONSTRUCTION	477
SECTION 6	DECK FRAMING	480
SECTION 7	PLANE TRANSVERSE OILTIGHT BULKHEADS	482
SECTION 8	PLANE LONGITUDINAL OILTIGHT BULKHEADS	485
SECTION 9	CORRUGATED TRANSVERSE OILTIGHT BULKHEADS	488
SECTION 10	CORRUGATED LONGITUDINAL OILTIGHT BULKHEADS	489
SECTION 11	NON-OILTIGHT BULKHEADS AND WASH BULKHEADS	492
SECTION 12	SPECIAL REQUIREMENTS	494
SECTION 13	CARGO TANK HATCHWAYS	497
APPENDIX 1	DIRECT STRENGTH CALCULATION OF DOUBLE HULL OIL TANKERS	497
CHAPTER 5	SINGLE HULL OIL TANKERS	504
SECTION 1	GENERAL PROVISIONS	504
SECTION 2	SHELL PLATING AND DECKS	504
SECTION 3	LONGITUDINAL BOTTOM FRAMING	506
SECTION 4	TRANSVERSE BOTTOM FRAMING	510
SECTION 5	LONGITUDINAL SIDE FRAMING	511
SECTION 6	TRANSVERSE SIDE FRAMING	513
SECTION 7	TRANSVERSE DECK FRAMING	515
SECTION 8	TRUNK STRUCTURE	516
CHAPTER 6	CONTAINER SHIPS	518

SECTION 1	GENERAL PROVISIONS	518
SECTION 2	LONGITUDINAL STRENGTH	519
SECTION 3	DECK STRUCTURE	534
SECTION 4	SHELL PLATING	536
SECTION 5	SIDE FRAMING	537
SECTION 6	DOUBLE BOTTOM	537
SECTION 7	BULKHEADS	539
SECTION 8	BOW SIDE STRUCTURE STRENGTHENING	539
SECTION 9	ADDITIONAL REQUIREMENTS FOR CONTAINER SHIPS OF GREATER THAN 250 M IN LENGTH	542
SECTION 10	LONGITUDINAL STRENGTH OF COMBINED BENDING AND TORSIONAL MOMENTS FOR SHIPS WITH LARGE OPENINGS	552
APPENDIX 1	CONTAINER SECURING	555
APPENDIX 2	DIRECT STRENGTH CALCULATION OF CONTAINER SHIPS	583
APPENDIX 3	CALCULATION OF SHEAR FLOW	619
APPENDIX 4	BUCKLING CAPACITY	622
APPENDIX 5	HULL GIRDER ULTIMATE BENDING CAPACITY	637
CHAPTER 7	BULK CARRIERS	648
SECTION 1	GENERAL PROVISIONS	648
SECTION 2	BOTTOM STRUCTURES	650
SECTION 3	SIDE FRAMING	651
SECTION 4	WATERTIGHT BULKHEADS	654
SECTION 5	HOPPER TANKS	655
SECTION 6	TOPSIDE TANKS	659
SECTION 7	ADDITIONAL REQUIREMENTS FOR LOADING MANUALS AND LOADING INSTRUMENTS	663
SECTION 8	OVERALL LONGITUDINAL STRENGTH IN FLOODED CONDITION	667
SECTION 9	STRENGTH OF CORRUGATED TRANSVERSE WATERTIGHT BULKHEADS IN HOLD-FLOODED CONDITIONS	668
SECTION 10	ALLOWABLE HOLD LOADING CONSIDERING HOLD FLOODING	680
SECTION 11	HATCH COVERS OF CARGO HOLDS	685
SECTION 12	HARMONIZED NOTATIONS AND CORRESPONDING DESIGN LOADING CONDITIONS FOR BULK CARRIERS	685
SECTION 13	REQUIREMENTS FOR THE FITTING OF A FORECASTLE	693
SECTION 14	DOUBLE SIDE STRUCTURE	695
SECTION 15	ADDITIONAL REQUIREMENTS FOR STIFFENING STRUCTURAL MEMBERS	699
APPENDIX 1	DIRECT STRENGTH CALCULATION OF BULK CARRIERS	701
APPENDIX 2	HOLD MASS CURVES	707
CHAPTER 8	ROLL ON-ROLL OFF SHIPS, PASSENGER SHIPS, RO-RO PASSENGER SHIPS AND FERRIES	715
SECTION 1	GENERAL PROVISIONS	715
SECTION 2	HULL STRUCTURE	716
SECTION 3	MOVABLE PLATFORMS AND SLOPING VEHICLE RAMPS	720
SECTION 4	BOW DOORS AND INNER DOORS	721

SECTION 5	SIDE SHELL AND STERN DOORS	731
SECTION 6	VEHICLE RAMPS	736
SECTION 7	DIRECT CALCULATIONS	737
SECTION 8	EXTERNAL GLASS BALUSTRADES	741
CHAPTER 9	TUGS	744
SECTION 1	GENERAL PROVISIONS	744
SECTION 2	HULL FRAMING	744
SECTION 3	MACHINERY CASINGS	745
SECTION 4	BULWARKS AND FENDERS	745
SECTION 5	TOWING ARRANGEMENTS AND SUPPORTING STRUCTURE	745
SECTION 6	TOWING WINCH EMERGENCY RELEASE SYSTEMS	746
CHAPTER 10	OFFSHORE SUPPLY SHIPS	751
SECTION 1	GENERAL PROVISIONS	751
SECTION 2	CARGO CONTAINMENT AND OTHER FITTINGS	752
SECTION 3	SHELL AND DECK PLATING	754
SECTION 4	HULL ENVELOPE FRAMING	755
SECTION 5	SUPERSTRUCTURES AND DECKHOUSES	755
CHAPTER 11	BARGES	756
SECTION 1	GENERAL PROVISIONS	756
SECTION 2	LONGITUDINAL STRENGTH	758
SECTION 3	SHELL AND DECK PLATING	759
SECTION 4	HULL ENVELOPE FRAMING	760
SECTION 5	STRENGTHENING AT ENDS OF SHIP	766
APPENDIX 1	METHOD OF CHECKING TRANSVERSE STRENGTH OF PONTOON BARGES	768
CHAPTER 12	FLOATING CRANES	772
SECTION 1	GENERAL PROVISIONS	772
SECTION 2	LONGITUDINAL STRENGTH	773
SECTION 3	SHELL PLATING	773
SECTION 4	DECKS	774
SECTION 5	SINGLE BOTTOMS	774
SECTION 6	DOUBLE BOTTOMS	775
SECTION 7	SIDE FRAMING	777
SECTION 8	STRENGTH DECK FRAMING	777
CHAPTER 12	RE CARRIERS	779
SECTION 1	GENERAL PROVISIONS	779
SECTION 2	LONGITUDINAL STRENGTH	781
SECTION 3	HULL FRAMING	782

SECTION 4	BULKHEADS	788
SECTION 5	EASY LOADING REQUIREMENTS	790

CHAPTER 1 - GENERAL

SECTION 1 - GENERAL PROVISIONS

1.1.1 Application

1.1.1.1 This PART applies to sea-going steel ships of all welded construction.

1.1.1.2 In addition, the hull is to comply with the applicable requirements in PART ONE of the Rules.

1.1.1.3 CSR oil tankers and bulk carriers are to satisfy the requirements of PART NINE of the Rules.

1.1.2 Definitions

1.1.2.1 Length of ship L (in m), i.e. the Rule length, is the distance measured on the waterline at the scantling draught from the forward side of the stem to the aft side of the rudder post, or to the centre of the rudder stock if there is no rudder post. L is not to be less than 96%, and need not be greater than 97%, of the extreme length on the waterline at the scantling draught. In ships with unusual stern and bow arrangement, the length L is to be specially considered.

For pontoon hulls, L is the distance on the waterline at the scantling draught from the forward side of the fore end plate to the aft side of the aft end plate.

For ships without rudder stocks (such as ships provided with azimuth thrusters), L is 97% of the extreme length on the waterline at the scantling draught.

1.1.2.2 Breadth of ship B (in m), is the greatest moulded breadth measured amidships at the scantling draught.

1.1.2.3 Moulded depth D (in m), is the vertical distance measured at the middle of the length L from top of keel to top of the deck beam at side on the uppermost continuous deck. When a rounded gunwale is arranged, the moulded depth is to be measured to the point of intersection of the continued moulded lines of the deck and side shell plating.

1.1.2.4 Draught d (in m), i.e. the scantling draught, is the vertical distance measured at the middle of the length L from top of keel to the waterline at the scantling draught. Scantling draught, at which the strength requirements for the scantlings of the ship are met and represents the full load condition. The scantling draught is to be not less than that corresponding to the assigned freeboard.

1.1.2.5 Block coefficient C_b is the moulded block coefficient corresponding to the waterline at the scantling draught, to be determined by the following formula:

$$C_b = \frac{\nabla}{LBd}$$

where: ∇ — moulded displacement, in m^3 , at scantling draught d ;
 L, B, d — see 1.1.2.1, 1.1.2.2 and 1.1.2.4 of this Section.

1.1.2.6 Uppermost continuous deck is the uppermost deck which extends from the stem to the stern.

1.1.2.7 Strength deck means:

- (1) the uppermost continuous deck;
- (2) the superstructure deck extending within $0.5 L$ amidships, and having a length not less than $0.15 L$, and the uppermost continuous deck extending outside the region of such a superstructure.

1.1.2.8 Lower decks: The continuous deck next below the uppermost continuous deck is to be named as 2nd deck, and so on. They are generally called lower decks.

1.1.2.9 Bulkhead deck is the highest deck to which the transverse watertight bulkheads extend.

1.1.2.10 Freeboard deck is the deck from which the freeboard is measured in accordance with the International Convention on Load Lines, 1966.

1.1.2.11 Platform decks are the non-continuous decks below the strength deck, which are not considered to be effective decks for longitudinal strength.

1.1.2.12 Superstructure and deckhouse: Superstructure is an enclosed structure on the uppermost continuous deck, extending from side to side of the ship or with the side plating not being inboard of the shell plating more than 4% of the breadth B . Forecastle, bridge and poop are regarded as superstructures. All other enclosed structures are to be termed as deckhouses.

1.1.2.13 Long superstructure and short superstructure: A superstructure having a length greater than $0.15 L$ and not less than 6 times its height is to be termed as a long superstructure, otherwise it is to be regarded as a short superstructure.

1.1.2.14 Long deckhouse and short deckhouse: A deckhouse having a length greater than $0.15 L$ and not less than 6 times its height is to be termed as a long deckhouse, otherwise it is to be regarded as a short deckhouse.

1.1.2.15 Stowage rate γ (m^3/t) is the volume of the hold, in m^3 , excluding the volume contained within the depth of the cargo hatchway, divided by the mass of cargo, in tons, stowed therein.

1.1.2.16 Forward and after perpendiculars: The forward perpendicular is to coincide with the foreside of the stem on the scantling draught waterline on which the length L is measured. The after perpendicular is the perpendicular to the scantling draught waterline at a distance L aft of the fore end.

1.1.2.17 Large openings: A deck opening is to be regarded as a large opening if any of the following conditions applies:

- (1) $\frac{b}{B_1} \geq 0.7$;
- (2) $\frac{l_H}{l_{BH}} \geq 0.89$;
- (3) $\frac{b}{B_1} > 0.6$ and $\frac{l_H}{l_{BH}} > 0.7$.

where: b — breadth of the opening, in m. Where there are several hatches

B_1 — maximum breadth of deck, in m, including opening, measured at the mid-length of the opening;

l_H — length of the hatch, in m;

l_{BH} — distance between centrelines of the deck strips at each end of the opening, in m, as shown in Figure 1.1.2.17. Where there are no further hatches fore or aft of the one under consideration, then l_{BH} is to be measured to the bulkhead.

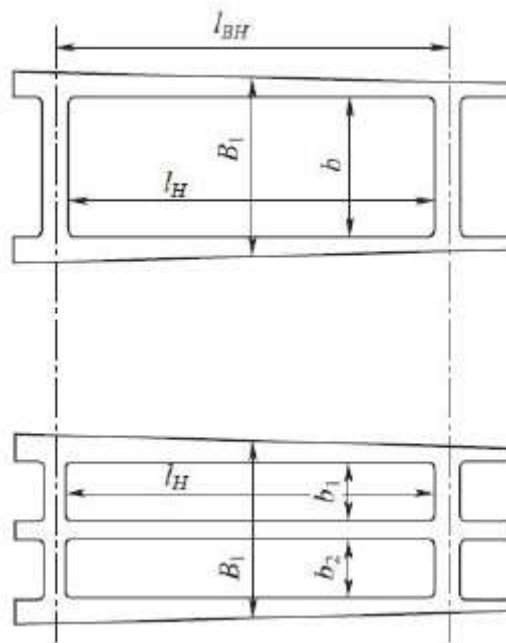


Figure 1.1.2.17

1.1.2.18 Primary members: The primary supporting members of hull are regarded as primary members, such as web frames, side stringers, transverses, deck girders, plate floors, bottom girders, bulkhead webs, etc.

1.1.2.19 Secondary members: The stiffeners of the plate are generally regarded as secondary members, i. e. frames, longitudinals, beams, bulkhead stiffeners and members of bracket floors, etc.

1.1.2.20 Load line length L_L (in m) is the ship's length as defined in Regulation 3 of Annex I to the International Convention on Load Lines, 1966.

1.1.2.21 Position 1 is as defined in Regulation 13 of Annex I to the International Convention on Load Lines, 1966.

1.1.2.22 Position 2 is as defined in Regulation 13 of Annex I to the International Convention on Load Lines, 1966.

1.1.2.23 Main frames are side frames between the collision bulkhead and the aft peak bulkhead, and below the lowest deck.

1.1.2.24 Frames in a 'tween deck space are frames between two decks.

1.1.2.25 Fore peak is a compartment situated forward of the collision bulkhead and below the bulkhead deck.

1.1.2.26 Aft peak is a compartment situated aft of the aft watertight bulkhead at the aft end of the ship and below the bulkhead deck or the watertight platform deck.

1.1.2.27 *V*, the maximum service speed, in knots, means the greatest speed which the ship is designed to maintain in service at her deepest seagoing draught at the maximum propeller RPM and corresponding engine MCR (Maximum Continuous Rating).

SECTION 2 - HULL STRUCTURAL MEMBERS

1.2.1 General requirements

1.2.1.1 Except where otherwise stated, the Rule section modulus or moment of inertia in this PART is the minimum required value of the section in association with attached plating, and the attached plating is assumed as being normal to the web. When the attached plating is not normal to the web and the angle between them is less than 75°, the sectional characteristics (moment of inertia, section modulus and shear area) are to be calculated in respect to the axis parallel to the attached plating. When a structural member is of rolled section(s), its actual section modulus may be approximately determined by the following formula:

$$W = W' \sin \alpha \quad \text{cm}^3$$

where: *W'* — actual section modulus with the attached plating assumed as being normal to the
 α — angle between web and attached plating, in degrees.

1.2.1.2 Except where otherwise stated in the Rules, holes are not to be cut at random in the structural members specified in this PART.

1.2.1.3 In formulae or tables where only midship and end scantlings are given, the reduction from the midship to the end scantlings is to be effected in as gradual a manner as practicable. At the break of structures, constructional arrangement is to be made to ensure a gradual transition.

1.2.1.4 Unless otherwise stated, any intermediate value between the values listed in the Tables may be obtained by linear interpolation.

1.2.1.5 As commercialized marine plates and rolled sections are not produced in sequential size series and for the purpose of providing an economic and reasonable structural requirement without compromising structural strength, the rounding tolerance for selecting steel plates according to the sizes of structural members as required in this PART is to be based on the following principles:

- (1) Where the decimal part of the calculated plate thickness in this PART is 0.25 mm or less, it may be neglected; where it is greater than 0.25 mm but less than 0.75 mm, to be taken as 0.5 mm; where it is 0.75 mm or more, a round number of 1 mm is to be taken.
- (2) For a structural member made of rolled section(s), its section modulus with the effective attached plate being taken into account, may be 3% less than the value required in this PART.
- (3) When same sizes are taken during construction for a group of members of a same type made of rolled sections adjacent to each other in the same area, their respective section moduli with their effective attached plates being taken into account, are not to be less than the mean value of the values respectively required in this PART for individual members of the group. However, this mean value is not to be less than 95% of the greatest value required in this PART for an individual member of the group.
- (4) The above principles (2) and (3) are not to be applied together.

1.2.1.6 Unless otherwise stated, all scantlings given in this PART are to be regarded as the minimum required. When designing structural members, those subject to excessive corrosion or wear and tear in service may be adequately increased in thickness.

1.2.1.7 Local members which may frequently bear the forces resulting from docking, pushing or towing, etc., are to be strengthened appropriately.

1.2.2 Attached plating of members

1.2.2.1 The effective sectional area A of attached plating of primary members is to be determined as follows, but is not to be less than the sectional area of the face plate:

- (1) For a member attached to plane plating:

$$A = 10 f b t_p \text{ cm}^2$$

- (2) For a member attached to corrugated plating and parallel to the corrugations:

$$A = 10 a t \text{ cm}^2$$

- (3) For a member attached to corrugated plating and at right angles to the corrugations:

$$A = 10 b f t_f \text{ cm}^2$$

where: f — factor, equal to $0.3(l/b)^{2/3}$, but not to exceed 1;

b — the mean width, in m, of the load-bearing area of primary members;

l — the overall length, in m, of the primary member;

t_p — the mean thickness, in mm, of the attached plating;

b_f — the width, in m, of the face plate of primary members;

t_f — the thickness, in mm, of the face plate of primary members;

a — the width, in m, of corrugated plating flange;

t — the thickness, in mm, of corrugated plating.

1.2.2.2 For secondary members, the width of attached plating is taken as one spacing of the corresponding members.

1.2.3 The span point of members

1.2.3.1 Except where otherwise stated, the span used for the calculating of the members in this PART is the effective span between the span points.

1.2.3.2 For primary members, the span point is to be taken at a point b_e distant from the end of the member (See Figure 1.2.3.2):

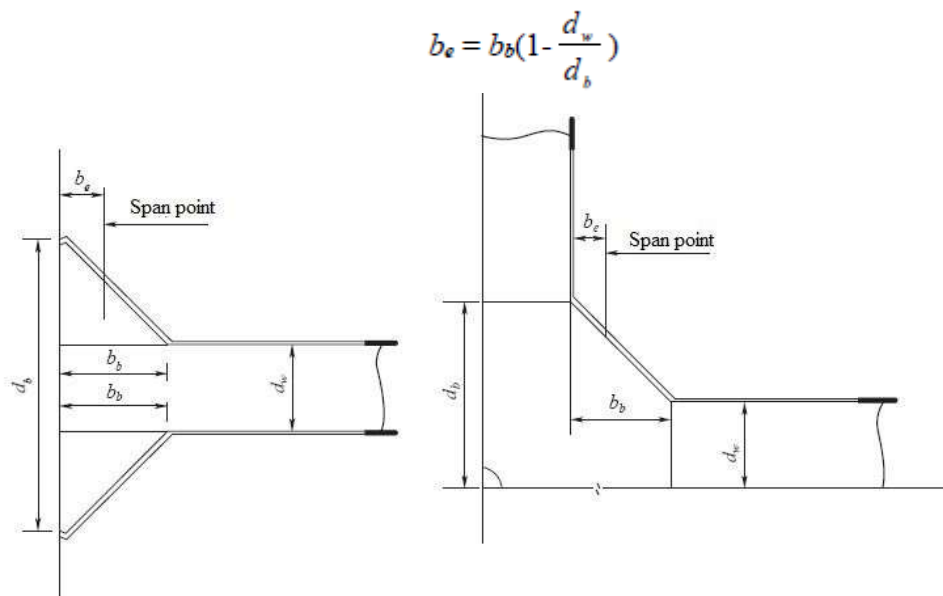


Figure 1.2.3.2

1.2.3.3 For span points of secondary members where end brackets are fitted, see Figure 1.2.3.3 (1) (1) Where there is no end bracket, the span point is to be taken at the end of the member (as shown in Figure 1.2.3.3 (2)).

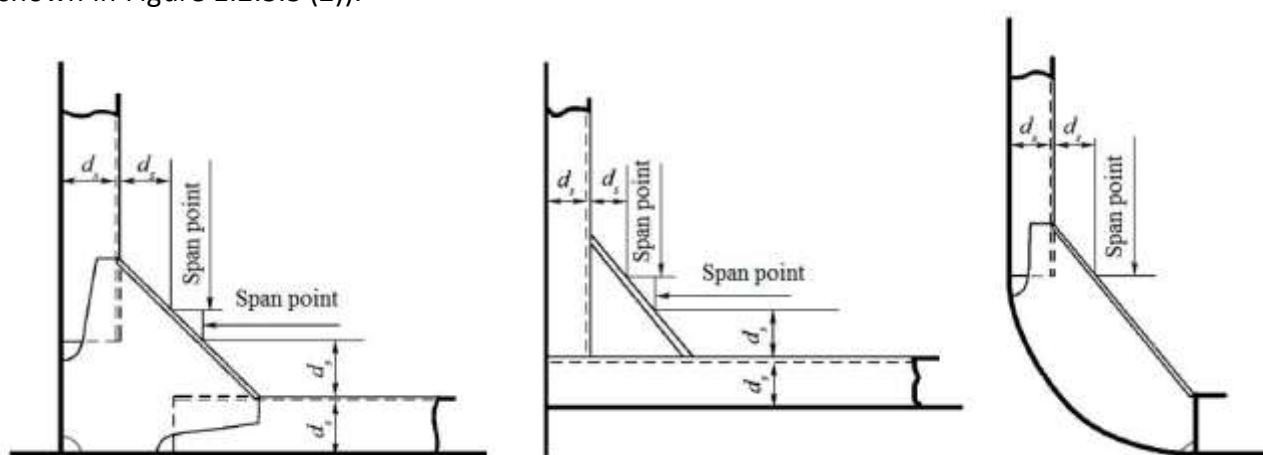


Figure 1.2.3.3(1)

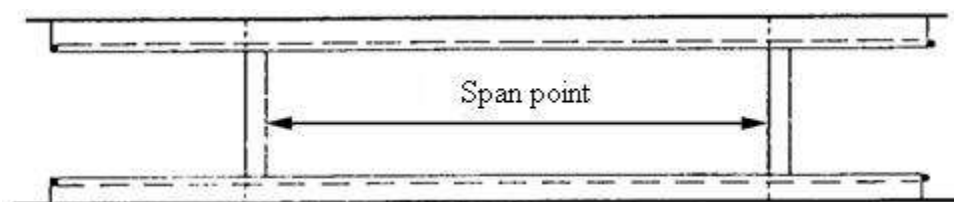


Figure 1.2.3.3(2)

1.2.3.4 Unless otherwise specified in this PART, the span of curved members is defined as the chord length between span points.

1.2.3.5 Where the ends of stiffening members are not substantially fixed against rotation and displacement, consideration will be given to the effective span to be used for the stiffener.

1.2.4 Geometrical characteristics of members.

1.2.4.1 Section area A_z , moment of inertia I and section modulus W of rolled sections (including bulb flats, unequal angle bars, and unequal angle bars of unequal thickness) (see Figure 1.2.4.1) together with attached plating are to be calculated by the following formulae:

$$A_z = A_1 + A \quad \text{cm}^2$$

$$I = I_{x1} + (y_1 - y)^2 A_1 + \frac{At^2}{12} \times 10^{-2} + (0.05 t + y)^2 A \quad \text{cm}^4$$

$$W = \frac{I}{0.1h - y} \quad \text{cm}^3$$

where: h — height of the sections, in mm;

A_1 — sectional area of the sections, in cm^2 ;

I_{x1} — moment of self-inertia of the sections, in cm^4 ;

y_1 — neutral axis of the sections, in cm;

A — sectional area of the attached plate, in cm^2 ;

t — thickness of the attached plate in mm;

y — neutral axis with attached plate being considered, to be calculated by the following formula:

$$y = \frac{A_1 y_1 - 0.05 A t}{A_z} \quad \text{cm}$$

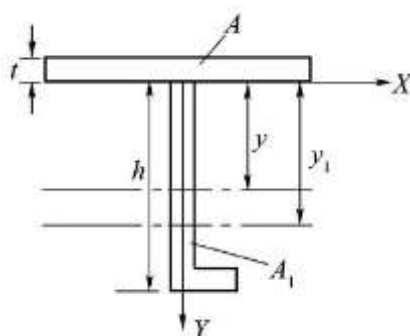


Figure 1.2.4.1

1.2.4.2 Where the thickness of both face plate and attached plate of T sections is not greater than 1/10 of web depth, section modulus W and moment of inertia I for T sections with attached plating (see Figure 1.2.4.2) may be calculated by the following formulae:

$$W = \frac{d_w}{10} \left[a + \frac{f_s}{6} \left(1 + \frac{2(A-a)}{2A+f_s} \right) \right] \text{ cm}^3$$

$$I = \frac{d_w^3}{100} \left[\frac{1}{3} f_s + \frac{Aa - 0.25 f_s^2}{A + a + f_s} \right] \text{ cm}^4$$

where: A — sectional area of attached plating, in cm^2 ; where $A < a$, it is taken as $A = a$;

f_s — sectional area of web plate, in cm^2 ;

d_w — depth of web, in mm.

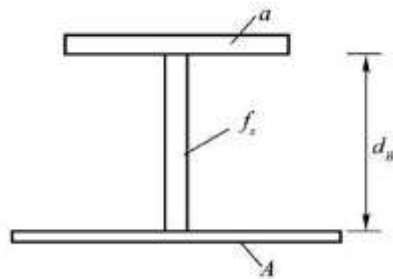


Figure 1.2.4.2

1.2.4.3 The section modulus W and moment of inertia I of a corrugation over a spacing s for corrugated bulkheads (see Figure 1.2.4.3) may be calculated by the following formulae:

$$W = d_w t \left(a + \frac{b}{3} \right) \text{ cm}^3$$

$$I = \frac{1}{20} d_w^3 t \left(a + \frac{b}{3} \right) \text{ cm}^4$$

where: a — width of corrugation flange, in m;

b — width of corrugation web, in m;

d_w — depth of corrugation, in mm;

t — thickness of corrugated bulkhead plating, in mm;

α — angle between web and flange of a corrugation.

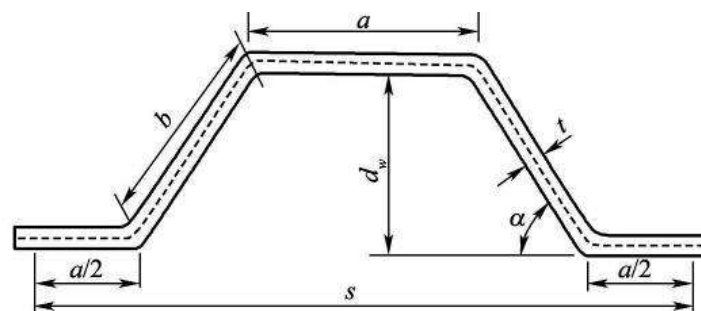


Figure 1.2.4.3

1.2.4.4 The section modulus W and moment of inertia I of double skin bulkheads (see Figure 1.2.4.4) may be calculated by the following formulae:

$$W = b \left(f s t_p + \frac{b t_w}{6} \right) \times 10^3 \quad \text{cm}^3$$

$$I = 5 \left(f s t_p + \frac{b t_w}{6} \right) b^2 \times 10^4 \quad \text{cm}^4$$

where: b — spacing of double skins, in m;
 s — average spacing of diaphragms, in m;
 t_p — thickness of double skin bulkheads, in mm;
 t_w — thickness of web, in mm;
 f — factor, the same as specified in 1.2.2.1 of this Chapter.

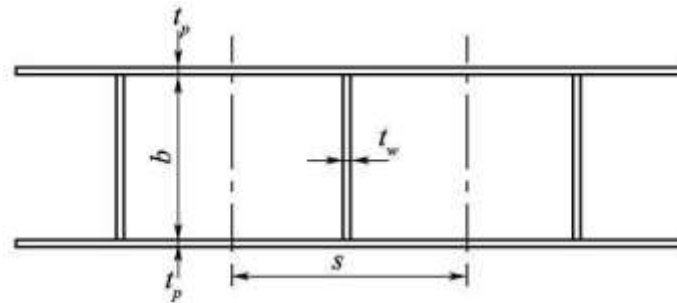


Figure 1.2.4.4

1.2.4.5 The minimum radius r of inertia of sectional area of members is to be calculated by the following formula:

$$r = \sqrt{\frac{I}{A}} \quad \text{cm}$$

where: I — minimum moment of inertia of sectional area of members, in cm^4 ;
 A — sectional area of members, in cm^2 .

1.2.5 Structural details

1.2.5.1 Primary members are to be so arranged as to ensure effective continuity of structure, and abrupt changes of depth or section are to be avoided. Where members abut on both sides of a bulkhead, or on other members, arrangements are to be made to ensure that they are in alignment. Primary members in tanks are to form a continuous line of support and wherever possible, a complete ring framing. The connections of the ring framing are to be made of rounded corners having an adequate radius, and the radius of rounded corners is in general not to be less than the web depth of the adjacent members.

1.2.5.2 The web thickness t_w of primary members is not to be less than $0.01 S_w$, in mm (where S_w = spacing of horizontal stiffeners on primary member web, or depth of unstiffened web, in mm); but not less than 7 mm in dry spaces and not less than 8 mm in tanks. For ships of less than 60 m in length, the web thickness may be reduced by 1 mm. For ships of less than 40 m in length, the web thickness may be reduced by 2 mm.

1.2.5.3 The sectional area A_f of face plate of primary members is not to exceed $d_w t_w / 150$, in cm^2 (where d_w = depth of primary member web, in mm, t_w = thickness of primary member web, in mm).

1.2.5.4 Primary members are to be supported by tripping brackets. Where the primary members are of symmetrical section, the tripping brackets are to be fitted four secondary member spaces apart and if the width of the face plate of primary members is more than 400 mm, a back bracket is to be provided in way of the tripping bracket. Where the primary members are of asymmetrical section, tripping brackets are to be fitted on one side of the web at alternate secondary members. Tripping brackets are also to be fitted to the primary members in way of concentrated loads. If the ratio of depth to thickness of the web is greater than 55, tripping brackets or stiffeners are to be fitted close to the toes of end brackets. The height of tripping brackets is to be extended to the face plate of primary members. The breadth is not to be less than 40% of the height. Where the unsupported breadth of the face plate or flange of primary members exceeds $15 t$ (t being thickness of face plate of primary members), the tripping brackets are to be welded to the face plate or flange of primary members. The thickness t_b (in mm) of tripping brackets is not to be less than $5 + 0.025 L$, but need not be greater than that of web of primary members, where L being length of ship (which need not be greater than 300 m in calculation). Where the free edge length l_b (in m) is greater than $0.06 t_b$, the tripping brackets are to have face plate or flange, and the sectional area A (in cm^2) of which is generally not to be less than $10 l_b$.

1.2.5.5 All openings on structural members are to be kept clear of areas of stress concentration and where this is impracticable, corresponding compensation is to be made. All corners of openings are to be well rounded. Where structural members are directly connected with plates, hard points are to be avoided.

1.2.5.6 Within $0.4 L$ amidships, where the web height of strength deck girders is greater than $65 t K$ (t being web thickness, while K being material factor), horizontal stiffeners are to be provided parallel to face plate.

1.2.6 Secondary member end connections

1.2.6.1 Unless otherwise specified in this PART, the end connections of secondary members are to comply with the requirements of 1.2.6.

1.2.6.2 The ends of secondary members are generally to be bracketed, see Figure 1.2.6.2. Where secondary members pass through primary members, secondary members are to be connected to the webs of primary members by welding.

1.2.6.3 Where the secondary members contributing to longitudinal bending strength are cut in way of bulkheads or transverse primary members, connecting brackets are to be provided so as to ensure the longitudinal continuity. The brackets at both sides of the bulkheads or transverse primary members are to be in alignment.

1.2.6.4 The section modulus W of frames that is used for determining the scantlings of brackets is to be selected as follows:

- (1) For the brackets connecting the secondary to the primary members, W is the section modulus of the secondary members.
- (2) For the brackets at frame ends, W is the section modulus of the frames.
- (3) For other brackets, W is the lesser of section moduli of two connecting members.

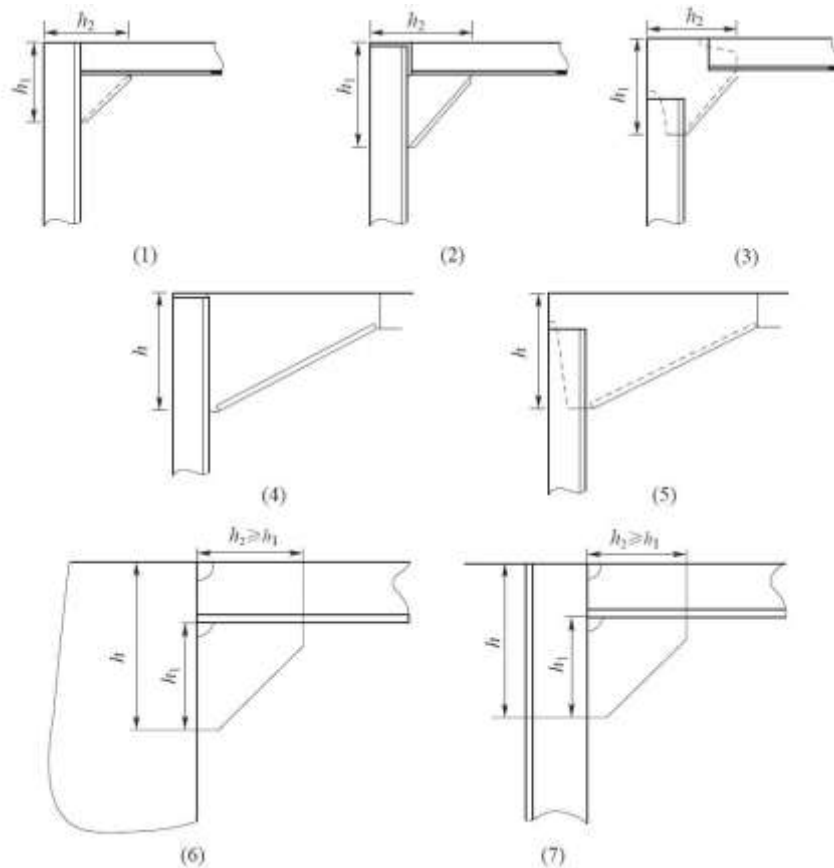


Figure 1.2.6.2

1.2.6.5 The thickness t of brackets is to be not less than that obtained from the following formulae:
mm, for brackets with face plate or flanged brackets

$$t = (0.25\sqrt{W} + 2) \sqrt{\frac{R_{eH\_s}}{R_{eH\_b}}} + C \quad \text{mm, for brackets with face plate or flanged brackets}$$

$$t = (0.25\sqrt{W} + 3.5) \sqrt{\frac{R_{eH\_s}}{R_{eH\_b}}} + C \quad \text{mm, for brackets without face plate or unflanged brackets}$$

where: W — Rule section modulus of frames, in cm^3 ;

R_{eH_s} — yield stress of material of frames, in N/mm^2 ;

R_{eH_b} — yield stress of material of brackets, in N/mm^2 ;

C — coefficient, taken as 2.5 for brackets in tanks or 1.5 for other brackets.

The minimum thickness of brackets is generally to be 6.5 mm and need not be greater than 15 mm.

1.2.6.6 Where the Rule section modulus W of frames is not less than 500 cm³ or the free edge is more than 50 times the thickness of brackets in length, the brackets are to be flanged or fitted with face plates. The breadth b of the flanges or face plates is not to be less than that obtained from the following formula:

$$b = 0.04W + 40 \text{ mm, and not less than 50 mm}$$

where: W — Rule section modulus of frames, in cm³.

1.2.6.7 The arm length h of brackets is not to be less than 2.2 times the web depth of frames (where the ends of frames are welded, it may be reduced to not less than twice the web depth, see Figure 1.2.6.2 (1)), and is not to be less than that obtained from the following formula:

$$h = 75 \sqrt{\frac{W}{t - C}} \text{ mm}$$

where: W — Rule section modulus of frames, in cm³;

t — thickness of brackets, in mm;

C — coefficient, see 1.2.6.5 of this Section.

1.2.6.8 The two arms of the brackets are to be as far as possible equal in length. Where the two arms are not the same in length, they are to comply with the following:

$$h_1 + h_2 \geq 2h \quad h_1 \geq 0.8h$$

$$h_2 \geq 0.8h$$

where: h_1, h_2 — actual length of bracket arms, in mm, as shown in Figure 1.2.6.2;

h — arm length of brackets, in mm, see 1.2.6.7 of this Section.

1.2.6.9 Where the frame is lapped to the bracket, the length of overlap is not to be less than 1.25 times the web depth of the frame.

1.2.6.10 Where the frames are bracketed to primary members, such brackets are in general to be extended to the face plates of primary members.

1.2.7 Primary member end connections

1.2.7.1 Unless otherwise specified in this PART, the end connections of primary members are to be in compliance with the requirements of 1.2.7.

1.2.7.2 The ends of primary members are to be fitted with connecting brackets. Where two primary members are connected with a bracket, the scantlings of the bracket may be determined based upon the primary member having the lesser section modulus.

1.2.7.3 The arm length of the end bracket, which includes the web depth of the primary member, is not to be less than twice the web depth of the primary member, and the thickness of the bracket is not to be less than that of the web plate of the primary member. The brackets are to be flanged or fitted with face plates, the scantlings of which are generally to be the same as the face plates of primary members. The web plates of primary members are to be welded to connecting members.

Where the side length of the non-stiffened triangle of the bracket is greater than $100t$ (t being the web thickness of the bracket), stiffeners parallel to the face plate of the bracket are to be fitted in accordance with 5.12.2.6 of Chapter 5 of this PART.

1.2.7.4 Where primary members, which are not in tanks, are connected by integral end brackets to bulkheads (i.e. the web plates of primary members gradually raised at ends), the arm length of brackets is not to be less than 1.5 times the web depth of primary members. The web plates of primary members are to be welded to bulkheads and the face plates are to be extended continuously to the bulkheads.

1.2.7.5 Where the deck girders or transverses are to be connected to bulkheads or vertical members of shell plating, the increase of scantlings of the vertical members may be required in order to ensure that connecting joints have adequate resistance to rotation.

1.2.7.6 In order to avoid the stress concentration at ends of primary strength members, the thickness of their web plates are to be adequately increased in way of toe ends of large brackets, and the face plates of brackets are to be beveled to ends. The height of toes is in general not to be greater than the thickness t_w of bracket toes, and is not to be less than 15 mm. For the recommended structural configuration of toe ends of large brackets, see Figure 1.2.7.6.

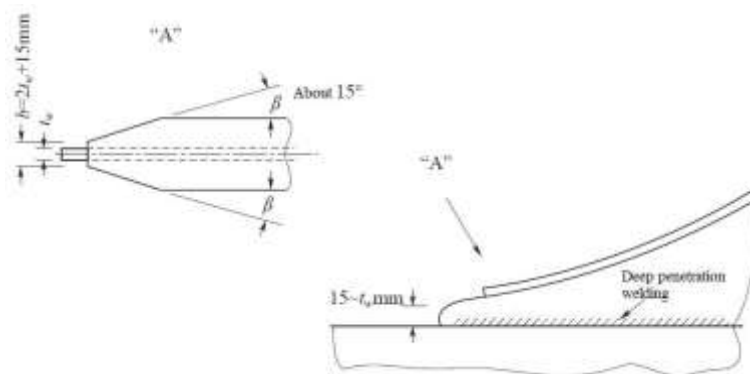


Figure 1.2.7.6

1.2.8 Standard spacing of framing members

1.2.8.1 The standard spacing sb of frames, beams or longitudinals (bottom, side and deck) is to be calculated by the following formula:

$$sb = 0.0016L + 0.5 \text{ m, but not greater than } 0.7 \text{ m where: } L \text{ — length of ship, in m.}$$

1.2.8.2 In fore and aft peak tanks, the standard spacing sb of frames or side longitudinals is to be that obtained from 1.2.8.1 or 0.6 m, whichever is the lesser.

1.2.8.3 Within $0.05L$ at ends, the standard spacing sb of deck longitudinals or deck transverses of superstructures and deckhouses is to be that obtained from 1.2.8.1 or 0.6 m, whichever is the lesser.

SECTION 3 – MATERIALS

1.3.1 General requirements

1.3.1.1 The chemical composition and mechanical properties of hull structural steels are to comply with the relevant requirements of Chapter 3 of PART ONE of ISC Rules for Materials and Welding.

1.3.1.2 Manufacture and testing of hull structural steels are to comply with the requirements of Chapter 1 and Chapter 2 of PART A of ISC Rules for Materials and Welding.

1.3.1.3 Steel castings or steel forgings used for the construction of stems, rudder posts, shaft brackets, rudder stocks and other hull structures are to comply with the relevant requirements of Chapter 5 and Chapter 6 of PART ONE of ISC Rules for Materials and Welding.

1.3.1.4 Except where otherwise stated, the elastic modulus of steel is to be taken as 2.06×10^5 N/mm².

1.3.1.5 Steels having a yield point not less than 265 N/mm² are regarded as higher tensile steels.

1.3.1.6 Where higher tensile steel is used for hull structures, its category, grade, location and extent are to be marked on the structural drawings so as to facilitate for maintenance.

1.3.1.7 The material factor *K* of hull structural steel is given in Table 1.3.1.7.

1.3.1.8 Unless specially provided, the yield strength of material (yield stress or yield point of material) is the specified minimum yield stress in the Rules for Materials and Welding, and the non-proportional extension strength is the minimum value of specified non-proportional extension stress.

Material Factor *K*-Table 1.3.1.7

Yield strength <i>ReH</i> (N/mm ²)	Material factor <i>K</i>	Yield strength <i>ReH</i> (N/mm ²)	Material factor <i>K</i>
235	1	355	0.72
265	0.92	390	0.68 (0.66 ^①)
315	0.78	460	0.62 ^②

Notes:

① only apply to the strength deck and hatch coaming of containerships complying with the requirements of 7.1.1.4 of Section 1, Chapter 7 of this PART;

② only apply to the strength deck, hatch coaming plate and top plating with the range of thickness $50 \text{ mm} < t \leq 100 \text{ mm}$ onboard container ships.

③ for materials with yield strength not listed in the table, the material factor may be specially considered.

1.3.2 Requirements for hull structural steel at normal temperature

1.3.2.1 In ships of 90 m or over in length, the hull structural steel is to comply with the requirements of 1.3.2.2 below. For strength members not covered by Tables 1.3.2.2(1) to 1.3.2.2(6) or in ships of less than 90 m in length, grade A/AH steel can generally be used for hull structure. The steel grade is to correspond to the as-built plate thickness and material class.

1.3.2.2 Materials in the various strength members are not to be of lower grade than those corresponding to the material classes and grades specified in Table 1.3.2.2(1) to Table 1.3.2.2(7). General requirements are given in Table 1.3.2.2(1), while additional minimum requirements are given in the following Tables:

Table 1.3.2.2(2): for ships, excluding liquefied gas carriers covered in Table 1.3.2.2(3), with length exceeding 150 m and single strength deck;

Table 1.3.2.2(3): for membrane type liquefied gas carriers with length exceeding 150 m;

Table 1.3.2.2(4): for ships with length exceeding 250 m;

Table 1.3.2.2(5): for single side bulk carriers subjected to SOLAS regulation XII/6.4;

Table 1.3.2.2(6): for ships with ice strengthening.

1.3.2.3 For hull structural members of different material classes, the grades of steel are to be selected from Table 1.3.2.2(7) in accordance with the thickness of the structural members.

1.3.2.4 Where plate thickness is greater than that required in the Rules, the grade of steel is to be selected from Table 1.3.2.2(7) in accordance with the as-built thickness of plates.

Table 1.3.2.2(1) - Material Classes and Grades for Ships in General

Category	Structural member	Material class/grade
Secondary	(1) Longitudinal bulkhead plating, other than that belonging to the Primary category (2) Deck plating exposed to weather, other than that belonging to the Primary or Special category (3) Side plating	Class I within 0.4L amidships Grade A/AH outside 0.4L amidships
Primary	(1) Bottom plating, including keel plate (2) Strength deck plating, excluding that belonging to the Special category (3) Continuous longitudinal plating of strength members above strength deck, excluding hatch coamings (4) Uppermost strake in longitudinal bulkhead (5) Vertical strake (hatch side girder) and uppermost sloped strake in top wing tank	Class II within 0.4L amidships Grade A/AH outside 0.4L amidships
Special	(1) Sheer strake at strength deck①	
	(2) Stringer plate in strength deck①	
	(3) Deck strake at longitudinal bulkhead, excluding deck plating in way of inner-skin bulkhead of double-hull ships①	
	(4) Strength deck plating at outboard corners of cargo hatch openings in container carriers and other ships with similar hatch opening configurations	Class III within 0.4L amidships Class II outside 0.4L amidships Class I outside 0.6L amidships
	(5) Strength deck plating at corners of cargo hatch openings in bulk carriers, ore carriers, combination carriers and other ships with similar hatch opening configurations (5.1) Trunk deck and inner deck plating at corners of openings for liquid and gas domes in membrane type liquefied gas carriers	Class III within 0.6L amidships Class II within rest of cargo region
	(6) Bilge strake in ships with double bottom over the full breadth and length less than 150 m	Class II within 0.6L amidships Class I outside 0.6L amidships
	(7) Bilge strake in other ships①	Class III within 0.4L amidships Class II outside 0.4L amidships Class I outside 0.6L amidships

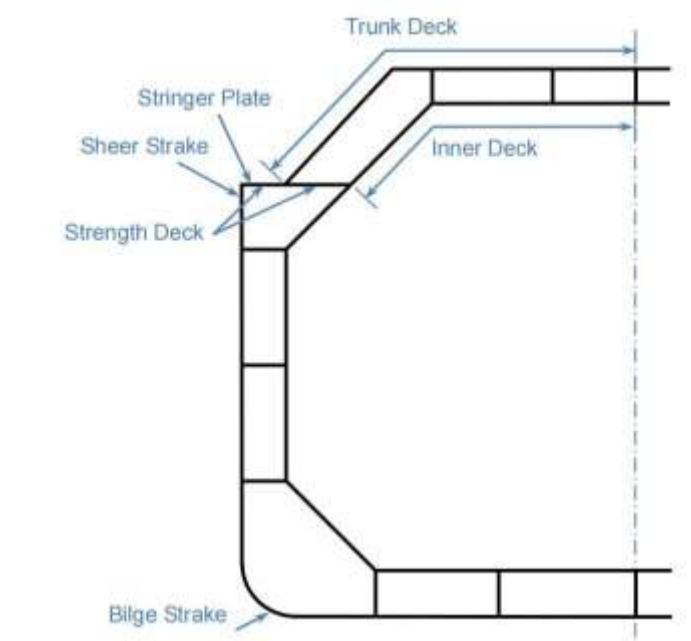
	(8) Longitudinal hatch coamings of length greater than 0.15L including coaming top plate and flange	Class III within 0.4L amidships Class II outside 0.4L amidships Class I outside 0.6L amidships Not to be less than Grade D/DH
	(9) End brackets and deck house transition of longitudinal cargo hatch coamings	

Note: ① Single strakes required to be of Class III within 0.4L amidships are to have breadths not less than $800 + 5L$ mm (L being the ship's length), need not be greater than 1,800 mm, unless limited by the geometry of the ship's design.

Table 1.3.2.2(2) - Minimum Material Grades for Ships with Length Exceeding 150 m and Single Strength Deck

Structural member category	Material grade
Longitudinal plating of strength deck where contributing to the longitudinal strength	Grade B/AH within 0.4L amidships
Continuous longitudinal plating of strength members above strength deck	
Single side strakes for ships without inner continuous longitudinal bulkhead(s) between bottom and the strength deck	Grade B/AH within cargo region

Note: This Table is applicable to ships other than the liquefied gas carriers covered in Table 1.3.2.2(3).



Minimum Material Grades for Ships with Length Exceeding 250 m Table 1.3.2.2(3)

Structural member category	Material grade
Shear strake at strength deck ①	Grade E/EH within 0.4L amidships
Stringer plate in strength deck ①	Grade E/EH within 0.4L amidships
Bilge strake ①	Grade D/DH within 0.4L amidships

Note: ① Single strakes required to be of Grade D/DH or Grade E/EH as shown in the above table and within 0.4L amidships are to have breadths not less than $800 + 5L$ mm (L being the ship's length), need not be greater than 1800 (mm), unless limited by the geometry of the ship's design.

Table 1.3.2.2(4) - Minimum Material Grades for Single-Side Skin Bulk Carriers Subjected to SOLAS Reg. XII/6.4

Structural member category	Material
Lower bracket of ordinary side frame ^① ^②	Grade D/DH
Side shell strakes included totally or partially between the two points located to 0.125 λ above and below the intersection of side shell and bilge hopper sloping plate or inner bottom plate ^②	Grade D/DH

Notes:

① The term “lower bracket” means webs of lower brackets and webs of the lower part of side frames up to the point of 0.125 λ above the intersection of side shell and bilge hopper sloping plate or inner bottom plate.

② The span of the side frame, λ , is defined as the distance between the supporting structures.

Table 1.3.2.2(5) - Steel grade requirements for Material Classes

Material class	I		II		III	
Thickness (mm)	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel
$t \leq 15$	A	AH	A	AH	A	AH
$15 < t \leq 20$	A	AH	A	AH	B	AH
$20 < t \leq 25$	A	AH	B	AH	D	DH
$25 < t \leq 30$	A	AH	D	DH	D	DH
$30 < t \leq 35$	B	AH	D	DH	E	EH
$35 < t \leq 40$	B	AH	D	DH	E	EH
$40 < t \leq 50$	D	DH	E	EH	E	EH

1.3.2.5 Plating materials for stern frames supporting the rudder and propeller boss, rudders, rudder horns and shaft brackets are, in general, not to be of lower grades than those corresponding to class II. For rudder and rudder body plates subjected to stress concentrations, e.g. in way of lower support of semi-spade rudders (i.e. rudder horn recess) or at upper part of spade rudders, class III is to be applied.

1.3.2.6 For ships of less than 90 m in length, single strakes required to be of class III within 0.4 L amidships are to have breadths not less than $800 + 5L$ mm (L being length of the ship, in m), but need not be greater than 1,800 mm.

1.3.2.7 The material class used for reinforcement and the quality of materials (i.e. whether mild or higher tensile steel) used for welded attachments, such as backing bars of bilge keels, is generally to be similar to that of the hull envelope plating in way.

Where attachments are made to rounded gunwale plates, special consideration will be given to the required grade of steel, taking account of the intended structural arrangements and attachment details.

1.3.2.8 The material class for deck plating, sheer strake and upper strake of longitudinal bulkhead within 0.4 L amidships is also to be applied at the poop front and at the ends of the bridge.

1.3.2.9 In the case of container ships, the material class for strength deck, sheer strake and torsion box structure within 0.4 L amidships is also to be applied in way of the entire cargo area.

1.3.2.10 On tankers having a poop, the quality of strength deck plating extending forward of the poop to any pump room openings is to be kept unchanged.

1.3.2.11 For hull structures having T connections or cruciform connections, with full penetration welding, and plate material of which is subject to high tensile stress through thickness, the use of Z-direction steel plates having through thickness properties is recommended.

1.3.3 Requirements for steel used for refrigerated space structures

1.3.3.1 Where the minimum design temperature t_D of the steel falls below 0 °C in refrigerated spaces, in addition to the requirements of 1.3.2 of this Section, the steel grade for the deck plating, webs of deck girders, longitudinal bulkhead strakes attached to deck and beams for supporting hatchway covers and their face plates is to comply with the requirements of Table 1.3.3.1.

Table 1.3.3.1 - Steel Grade of Structural Members in Refrigerated Spaces

Thickness (mm)	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel
$t \leq 12.5$	B	AH	D	DH	E	EH
$12.5 < t \leq 25.5$	D	DH	E	EH	Specially considered ^①	Specially considered ^②
$t > 25.5$	E	EH	Specially considered ^①	Specially considered ^②	Specially considered ^①	Specially considered ^②

Notes: ① Austenitic stainless steel may generally be used. ② Grade FH may generally be used.

1.3.3.2 The minimum design temperature of the refrigerated space deck may be assessed by a temperature gradient calculation or may be determined in accordance with Table 1.3.3.2. Where one of the internal spaces concerned is not refrigerated, the temperature of the space is to be taken as 5 °C.

Table 1.3.3.2 - Minimum Design Temperature of Refrigerated Space Deck

Item	Arrangement	Deck temperature
1	Deck not covered with insulation in the refrigerated space	Temperature of the refrigerated space
2	Deck covered with insulation in the refrigerated space and not insulated on the other side	Temperature of the space on the uninsulated side
3	Deck covered with insulation on both sides: (1) Temperature difference not greater than 11 °C (2) Temperature difference greater than 11 °C but not greater than 33 °C	Mean of the temperatures of the spaces above and below the deck Mean of the temperatures of the spaces above and below the deck less 3 °C

1.3.4 Ships exposed to low air temperatures

1.3.4.1 For ships intended to operate in areas with low air temperatures (below -10 °C), e.g. regular service during winter seasons to Arctic or Antarctic waters, the materials in exposed structures are to be selected based on the design temperature t_D . The design temperature t_D is to be taken as defined in 1.3.4.6.

1.3.4.2 Materials in the various strength members above the lowest ballast waterline (BWL) exposed to low air temperatures (including the plating covered by note ⑤ of Table 1.3.4.2) and materials of cargo tank boundary plating to which 1.3.4.7 is applicable are not to be lower than those as given in Table 1.3.4.2. For non-exposed hull structural steel above BWL (except for ⑤) as

indicated in Table 1.3.4.2) and hull structural steel below BWL, the requirements in 1.3.2 of this Section apply.

1.3.4.3 Grades of steel for hull structural members of different material classes are to be selected according to Table 1.3.4.3 depending on plate thickness and design temperature. Where the design temperature t_D is below -55°C , the grades of steel are to be subject to special consideration by ISC.

1.3.4.4 Single strakes required to be of class III or of grade E/EH or FH are to have breadths not less than $800 + 5L$ mm (L being length of the ship, in m), but need not be greater than 1,800 mm.

1.3.4.5 Plating materials for stern frames, rudders, rudder horns and shaft brackets are not to be of lower grades than those required in 1.3.2 of this Section.

Table 1.3.4.2 - Material Classes at Low Temperatures

Structural member category	Structural member	Material class	
		Within 0.4L amidships	Outside 0.4L amidships
Secondary	Deck plating exposed to weather in general, side plating above BWL, transverse bulkheads above BWL ^⑤ Cargo tank boundary plating exposed to cold cargo ^⑥	I	I
Primary	Strength deck plating ^① Continuous longitudinal members above strength deck, excluding longitudinal hatch coamings Longitudinal bulkhead above BWL ^⑤ Top wing tank bulkhead above BWL ^⑤	II	II
Special	Sheer strake at strength deck, including rounded gunwale ^② ^② Stringer plate in strength deck Deck strake at longitudinal bulkhead ^③ Continuous longitudinal hatch coamings ^④	III	III

Notes:

- ① Plating at corners of large hatch openings to be specially considered. Class III or grade E/EH to be applied in positions where high local stresses may occur.
- ② Not to be less than grade E/EH within 0.4 L amidships in ships with length exceeding 250 m.
- ③ In ships with breadth exceeding 70 m at least three deck strakes to be class III.
- ④ Not to be less than grade D/DH.
- ⑤ Applicable to plating attached to hull envelope plating exposed to low air temperature. At least one strake is to be considered in the same way as exposed plating and the strake width is to be at least 600 mm.
- ⑥ For cargo tank boundary plating exposed to cold cargo for ships other than liquefied gas carriers, the requirements of 1.3.4.7 are to be satisfied.

Table 1.3.4.3 - Material Grade Requirements for Classes I, II and III at Low Temperatures

Class I	-11 ~ -15°C		-16 ~ -25°C		-26 ~ -35°C		-36 ~ -45°C		-46 ~ -55°C	
Plate thickness, in mm	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel
$t \leq 10$	A	AH	A	AH	B	AH	D	DH	D	DH
$10 < t \leq 15$	A	AH	B	AH	D	DH	D	DH	D	DH
$15 < t \leq 20$	A	AH	B	AH	D	DH	D	DH	E	EH
$20 < t \leq 25$	B	AH	D	DH	D	DH	D	DH	E	EH
$25 < t \leq 30$	B	AH	D	DH	D	DH	E	EH	E	EH
$30 < t \leq 35$	D	DH	D	DH	D	DH	E	EH	E	EH
$35 < t \leq 45$	D	DH	D	DH	E	EH	E	EH	—	FH
$45 < t \leq 50$	D	DH	E	EH	E	EH	—	FH	—	FH

Class II	-11~-15°C		-16~-25°C		-26~-35°C		-36~-45°C		-46~-55°C	
Plate thickness, in mm	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel
$t \leq 10$	A	AH	B	AH	D	DH	D	DH	E	EH
$10 < t \leq 20$	B	AH	D	DH	D	DH	E	EH	E	EH
$20 < t \leq 30$	D	DH	D	DH	E	EH	E	EH	—	FH
$30 < t \leq 40$	D	DH	E	EH	E	EH	—	FH	—	FH
$40 < t \leq 45$	E	EH	E	EH	—	FH	—	FH	—	—
$45 < t \leq 50$	E	EH	E	EH	—	FH	—	FH	—	—

Class III	-11~-15°C		-16~-25°C		-26~-35°C		-36~-45°C		-46~-55°C	
Plate thickness, in mm	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel
$t \leq 10$	B	AH	D	DH	D	DH	E	EH	E	EH
$10 < t \leq 20$	D	DH	D	DH	E	EH	E	EH	—	FH
$20 < t \leq 25$	D	DH	E	EH	E	EH	E	FH	—	FH
$25 < t \leq 30$	D	DH	E	EH	E	EH	—	FH	—	FH
$30 < t \leq 35$	E	EH	E	EH	—	FH	—	FH	—	—
$35 < t \leq 40$	E	EH	E	EH	—	FH	—	FH	—	—
$40 < t \leq 50$	E	EH	—	FH	—	FH	—	—	—	—

Note: “—” in the Table = Not applicable.

1.3.4.6 The design temperature t_D is to be taken as the lowest mean daily average air temperature in the area of operation, where:

- mean: statistical mean over observation period;
- daily average: average during one day and night;
- lowest: lowest during year.

For seasonally restricted service the lowest value within the period of operation applies.

Figure 1.3.4.6 illustrates the temperature definition.

For the purpose of issuing a Polar Ship Certificate in accordance with the Polar Code, the design temperature t_D is to be no more than 13°C higher than the Polar Service Temperature (PST) of the ship. In the Polar Regions, the statistical mean over observation period is to be determined for a period of at least 10 years.

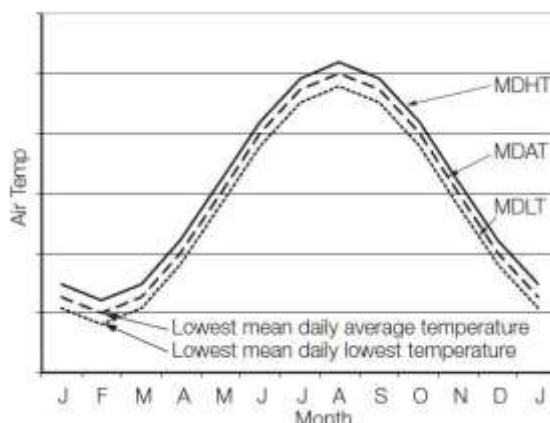


Figure 1.3.4.6 General Temperature Definitions

1.3.4.7 Cold cargo for ships other than liquefied gas carriers

For ships other than liquefied gas carriers, intended to be loaded with liquid cargo having a temperature below -10°C, e.g. loading from cold onshore storage tanks during winter conditions, the material grade of cargo tank boundary plating is defined in Table 1.3.4.3 based on the following:

- (1) t_c design minimum cargo temperature in °C;
- (2) steel grade corresponding to Class I as given in Table 1.3.4.2.

The design minimum cargo temperature, t_c is to be specified in the loading manual.

1.3.5 Use of aluminum alloy

1.3.5.1 The use of aluminum alloy is permitted for superstructures, deckhouses, hatch covers, or other similar structures, based on equivalent strength, instead of hull structural steel as required in the Rules. The chemical composition and mechanical properties of aluminum alloys used are to comply with the relevant requirements of Chapter 8, PART ONE of ISC Rules for Materials and Welding.

1.3.5.2 Unless stated otherwise, the modulus of elasticity of Aluminum alloy may be taken as 70,000 N/mm².

1.3.5.3 The scantlings of Aluminum alloy structures may be obtained from the following formulae:

$$\text{For plating thickness: } t_a = t_s \sqrt{K_a} \quad \text{mm}$$

$$\text{For section modulus: } W_a = W_s K_a \quad \text{cm}^3$$

where:

t_s — thickness of mild steel plating as required in the Rules, in mm;

W_s — section modulus of mild steel as required in the Rules, in cm³;

K_a — material factor for aluminum alloy, $K_a = \frac{235}{R_{tm}}$;

R'_{lim} — the minimum yield stress $R'_{p0.2}$ of parent material which could be guaranteed under welding condition, in N/mm², to be taken not greater than 70% minimum tensile strength R'_m of parent material which could be guaranteed under welding condition:

$$R'_{p0.2} = \eta_1 R_{p0.2}$$

$$R'_m = \eta_2 R_m$$

$R_{p0.2}$ — the minimum yield stress of parent material which could be guaranteed under delivery condition, in N/mm²;

R_m — the minimum tensile strength of parent material which could be guaranteed under delivery condition, in N/mm². η_1 and η_2 are given in Table 1.3.5.3 (1)

Table 1.3.5.3 (1) - Aluminum Alloy used for Welded Structures

Aluminum alloy	η_1	η_2
Not treated by hardening (5000 series under annealed condition O or	1	1
Treated by hardening (5000 series other than O or H111)	$R'_{p0.2} / R_{p0.2}$	R'_m / R_m
Heat treated and hardened (6000 series) (1)	$R'_{p0.2} / R_{p0.2}$	0.6

Note: (1) If information is not provided, the factor η_1 defined in Table 1.3.5.3(2); is to be taken as metallographic efficiency coefficient β

$R'_{p0.2}$ — the minimum yield stress of material which could be guaranteed under welding condition, in N/mm²;

R'_m — the minimum tensile strength of material which could be guaranteed under welding condition, in N/mm².

Table 1.3.5.3(2) - Aluminum Alloy — Metallographic Efficiency Coefficient β

Aluminum Alloy	Tempering Condition	Total Thickness (mm)	β
6005A (opening section)	T5 or T6	$t \leq 6$	0.45
	$t > 6$	0.4	
6005A (closed section)	T5 or T6	All	0.5
6061 (section)	T6	All	0.53
6082 (section)	T6	All	0.45

1.3.5.4 The welding procedures for aluminum alloy are to be subject to approval. The methods used for connecting aluminum alloy with steel members and the information for measures to be taken for corrosion control are to be submitted to ISC for examination.

1.3.6 Use of stainless steel

1.3.6.1 Stainless steel may be used for tanks onboard oil tankers and chemical tankers to equivalently substitute the hull structure steels required in the Rules.

1.3.6.2 Except where otherwise stated, the elastic modulus of stainless steel may be taken as $2.06 \times 10^5 \text{ N/mm}^2$.

1.3.6.3 The material factor K is to be calculated by the following formula:

$$K = \frac{235}{R_{eHT}}$$

where: R_{eHT} — the minimum yield strength or non-proportional extension strength of stainless steel under the designed allowable maximum cargo temperature, in N/mm^2 , to be calculated by the following formulae:

for no nitrogen austenitic stainless steel:

$$R_{eHT} = -40 \ln(T) + 127 + R_{p0.2}$$

for nitrogen austenitic stainless steel:

$$R_{eHT} = -48 \ln(T) + 142 + R_{p0.2}$$

for duplex stainless steel:

$$R_{eHT} = -65 \ln(T) + 200 + R_{p0.2}$$

T — the designed allowable maximum cargo temperature, in $^{\circ}\text{C}$;

$R_{p0.2}$ — the minimum yield strength or non-proportional extension strength of stainless steel, in N/mm^2 at room temperature, in accordance with the relevant requirements of Section 8, Chapter 3, PART ONE of ISC Rules for Materials and Welding.

For duplex stainless steel, K is not to be less than 0.68.

SECTION 4 - WELD DESIGN FOR HULL STRUCTURES

1.4.1 General requirements

1.4.1.1 This Section applies to the weld design for normal hull structures and components. Welding procedures for the construction of hull are to comply with the relevant requirements of ISC Rules for Materials and Welding.

1.4.1.2 The arrangement of welds in hull structures is to be such as to allow adequate access for completion of all welding operations. Welded joints are to be so arranged as to facilitate the use of flat (downhand) welding wherever possible.

1.4.1.3 Where welding is used for hull structures, care is to be taken to avoid the arrangement of welded joints in positions of stress concentration. Adequate transition is to be made in way of the abrupt changes of shape or section, and excessive concentration of welds over such positions is to be avoided.

1.4.1.4 Parallel welded seams in the main hull structures are to be spaced an adequate distance apart. The distance l_1 between two parallel butt welded seams is not to be less than 100 mm, and the butt welded seams are not to be intersected with an acute angle. Where a butt welded seam is in parallel with a fillet welded seam, the distance l_2 between them is not to be less than 10 mm. The distance between the above two welded seams is in general the distance between inner edges of two weld toes (as shown in Figure 1.4.1.4).



Distance between butt weld toes

Distance between butt and fillet weld toes

Figure 1.4.1.4 Distance between parallel welded seams

1.4.1.5 The shell plating, deck plating, inner bottom plating and bulkhead plating are all to be connected by butt welds.

1.4.1.6 Overlaps are generally not to be used to connect plates in hull structures, particularly for plates which may be subjected to high stress.

1.4.1.7 The use of permanent backing bars in highly stressed welds in hull structures is to be avoided as far as possible.

1.4.1.8 Double continuous fillet welding is to be adopted in the following locations:

- (1) boundaries of weathertight decks and erections, including hatch coamings, companionways and coamings of other openings;
- (2) boundaries of tanks and watertight compartments;
- (3) connections in foundations and supporting structures;

- (4) all structure in the aft peak and the aft peak bulkhead stiffeners;
- (5) all welding inside tanks intended for chemicals or edible liquid cargoes;
- (6) main frames and their upper and lower brackets in cargo holds of bulk carriers to side shell plating and sloped bulkhead plating of topside tanks and hopper side tanks;
- (7) all lap welds in tanks;
- (8) primary and secondary members to bottom shell in the 0.25 *L* forward;
- (9) centreline girder to keel plate;
- (10) boundaries of galleys, pantries, laundry rooms, bathrooms, toilets and storage battery rooms, etc.;
- (11) primary and secondary members to plating in way of end connections, and end brackets to plating in the case of lap connections;
- (12) other special connections or attachments, and in particular the attachment of minor fittings to higher tensile steel plating, will be specially considered.

1.4.1.9 Where higher tensile steel is used, double continuous fillet welds are normally to be adopted.

1.4.1.10 Details of the welded connections of main structural members of the hull, including type and size of welds, are to be clearly indicated on the plans submitted for approval. The extent to which automatic welding is used is to be indicated on the plans.

1.4.1.11 When arranging side joints of shell plating, the arrangement of longitudinal members such as deck plating, longitudinals and inner bottom margin plates are to be taken into account, avoiding coincidence of the side joints and fillet welds of longitudinal members or their intersection to an excessively small angle. The butt welds of end joint of the shell are to avoid the toes of internal longitudinal members and the fillet welding of transverse members as far as practicable.

1.4.2 Welding consumables

1.4.2.1 Welding consumables used for hull structures are to comply with the requirements of ISC Rules for Materials and Welding. The grade of welding consumables selected is to be suitable for the grade of hull structural steel, and is to comply with the requirements of Table 1.4.2.1. Welding consumables of H47 steels are to be selected by referring to ISC Guidelines for Application of Thick Higher Strength Steel Plates for Ships and welding consumables of other steels are to be selected by referring to ISC Guidelines for Inspection of Hull Welds.

Table 1.4.2.1-Selection of Welding Consumables

Hull structural steel grade Grade of welding consumables	A	B	D	E	AH27 AH32 AH36	DH27 DH32 DH36	EH27 EH32 EH36	FH27 FH32 FH36	AH40	DH40	EH40	FH40
1	x											
2	x	x	x									
3	x	x	x	x								
1Y	x				x(2)							
2Y	x	x	x		x	x						
3Y	x	x	x	x	x	x	x					
4Y	x	x	x	x	x	x	x	x				
2Y40	①	①	①		x	x			x	x		
3Y40	①	①	①	①	x	x	x		x	x	x	
4Y40	①	①	①	①	x	x	x	x	x	x	x	x
5Y40	①	①	①	①	x	x	x	x	x	x	x	x

Notes: “x” means applicable;

① When joining structural steels of normal strength, it is not recommended to use a much higher grade of welding consumable.

② When using Grade 1Y welding consumables, the material thicknesses should not exceed 25 mm.

1.4.2.2 For the joining of steels of different strength levels, the welding consumables in general may be of a type suitable for the lower strength level except at structural discontinuities or areas of stress concentration. For the joining of steels of the same strength level but of different toughness grades, the welding consumables in general may be of a type suitable for the lower toughness grade except for the structural members subjected to complicated forces or severe construction conditions.

1.4.2.3 Low hydrogen welding consumables are to be used for the welding of the following structural members and components:

- (1) Circumferential butt welds in the joining of block sections and butt welds of girders;
- (2) End and side joints of the shell of ships with ice strengthening;
- (3) Masts, derricks, boat davits, bollards and other outfits subjected to heavy loads and all other highly stressed fittings;
- (4) Components for which high rigidity is required, such as stems, stern frames, propeller shaft brackets, and joints between them and the shell plating and the hull framing;
- (5) Main engine seatings and the associated structural members.

1.4.2.4 It is recommended that low hydrogen welding consumables be used for the joining of higher strength structural steel or of steel with carbon equivalent over 0.41%.

1.4.3 Butt, lap and slot welds

1.4.3.1 Where plates of different thicknesses are to be butt welded and the difference in thickness of one side is less than or equal to 4 mm, the transition may be achieved within the width of the weld. Where the difference in thickness of one side is greater than 4 mm, the edge of the thicker plate is to be tapered so as to ensure a uniform transition with the weld. The width is not to be less

than 3 times the difference in thickness of one side, and the difference in height of the two sides of the groove d is not to be greater than 4 mm, as shown in Figure 1.4.3.1(1). Where the groove width is not less than 3 times the difference in thickness of one side, taper may not be necessary and the transition may be achieved within the width of the weld, as shown in Figure 1.4.3.1(2).

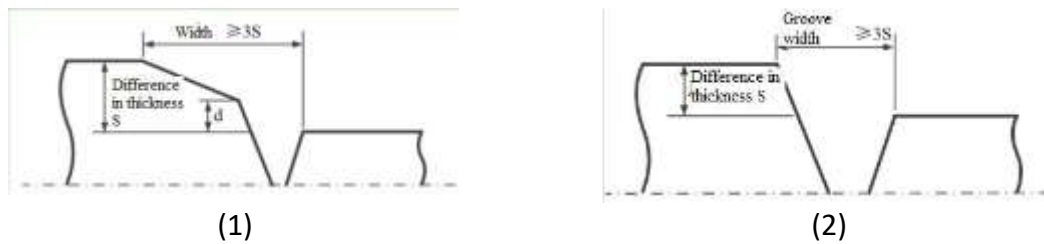


Figure 1.4.3.1 Butt welding of steel plates of different thickness

1.4.3.2 Overlaps are generally not to be used to connect plates which may be subjected to high tensile stress or compressive loading. Where plate overlaps are adopted, the breadth (b) of the overlap is not to exceed four times nor be less than three times the thickness of the thinner plate, see Figure 1.4.3.2. The joints are to be positioned as to allow adequate access for completion of sound welds. The faying surfaces of lap joints are to be in close contact and both edges of the overlap are to have continuous fillet welds.

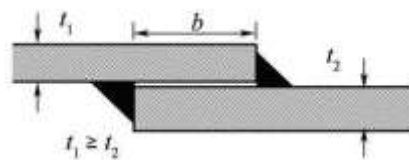


Figure 1.4.3.2

1.4.3.3 For the connection of plating to internal webs, where access for fillet welding is not practicable, the closing plating is to be attached by continuous full penetration welds or slot fillet welds to face plates fitted to the webs. Slots are to have a minimum length of 75 mm and a minimum width of twice the plating thickness, with well rounded ends, and spaced not more than 150 mm apart. Slots are normally not to be filled with welding.

1.4.4 Fillet welds

1.4.4.1 T-connections of hull structures are generally to be made by fillet welds on both sides of the abutting plate, including fillet welds, partial penetration fillet welds and full penetration fillet welds. The types and application of fillet welds are to be as shown in Table 1.4.4.1.

1.4.4.2 The size of fillet welds for hull structural connection is to be determined as follows:

(1) The throat thickness h of fillet welds is to be determined from the following formula:

$$h = w_r t_p \frac{d}{l} \quad \text{mm}$$

where: t_p — thickness of the thinner plate of the abutting plates, in mm, e.g. t_1 or t_2 in item 1 of Table 1.4.4.1 of this Section, whichever is the lesser;

d — distance between weld fillets, in mm, i.e. the distance between start positions of successive weld fillets for intermittent welding, as shown in items Figure 1.4.4.2 of this Section; where the fillet weld is continuous, d is to be equal to l ;

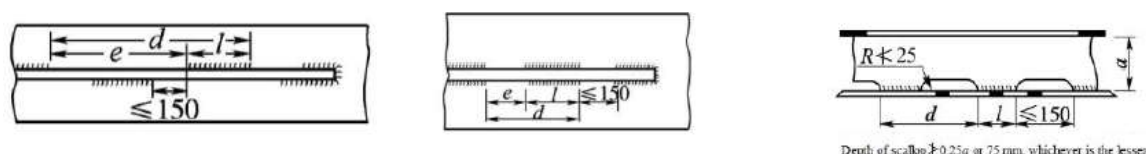
L — the length of weld fillet, in mm, clear of end craters, and is not to be less than 75 mm;

w_τ — weld factor. The weld factors used for hull structures are as specified in Table 1.4.4.2 of this Section. Where an approved automatic deep penetration procedure is used, w_τ may be 85% of the value given in the Table.

The fillet leg length K is not to be less than the value obtained from the following formula:

$$K = \sqrt{2h} \text{ mm}$$

- (2) In case of full penetration welding, there is no requirement for root face. For partial penetration welds the root face, f , is, to be taken between 3 mm and $1/3t$. The groove angle made to ensure welding bead penetrating up to the root of the groove, α , is usually from 40° to 60° . The welding bead of the full/partial penetration welds is to cover root of the groove.



l — length of weld, e — spacing of welds, d — distance between weld fillets, welding to be carried round both ends of plating for intermittent fillet welds and ends of all lugs for scalloped construction.

Figure 1.4.4.2

Table 1.4.4.1 - Types of Fillet Welds

Item	Fillet Weld	Type	Remark
1	Double continuous		Used for ordinary connection K — leg length h — throat thickness t_1, t_2 — thickness of plates
2	Double full penetration welding		Used in areas with high tensile stresses or areas considered critical α — groove angle
3	Double symmetrical groove partial penetration welding		Used in areas with relatively high tensile stresses or areas considered critical t — thickness of weldment f — root face α — groove angle
4	Double asymmetrical groove partial penetration welding		Used in areas with relatively high tensile stresses or areas considered critical t — thickness of weldment f — root face α — groove angle

Table 1.4.4.2 - Weld Factors

Item	Weld Factor	Remark
1 General application (except as required below):		
(1) Watertight or oiltight plate boundaries	0.34	
(2) Non-tight plate boundaries	0.13	
(3) Longitudinals, frames, beams, and other secondary members to shell, deck or bulkhead plating	0.1	
– In tanks	0.13	
– In way of end connections	0.21	
(4) Panel stiffeners (i.e. small stiffeners)	0.1	
(5) Overlap welds	0.27	
(6) Longitudinals of the flat-bar type to plating	0.21	Double continuous
2 Bottom construction in way of holds or tanks		
(1) Tight centre girder		
– to keel	0.44	
– to inner bottom	0.44	
(2) Non-tight centre girder (or centre keelson)		
– to keel	0.27	
– to inner bottom (or face plate of centre keelson)	0.21	No scallops
(3) Tight boundaries of floors, girders	0.39	
(4) Non-tight boundaries of floors, girders (or side keelson) and brackets	0.16	
– In way of $0.2 \times$ span at ends	0.21	
– In way of brackets at lower end of main frame	0.27	
(5) Inner bottom longitudinals or reverse frames to inner bottom	0.13	Under holds strengthened for heavy cargoes
(6) Floors supporting plane, corrugated, double plate bulkheads and bulkhead stools to inner bottom	0.44	Double continuous
3 Hull framing		
(1) Webs of web frames and stringers to shell	0.16	
(2) Webs of web frames and stringers to face plate	0.13	
(3) Tank side brackets to shell and inner bottom	0.34	
(4) Main frames of cargo holds in bulk carriers to shell plating	0.4	See 8.3.6 in this PART
(5) End brackets of main frames of cargo holds in bulk carriers	0.44	See 8.3.6 in this PART
4 Decks and supporting structure		
(1) Strength deck plating to shell	0.44	See 5.2.5 of PART THREE of ISC Rules for Materials and Welding – Generally double continuous
(2) Other decks to shell and bulkheads (except where forming tank boundaries)	0.21	
(3) Webs of cantilevers to deck and to shell in way of root bracket	0.44	
(4) Webs of cantilevers to face plate	0.21	
(5) Pillars – end connections	0.34	0.21 in a length of 0.15 span of hatch girders at ends
– Tubular end connections	0.44	
(6) Girder web connections and brackets in way of pillar heads and heels	0.21	
(7) Web plates of hatch girders and deck web beams to deck, their face plates	0.16	

5 Bulkheads and tank construction		
(1) Watertight plane, corrugated, double plate bulkheads to bottom, inner bottom, bilge plating, hopper and topside tanks, decks and face plates of bulkhead stools	0.44	
(2) Upper and lower bulkhead stool plates to their face plates	0.44	Full penetration in way of lower stool
(3) Bulkhead stool plates to inner bottom, deck and bilge	0.44	
(4) Bulkhead plating to side shell	0.34	
(5) Bulkhead plating to secondary members where acting as pillars	0.13	
(6) Non-watertight pillar bulkhead boundaries	0.13	
(7) Perforated flats and wash bulkhead boundaries	0.1	
6 Structure in cargo tanks of oil tankers		
(1) Bottom longitudinals to shell	0.21	For forward of 0.25L
(2) Connections between primary structural members	0.44	At bottom
– At deck	0.34	
(3) Longitudinal oiltight bulkhead boundaries	0.44	Throat thickness $h \geq 0.34t$, t = bulkhead thickness in mm
(4) Transverse oiltight bulkhead to bottom	0.44	Throat thickness $h \geq 0.34t$
– Transverse oiltight bulkhead to deck, sides and longitudinal bulkhead	0.34	
(5) Non-tight bulkhead boundaries	0.21	Generally
(6) Boundaries of non-watertight girders and floors in double bottom	0.34	Within 0.2L at ends of ship
– Under bulkhead stools	0.4	
– Elsewhere	0.44	
(7) Frame rings in hopper and topside tanks to shell, deck and sloping (top) plating	0.34	
(8) Boundaries of diaphragms or frame rings, side girders in double hull	0.34	Generally
– Within 0.2L at ends of ship	0.4	
(9) Between primary structural members in double hull, double bottom, hopper tanks and topside tanks	0.34	
(10) Longitudinal girders or frame rings to face plates in hopper tanks, topside tanks and double hull	0.27	
(11) Web plates of primary structural members in cargo tanks to bulkheads, inner bottom and deck	0.34	Generally
– Within 0.2L at ends of ship	0.44	
(12) Web plates of primary structural members in cargo tanks to face plates	0.27	Generally
– Within 0.2L at ends of ship	0.34	
7 Structure in hoppers of hopper dredgers		
(1) Bulkhead boundary connections	0.44	At bottom and bilge
– At deck and coamings	0.34	
(2) Cross members to longitudinal bulkheads	0.44	
(3) Pillar end connections	0.34	
(4) Hopper door hinges of self-unloading ships	0.44	Partial penetration
8 Structure in machinery space		
(1) Non-tight centre girder (or centre keelson) to keel and inner bottom (or face plate of centre keelson)	0.27	
(2) Non-tight floors to centre girder (or keelson) in way of engine, thrust and boiler bearers	0.27	

(3) Non-tight floors and girders (or side keelsons) to shell and inner bottom	0.21	Partial penetration, girders tapered to both sides, root face $\leq 1/3$ girder thickness
(4) Main engine foundation girders to top plate	0.44	
– to hull structure	0.44	
– Floors to main engine foundation girders	0.27	
– Brackets to main engine foundation girders	0.21	
(5) Transverse and longitudinal framing to shell	0.13	
9 Construction in 0.25L forward		
(1) Floors and girders (or centre keelson, etc.) to shell and inner bottom	0.21	
(2) Bottom longitudinals to shell	0.13	
(3) Transverse and longitudinal side framing to shell	0.13	
(4) Tank side brackets to frame and inner bottom	0.34	
(5) Panting stringers to shell and frames	0.34	
(6) All internal structure in fore peak	0.13	Unless a greater weld factor is required
10 Aft peak construction	0.21	All internal structure including stiffeners on aft peak bulkhead – unless a greater weld factor is required
11 Superstructure and deckhouses		
(1) Connection of external bulkheads to deck	0.34	1st and 2nd tier erections
– Elsewhere	0.21	
(2) Internal bulkheads to deck	0.13	
12 Hatchways and closing arrangements		
(1) Hatch coamings to deck	0.34	0.44 at corners
(2) Hatch coaming stays (stiffeners, brackets)		
– To coaming	0.13	
– To deck	0.21	
(3) Hatch cover rest bar	0.16	
(4) Cleats and fittings	0.44	Increased welding may be required
(5) Primary and secondary stiffening of hatch covers	0.1	0.13 for tank covers / strengthened covers
13 Steering control systems		
(1) Rudder		
① Fabricated mainpiece and mainpiece to side plates and webs	0.44	
② Slot welds inside plates	0.44	
③ Remaining construction	0.21	
(2) Fixed and steering nozzles		
– Main structure	0.44	
– Elsewhere	0.21	
(3) Thruster units and stabilizers		
– Main structure	0.44	
– Elsewhere	0.21	
14 Miscellaneous fittings and equipment		
(1) Rings for manhole type covers to deck, inner bottom or bulkhead	0.34	
(2) Frames of shell and weathertight bulkhead doors	0.34	
(3) Stiffening of watertight doors	0.21	

(4) Ventilator, air pipe, etc., coamings	0.34	Positions 1 and 2 specified by Load Line assignment
– Elsewhere	0.21	
(5) Ventilator, etc., fittings	0.21	
(6) Scuppers and discharges to deck	0.44	
(7) Masts, derrick posts, crane pedestals, etc., to deck	0.44	See 5.2.7 of PART THREE of ISC Rules for Materials and Welding
(8) Deck machinery seats to deck	0.21	Special equipment subject to design
(9) Mooring equipment (bollards, etc.) seats to deck	0.21	Increased or full penetration welding may be required
(10) Bulwark stays to deck	0.21	
(11) Bulwark attachment and guard rails, stanchions, etc., to deck	0.34	
(12) Bilge keel backing bars to shell	0.34	
(13) Bilge keels to backing bars	0.21	

1.4.4.3 Where the thickness of the abutting member of the T connection (e.g. the web of a stiffener or longitudinal) is greater than 15 mm and exceeds the thickness of the table member (e.g. bulkhead plating, shell plating or deck plating), the welding is to be double continuous and the throat thickness h of the weld is to be neither less than the value given in Table 1.4.4.4(2) of this Section, nor less than the greater of the following:

$$h = 0.5Ct_v \text{ mm}$$

$$h = 0.21t_h \text{ mm}$$

where:

t_v — thickness of the abutting member, in mm;

t_h — thickness of the table member, in mm;

C — coefficient, 0.21 for dry cargo holds, or 0.27 for liquid tanks.

1.4.4.4 Except as permitted by 1.4.4.2 and 1.4.4.3 of this Section, the throat thickness of all fillet welds is to comply with the following requirements:

- (1) The limits of throat thickness are to be as shown in Table 1.4.4.4(1);
- (2) The minimum value of throat thickness is also to comply with the requirements of Table 1.4.4.4(2).

Table 1.4.4.4(1) - Limits of Throat Thickness

Item	Limits of throat thickness (mm)	
	Minimum	Maximum
Double continuous welding	0.21 t_p	0.44 t_p
Intermittent welding	0.27 t_p	0.44 t_p

Notes: ① For t_p , see 1.4.4.2(1) of this Section.

② When the actual plate thickness t'_p exceeds 25 mm, $0.5(t'_p + 25)$.

Table 1.4.4.4(2) - Minimum Throat Thickness

Plate thickness t_p		≤ 7.5	> 7.5
Minimum throat thickness (mm)	Manual or automatic welding	3	3.25
	Automatic deep penetration welding	3	3

Note: For t_p , see 1.4.4.2(1) of this Section.

1.4.4.5 Where intermittent fillet welds are used for the connection of hull members, double continuous fillet welding is to be carried out for a specified length of round-the-end weld in the following locations:

- (1) The length of the round-the-end weld at the ends of brackets is not to be less than the depth of the connecting members, nor less than 75 mm.
- (2) Where the ends of sections, particularly of short sections, are snipped off, the length of the round-the-end weld is to be not less than the height of such sections or the length of snipping.
- (3) Where fillet welding is used in way of brackets, lugs and scallops and at the orthogonal connections with other members, the length of the round-the-end weld is not to be less than 75 mm for plate thickness > 12 mm, and not less than 50 mm for plate thickness ≤ 12 mm.

1.4.4.6 Where scallops are cut in the structural members for intermittent welding, both ends of the scallop are to be rounded and smooth. But no scallops are permitted in the following positions:

- (1) in way of the ends of brackets where stress concentration occurs;
- (2) in the main frames, longitudinals and stiffeners for a region of at least 230 mm on each side of the intersection with a primary supporting member.

1.4.4.7 Where a structural member passes through a watertight or an oiltight bulkhead, in addition to the fitting of a welded collar on the bulkhead, a small semicircular notch is to be cut on one side of the passing member as shown in Figure 1.4.4.7(1). And double continuous fillet welding is to be carried out round the end of the semicircular notch to the bulkhead so as to ensure tightness of the bulkhead.

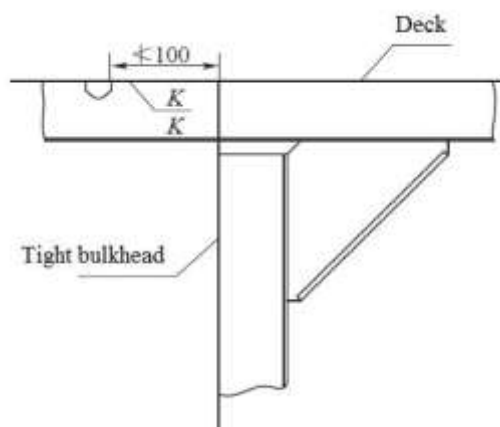


Figure 1.4.4.7(1)

For bulkheads adjacent to tanks, fillet welds in way of 150 mm fore and aft of oil/gastight or watertight bulkheads are to be properly beveled and full penetration is required in order to prevent the leakage of dangerous gases or liquids into adjacent compartments, see Figure 1.4.4.7(2). Other equivalent means may also be adopted.

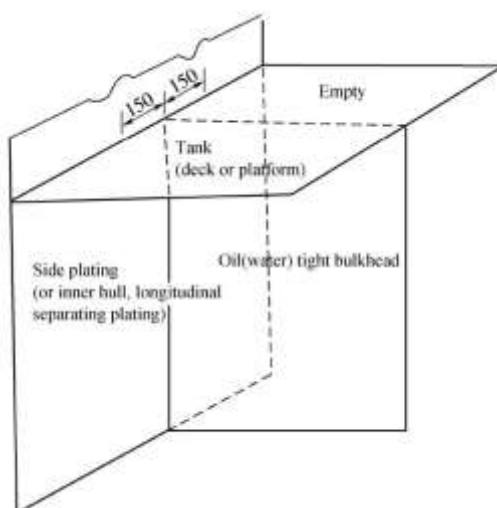


Figure 1.4.4.7(2)

1.4.4.8 The size of fillet welds in primary members is to comply with the following:

(1) Weld factors may be obtained from Table 1.4.4.8.

Table 1.4.4.8 - Weld Factors of Primary Members

Cross-sectional area of face plate of T-type members (cm ²)	Position ^①	In tanks		In dry spaces	
		To face plate	To plating	To face plate	To plating
A ≤ 30	At ends	0.21	0.27	0.21	0.21
	Remainder	0.1	0.16	0.1	0.13
30 < A ≤ 65	At ends	0.21	0.34	0.21	0.21
	Remainder	0.13	0.27	0.13	0.16
65 < A ≤ 95	At ends	0.34	0.44 ^③	0.21	0.27
	Remainder	0.27 ^②	0.34	0.16	0.21
95 < A ≤ 130	At ends	0.34	0.44 ^③	0.27	0.34
	Remainder	0.27 ^②	0.34	0.21	0.27
A > 130	At ends	0.44	0.44 ^③	0.34	0.44 ^③
	Remainder	0.34	0.34	0.27	0.34

Notes:

- ① The weld factors "at ends" are to be applied for 0.2 × the length of the member from each end, but at least beyond the toes of the member end brackets. On vertical webs the increased welding may be omitted at the top, but is to extend at least 0.3 × length from the bottom. "Length of the member" means the overall length of the member (including the end brackets).
- ② In cargo oil tanks, the weld factor is to be 0.34. The final throat thickness of the weld fillet is not to be less than 0.34 *tp*. For *tp*, see 1.4.4.2(1) of this Section.
- ③ Where the web plate thickness is increased locally, the throat thickness is to be determined by 0.44 *tp* or 0.34 *tc*, whichever is the greater. For *tp*, see 1.4.4.2(1) of this Section, and *tc* is the increased thickness of plate.
- ④ In oil tankers over 120 m in length, the weld factors of the connection of bottom transverses to shell, and of side transverses to shell and vertical webs to longitudinal and transverse bulkheads, all in the lower half depth, are not to be less than 0.34.

(2) Where the webs of primary members are cut for the passage of secondary members and the width of the notch exceeds 15% of the stiffener spacing, the weld factor $W\tau$ or the leg length K of fillet weld is to be multiplied by coefficient C obtained from the following formula:

$$C = \frac{0.85 \times \text{stiffener spacing}}{\text{length of web plating between notches}}$$

(3) In calculation of the throat thickness, the overall length of the weld at the ends of the member may be taken into account.

1.4.4.9 The area of welding of end connections of primary members is not to be less than the cross-sectional area of the member, and the weld factor is not to be less than 0.34 in tanks or 0.27 elsewhere.

1.4.4.10 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the area A_w of weld is not to be less than the cross-sectional area of the strength member.

1.4.4.11 Where the secondary member passes through, and is supported by, the web of a primary member, the weld connection is to be in accordance with the following:

- (1) The area A_w of weld is to be not less than $0.5 W$ and the weld factor not less than 0.34 in tanks or 0.27 in dry spaces, where W is the section modulus of the secondary member, in cm^3 .
- (2) In cargo oil tanks, the size of weld is to be increased by 20% above that obtained from (1) above.

1.4.4.12 The fillet welding of secondary member end connections is to be in accordance with Table 1.4.4.12 and where two values are given, the greater is to be taken.

Connection	2	Weld factor $w\tau$
1. Stiffener welded direct to deck, shell, bulkhead plating, etc.	0.25 A_s or 6.5	0.34
2. Stiffener to bracket or bracket lapped to stiffener		
(1) in dry space		0.27
(2) in tank		0.34
(3) main frame to tank side bracket in 0.15L forward		0.34
3. Bracket welded to face of stiffener and bracket connection to shell, deck, bulkhead plating, etc.	–	0.34
4. Stiffener to plating for $0.1 \times \text{span}$ at ends where not fixed by welding	–	0.34

Notes: A_s – cross-sectional area of the stiffener, in cm^2 ;

A_w – area of the weld (in cm^2), and is calculated as total length of weld (in cm) $\times$ throat thickness (in cm).

1.4.4.13 Single-sided continuous fillet welding may be acceptable for dry spaces in deckhouse. Where this is adopted, the fillet leg length K is to be 2 times the value calculated in 1.4.4.2, where d/l is to be taken as 1.

SECTION 5 - DIRECT STRENGTH CALCULATIONS

1.5.1 General requirements

1.5.1.1 Where specifically required in this PART, or a novel structural configuration is adopted, or structural arrangements, ship's proportions and scantlings are not covered by the Rules, direct calculations are to be performed.

1.5.1.2 Except as otherwise specified, this Section in general applies to finite element (FE) analysis of cargo holds and the whole ship.

1.5.1.3 The loading conditions taken into account for direct strength calculations are to include most severe conditions for the design of ships.

1.5.1.4 The as-built thicknesses are to be applied for FE model scantlings, no additional thickness given by the shipowner is to be taken into consideration.

1.5.1.5 Except as otherwise specified, the structural scantlings required by this PART can not be reduced for the direct strength calculation.

1.5.1.6 Suitable general programs may be employed in direct calculations. Where a not generally used program is to be employed, supporting information is also to be submitted to substantiate the validity of the computer program.

1.5.1.7 The service coefficient $f_r = 1$.

1.5.1.8 The following documentation is to be submitted:

- (1) list of drawings used;
- (2) description of FE calculation programs used;
- (3) detailed description of structural FE model;
- (4) description of physical properties and material properties of structural model;
- (5) detailed description of boundary conditions;
- (6) detailed description of loading conditions;
- (7) details of applied loads;
- (8) figures of the overall and local deformations;
- (9) results of yield strength evaluation;
- (10) results of buckling strength evaluation;
- (11) output showing whether the structure meet design criteria or not.

1.5.1.9 Definitions

- (1) A right-handed coordinate system is to be used, see Figure 1.5.1.9, with:
 - ① the X-axis measured in the longitudinal direction, positive forward;
 - ② the Y-axis measured in the transverse direction, positive to port from the centerline;
 - ③ the Z-axis measured in the vertical direction, positive upwards.

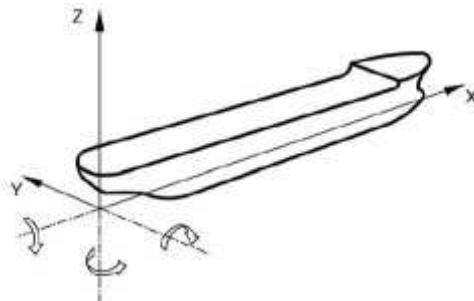


Figure 1.5.1.9 Coordinate system

- (2) The von Mises stress σ_e is to be determined by the following formula:

$$\sigma_e = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3\tau_{xy}^2}$$

where:

- σ_x — stress of element in direction x , in N/mm^2 ;
- σ_y — stress of element in direction y , in N/mm^2 ;
- τ_{xy} — shear stress of element in plane xy , in N/mm^2 .

- (3) The shear stress τ , in N/mm^2 ; for the primary structural members along the depth direction, the average shear stress of plate element may be calculated as follows:

$$\tau = \frac{\sum_{i=1}^n (\tau_i A_i)}{A_w} \quad \text{N/mm}^2$$

where:

A_i — the effective shear area of element i , in mm^2 ;

τ_i — the shear stress of element i , in N/mm^2 ;

A_w — the total effective shear area of actual structure, in mm^2 .

1.5.2 Motions and accelerations

1.5.2.1 Ship's absolute motions and accelerations

(1) The roll period T_R of the ship is to be calculated as follows:

$$T_R = 2 \frac{k_r}{\sqrt{GM}} \quad \text{s}$$

where:

k_r — roll radius of gyration, in m, to be assumed as follows if no specific values available:

$k_r = 0.35$ ballast condition for oil tankers;

$k_r = 0.25$ ore carriers;

$k_r = 0.39$ others;

where: B — breadth of ship, in m;

GM — initial metacentric height in the condition considered, to be assumed as follows if no specific

values available:

$GM = 0.12B$ for tankers and bulk carriers;

$= 0.07B$ for others.

(2) The maximum roll angle φ_m is to be calculated as follows, but need not be greater than 0.523 rad.

$$\varphi_m = f_r k \frac{62.5 - 1.25 T_R}{B + 75} \quad \text{rad}$$

where:

T_R — calculated as (1);

B — breadth of ship, in m;

f_r — service coefficient, see 1.5.1.7 of this Section;

k — coefficient, to be taken as follows:

$k = 1.2$ for ships without bilge keel;

$k = 1.0$ for ships with bilge keel;

$k = 0.8$ for ships with activated stabilizers.

(3) Pitch period T_p is to be calculated as follows:

$$T_p = 1.80 \sqrt{\frac{L}{10}} \quad \text{s}$$

where: L — length of ship, in m.

(4) The maximum pitch angle ψ_m is to be calculated as follows, but need not be greater than 0.14 rad:

$$\psi_m = 0.25 \frac{a_0}{C_b} \quad \text{rad}$$

where: C_b — block coefficient;

a_0 — acceleration factor, to be calculated as follows:

$$a_0 = f_r \left(3 \frac{C}{L} + C_v \frac{V}{\sqrt{L}} \right)$$

where: f_r — service coefficient, see 1.5.1.7 of this Section;

$$C_v = \frac{\sqrt{L}}{50}, \text{ not to be greater than } 0.2;$$

V — maximum service speed, in kn;

C — coefficient, see 2.2.3.1 of Section 2, Chapter 2 of this PART;

L — length of ship, in m.

1.5.2.2 Ship's relative motions and accelerations

(1) Surging acceleration a_x is to be calculated as follows:

$$a_x = 2a_0 \sqrt{C_b} \quad \text{m/s}^2$$

where: C_b — block coefficient;

a_0 — see 1.5.2.1(4) of this Section.

(2) Sway acceleration a_y is to be calculated as follows:

$$a_y = 3a_0 \text{ m/s}^2$$

where: a_0 — see 1.5.2.1(4) of this Section.

(3) Heave acceleration a_z is to be calculated as follows:

$$a_z = 7 \frac{a_0}{\sqrt{C_b}} \quad \text{m/s}^2$$

where: C_b — block coefficient;

a_0 — see 1.5.2.1(4) of this Section.

(4) Roll acceleration a_r is to be calculated as follows:

$$a_r = \varphi_m \left(\frac{6.28}{T_R} \right)^2 \quad \text{rad/s}^2$$

where: T_R — roll period, in sec., to be calculated according to 1.5.2.1(1) of this Section;

φ_m — maximum roll angle, in rad, to be calculated according to 1.5.2.1(2) of this Section.

(5) Pitch acceleration a_p is to be calculated as follows:

$$a_p = \psi_m \left(\frac{6.28}{T_p} \right)^2 \quad \text{rad/s}^2$$

where: T_p — pitch period, in sec., to be calculated according to 1.5.2.1(3) of this Section;

m — maximum pitch angle, in rad, to be calculated according to 1.5.2.1(4) of this Section.

(6) Transverse combined acceleration a_t is to be calculated as follows:

$$a_t = \sqrt{a_y^2 + [a_r(z - z_{rp}) + 10 \sin \varphi_m]^2} \quad \text{m/s}^2$$

where: a_y — sway acceleration, see 1.5.2.2(2);

- a_r — roll acceleration, see 1.5.2.2(4);
 φ_m — maximum roll angle, see 1.5.2.1(2) of this Section;
 z — vertical distance from the point considered to baseline;
 z_{rp} — vertical distance from axis of gyration for roll and that for pitch to baseline, to be taken from the values obtained by the following two formulae, whichever is the lesser;

$$z_{\eta 1} = \frac{D}{4} + \frac{d_1}{2} \quad \text{m}$$

$$z_{\eta 2} = \frac{D}{2} \quad \text{m}$$

where:

- D — moulded depth, in m;
 d_1 — draught the condition considered, in m.

(7) Longitudinal combined acceleration a_l is to be obtained by the following formula:

$$a_l = \sqrt{a_x^2 + [a_p(z - z_{rp}) + 10 \sin \psi_m]^2} \quad \text{m/s}^2$$

where: z_{rp} , z — see 1.5.2.2 (6);

a_x — surge acceleration, see 1.5.2.2 (1);

a_p — pitch acceleration, see 1.5.2.2 (5);

ψ_m — maximum roll angle, in rad, calculated according to 1.5.2.1 (4) of this Section.

(8) Vertical combined acceleration a_v is to be taken from the values obtained by the following two formulae, whichever is greater:

$$a_{v1} = \sqrt{a_z^2 + a_r^2 y^2} \quad \text{m/s}^2$$

$$a_{v2} = \sqrt{a_z^2 + a_p^2 (x - 0.45L)^2} \quad \text{m/s}^2$$

where: a_z — heave acceleration, see 1.5.2.2 (3);

a_r — roll acceleration, see 1.5.2.2(4);

a_p — pitch acceleration, see 1.5.2.2(5);

x — longitudinal distance from the point considered to AP, in m;

y — transverse distance from the point considered to longitudinal centerline, in m;

L — length of ship, in m.

1.5.3 External sea pressure

1.5.3.1 The external sea pressure consists of hydrostatic pressure and hydrodynamic wave pressure.

1.5.3.2 The hydrostatic pressure P_{hs} is to be calculated as follows:

$$P_{hs} = \rho_w g (d_1 - z) \quad \text{kN/m}^2 \quad \text{for the considered load point below the waterline;}$$

$$= 0 \quad \text{kN/m}^2 \quad \text{for the considered load point above the waterline.}$$

where: ρ_w — density of sea water, taken as 1.025 t/m³;

d_1 — draught in the considered condition, in m;

z — vertical distance measured from the considered point to the baseline, in m.

1.5.3.3 Hydrodynamic wave pressure

(1) The hydrodynamic wave pressure following formula p_{WL} at the side waterline of the ship is to be calculated by the following formula:

$$p_{WL} = f_r (2B^{0.66} + 3CC_b + 0.4d_1) \quad \text{kN/m}^2$$

where:

- f_r — service coefficient, see 1.5.1.7 of this Section;
- B — breadth of ship, in m;
- C_b — block coefficient;
- d_1 — draught under the loading condition for calculation, in m;
- C — coefficient, see 2.2.3.1 of Section 2, Chapter 2 of this PART.

- (2) The hydrodynamic wave pressure p_{BS} at the bilge of the ship is to be calculated by the following formula:

$$p_{BS} = p_{WL} - 1.2d_1 \quad \text{kN/m}^2$$

where: p_{WL} , d_1 — see 1.5.3.3(1).

- (3) The hydrodynamic wave pressure p_{BC} at the bottom centerline is to be calculated by the following formula:

$$p_{BC} = 0.5(p_{WL} - 1.2d_1) \quad \text{kN/m}^2$$

where: p_{WL} , d_1 — see 1.5.3.3(1).

- (4) The hydrodynamic wave pressure p_{hd} (see Figure 1.5.3.3) at any point below the waterline is to be calculated by the following formula:

$$p_{hd} = p_{WL} + (p_{BS} - p_{WL})\left(1 - \frac{z}{d_1}\right) + (p_{BC} - p_{BS})\left(1 - \frac{2y}{B}\right) \quad \text{kN/m}^2$$

where:

- p_{WL} — calculated according to 1.5.3.3 (1);
- p_{BS} — calculated according to 1.5.3.3 (2);
- p_{BC} — calculated according to 1.5.3.3 (3);
- B — breadth of ship, in m;
- d_1 — draught in the considered condition, in m;
- y — transverse distance measured from the considered point to the centreline, in m;
- z — vertical distance measured from the considered point to the baseline, in m.

- (5) The hydrodynamic wave pressure p_{hd} (see Figure 1.5.3.3) at any point at side shell plating above the waterline is to be calculated by the following formulae:

$$p_{hd} = p_{WL} - 10(z - d_1) \quad \text{kN/m}^2 \quad \text{for } d_1 < z \leq d_1 + \frac{p_{WL}}{10}$$

$$p_{hd} = 0 \quad \text{kN/m}^2 \quad \text{for } d_1 + \frac{p_{WL}}{10} < z$$

where:

- p_{WL} — calculated according to 1.5.3.3 (1);
- d_1 — draught under the considered condition, in m;

z — vertical distance measured from the considered point to the baseline, in m.

- (6) The green sea load p_{wdk} (see Figure 1.5.3.3) on weather deck is to be calculated by the following formula, but not less than zero:

$$p_{wdk} = p_{WL} - 10(z_{dk} - d_1) \quad \text{kN/m}^2$$

where:

p_{WL} — calculated according to 1.5.3.3(1);

d_1 — draught under the considered condition, in m;

z_{dk} — vertical distance measured from the weather deck to the baseline, in m.

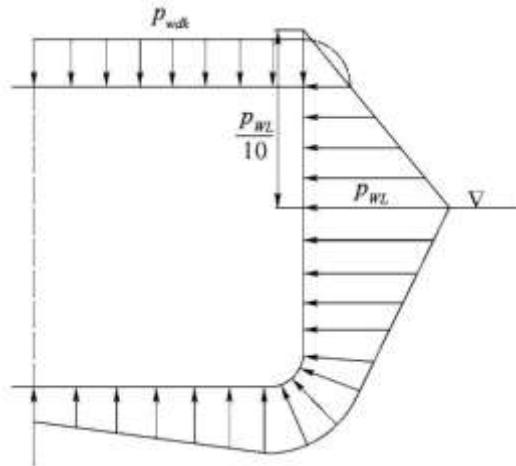


Figure 1.5.3.3 External Hydrodynamic Wave Pressure

1.5.4 Dry bulk cargo pressure

1.5.4.1 The pressure caused by dry bulk cargo is to be calculated according to 1.5.4.2 and 1.5.4.3.

1.5.4.2 The top surface of dry bulk cargo is to be determined according to the following requirements:

(1) For a prismatic cargo hold where the dry bulk cargo is loaded to the top of the hatch coaming, the top surface of cargo is to be determined equivalently according to the same cargo volume within the cargo hold. The equivalent cargo horizontal surface at h_C above the inner bottom, as shown in Figure 1.5.4.2(1), is to be calculated by the following formula:

$$h_C = h_{HPU} + h_0 \quad \text{m}$$

where:

h_{HPU} — vertical distance from inner bottom to the lower point of intersection of topside tank with side shell plating or inner hull plating, in m, see Figure 1.5.4.2(1);

h_0 — vertical distance from the lower point of intersection of topside tank with side shell plating

or inner hull to equivalent cargo horizontal surface, $h_0 = \frac{S_A}{B_H}$, in m;

where:

$$S_A = S_0 + \frac{V_{HC}}{l_H}$$

S_0 — shadow area from the lower point of intersection of topside tank with side shell plating or inner hull plating to horizontal surface of upper deck, in m^2 , see Figure 1.5.4.2(1);

V_{HC} — volume enclosed by hatch coaming from deck to coaming top, in m^3 ;

l_H — length of cargo hold, in m;

B_H — average breadth of cargo hold, in m.

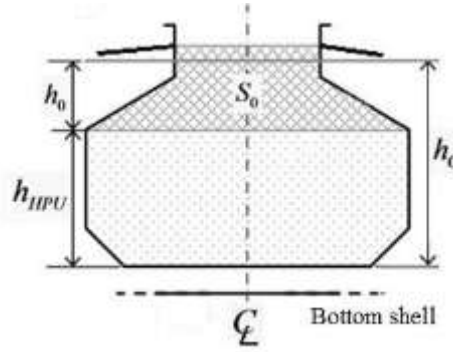


Figure 1.5.4.2(1) Definitions of h_c , h_0 , h_{HPU} and S_0

(2) For a prismatic cargo hold where the dry bulk cargo is not loaded to upper deck, it is assumed that its top surface is parabolic across along the hull and the shape of each cross section along the length of the cargo hold is the same, as shown in Figure 1.5.4.2(2). Parameters of the top surface shape are to be determined according to cargo volume in the cargo hold (taken as M/ρ_C) and calculated as follows:

$$\begin{aligned} h_c &= h_y + h_2 + h_{HPL} & \text{in m,} & \text{when } h_2 \geq 0 \\ h_c &= h_y + h_{22} & \text{in m,} & \text{when } |y| \leq \frac{B_2}{2} \text{ and } h_2 < 0 \\ h_c &= 0 & \text{in m,} & \text{when } |y| > \frac{B_2}{2} \text{ and } h_2 < 0 \end{aligned}$$

where:

h_2 — distance, in m, see Figure 1.5.4.2(2), to be calculated by the following formula:

$$h_2 = \frac{M}{\rho_C B_H l_H} - \frac{B_H + B_{IB}}{2 B_H} h_{HPL} - \frac{B_H}{6} \tan \delta + \frac{V_{TS}}{B_H l_H}$$

h_y — distance, in m, see Figure 1.5.4.2(2), to be calculated by the following formula:

$$\begin{aligned} h_y &= h_1 \left(1 - \frac{4y^2}{B_H^2}\right) & \text{if } h_2 \geq 0 \\ h_y &= h_1 \left(1 - \frac{4y^2}{B_2^2}\right) & \text{if } h_2 < 0 \end{aligned}$$

B_2 — cargo surface breadth if $h_2 < 0$, in m, see Figure 1.5.4.2(2), to be calculated by the following formula:

$$B_2 = \sqrt{\frac{\frac{6}{l_H} \left(\frac{M}{\rho_C} + V_{TS} \right) + \frac{3B_H^2}{B_H - B_{IB}} h_{HPL}}{\tan \delta + \frac{3h_{HPL}}{B_H - B_{IB}}}}$$

h_{22} — distance if $h_2 < 0$, in m, see Figure 1.5.4.2(2), to be calculated by the following formula:

$$h_{22} = h_{HPL} \left(\frac{B_2 - B_{IB}}{B_H - B_{IB}} \right)$$

h_{HPL} — vertical distance from inner bottom to the upper point of intersection of hopper side tank with side shell plating or inner hull, in m, see Figure 1.5.4.2(2). If there is no hopper side tank, h_{HPL} is taken as 0.

h_1 — distance, in m, see Figure 1.5.4.2(2), to be calculated by the following formula:

$$\begin{aligned} h_1 &= \frac{B_H}{4} \tan \delta & \text{if } h_2 \geq 0 \\ h_1 &= \frac{B_2}{4} \tan \delta & \text{if } h_2 < 0 \end{aligned}$$

M — mass of dry bulk cargo in cargo hold, in t;

V_{TS} — total volume of lower stool of transverse bulkhead within cargo hold length l_H , in m^3 . This does not include the portion of hopper side tank that passes through transverse bulkhead;

B_H, L_H — see (1) of this paragraph;

B_{IB} — average breadth of inner bottom, in m, see Figure 1.5.4.2 (2);

ρ_C — density of dry bulk cargo, in t/m^3 ;

δ — angle of repose of cargo, determined as follows:

$\delta = 35^\circ$ for ore and coal;

$\delta = 30^\circ$ for salt, yellow sand, stone, grain, etc.;

$\delta = 25^\circ$ for bulk cement;

y — transverse distance from considered point to the longitudinal centerline section, in m.

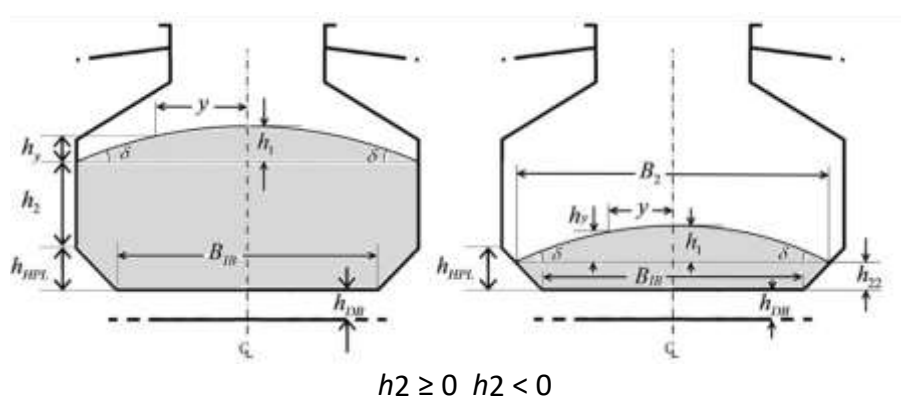


Figure 1.5.4.2(2) Definitions of h_y , h_1 , h_2 , h_{22} and h_{HPL}

(3) For a non-prismatic cargo hold, the top surface of dry bulk cargo may be taken at the horizontal surface of upper deck, and density taken as M/VH , where VH is cargo hold volume, not including its portion enclosed by hatch coaming.

1.5.4.3 The total pressure p_C caused by dry bulk cargo is to be calculated by the following formula and taken not less than zero:

$$p_C = \rho_C K_C (g + 0.5a_v)(h_C + h_{DB} - z) \quad \text{kN/m}^2$$

where:

ρ_C — density of dry bulk cargo, in t/m^3 ;

a_v — vertical acceleration in way of considered centroid of cargo hold, in m/s^2 , see 1.5.2.2 (8) of this Section;

h_C — vertical distance from the inner bottom to the top surface of dry bulk cargo, in m, determined according to 1.5.4.2 of this Section;

h_{DB} — height of double bottom, in m;

z — vertical height of the considered point, measured from baseline, in m;

K_C — coefficient, to be calculated as follows:

$K_C = \cos^2 \alpha + \tan^2 (45^\circ - 0.5\delta) \sin^2 \alpha$, for inner bottom, hopper side tank, transverse bulkhead and longitudinal bulkhead, lower stool, vertical upper stool, inner hull and side plate;

$K_C = 0$, for top side tank, upper deck and inclined upper stool;

α — included angle between considered plate and horizontal plane, in deg;

δ — angle of repose of cargo, in deg ($^\circ$), see 1.5.4.2(2) of this Section.

1.5.5 Liquid pressure in tank

1.5.5.1 The lateral pressure p_l caused by liquid in tank is to be calculated by the following formula:

$$p_l = \rho g (h + 2.5 f_r) \quad \text{kN/m}^2$$

where:

- ρ — mass density of liquid, in t/m^3 , to be taken not less than 1.025 t/m^3 ;
- h — vertical distance from the considered point to top of tank, or half the vertical distance to the top of the overflow, whichever is the greater, in m;
- f_r — service coefficient, see 1.5.1.7 of this Section.

1.5.6 Direct strength calculation for cargo holds

1.5.6.1 The design load is to be in compliance with the following requirements:

- (1) In general, the global load and local loads are to be taken into account, including vertical bending moment, external sea pressure, cargo loading, liquid pressure in tank, etc.
- (2) The wave bending moment M_W is to be calculated as in 2.2.3 of Section 2, Chapter 2 of this PART, and $f_r M_W$ is to be taken according to the service coefficient in 1.5.1.7 of this Section.

1.5.6.2 The extent of model is to be in compliance with the following requirements:

- (1) Normally, the longitudinal extent is to cover the length of $1/2$ hold + 1 hold + $1/2$ hold within the cargo area amidships.
- (2) In general, when both primary members and design loads are symmetrical to the longitudinal centerline section, only half breadth, starboard or port side is to be modeled. When the hold structure or load is not symmetrical to the longitudinal centerline section, a full-breadth model is to be required.
- (3) The vertical extent is to be taken as all members within the main hull, including all the primary members on the main deck.

1.5.6.3 The element is to be selected in compliance with the following principles:

- (1) In general, inner and external shell plates, deep webs of transverse rings, girders, floors, plane bulkhead web stiffeners, frames and other members as well as corrugated bulkheads and bulkhead stools are to be simulated by plate elements. In high stress areas and areas of significant stress gradient, such as lightening holes, manholes, connection of stool to bulkhead, positions adjacent to brackets or structural discontinuities, triangular elements are to be avoided as practicable as possible.
- (2) Stiffeners of plates, which are subject to external sea pressure or cargo pressure, are simulated by beam elements, taking eccentric effects into consideration. The face plates and stiffeners of primary members (e.g. girders, floor stiffeners, frames and brackets may be simulated by rod elements.

1.5.6.4 The meshing of elements is to be in compliance with the following principles:

- (1) Meshes are divided for each spacing of longitudinals or similar spacing in transverse and vertical direction of hull and for each spacing of frames or similar spacing in longitudinal direction of hull, and so are side meshes divided. Meshes are to be shaped square as far as practicable.

- (2) Not less than three plate elements are to be arranged in vertical direction for bottom girders and floors. Not less than two plate elements are to be arranged in vertical direction for ring structures of hopper tanks and top wing tanks.
- (3) In general, each flange plate or web plate of a corrugated bulkhead is to be taken at least as a plate element; for the plate elements at the lower end of the corrugated bulkhead in the vicinity of lower stool and for the elements adjacent to stool plate, the aspect ratio is to be close to 1.
- (4) Normally, the aspect ratio of plate elements is not to exceed 3, and the aspect ratio of plate elements for corrugated bulkhead is not to exceed 2. Triangular plate elements are to be minimized in modeling as far as possible; the aspect ratio of plate elements is to be close to 1 as far as possible within the high stress area or area of high stress gradient and triangular plate elements are to be avoided.

1.5.6.5 Strength evaluation is to be carried out for all primary members in the cargo holds amidships (including bulkheads) within the longitudinal extent.

1.5.6.6 When the stress distribution or stiffness of members is affected by the openings on primary members, the following methods may be adopted:

- (1) For openings, e.g. lightening holes, manholes, of web plates of primary structural members, simulation is to be carried out according to Table 1.5.6.6 of this Section.

Table 1.5.6.6-Simulation of Openings of Web Plates of Primary Structural Members

$h_0/h < 0.35$ and $g_0 < 1.2$	Modeling not needed for openings
$0.35 \leq h_0/h < 0.5$ and $g_0 < 1.2$	Equivalent plate thickness being $t_2 = \frac{h-h_0}{h} t_w$
$h_0/h < 0.5$ and $1.2 \leq g_0 < 2$	Equivalent plate thickness being $t_2 = \frac{h-h_0}{h g_0} t_w$
$h_0/h \geq 0.5$ or $g_0 \geq 2$	Modeling based on geometry of openings or by means of removing the appropriate elements in way of openings

where: t_w — thickness of web plates;

l_0 — opening length perpendicular to height of web plates, see Figure 1.5.6.6(1); where the space d_0 of continuous openings is less than $0.25 h$, l_0 is to be taken as the length across the openings, see Figure 1.5.6.6(2);

h_0 — opening height parallel to height of web plates, see Figure 1.5.6.6(1);

h — height of web plates in way of openings, see Figure 1.5.6.6(1);

$$g_0 = 1 + \frac{l_0^2}{2.6(h-h_0)^2}$$

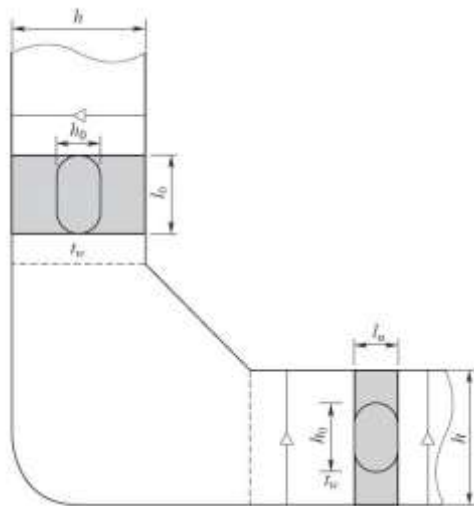
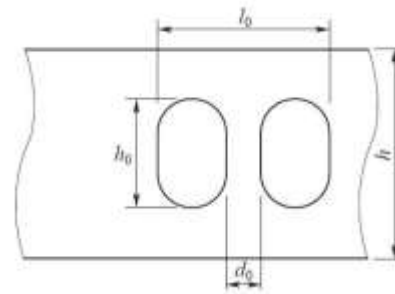


Figure 1.5.6.6(1) Openings of Web Plates

Figure 1.5.6.6(2) Length l_0 for Space of Continuous Openings $d_0 < 0.25 h$

- (2) For detailed stress analysis, the mesh size of the innermost two cycles of elements around the opening is not to be greater than 50 mm × 50 mm. The meshing is to be such that the transition from refined to coarse meshes is smooth. Stiffeners welded directly to the edges of the opening are to be simulated by plate elements; web stiffeners located more than 50 mm away from the edges of the opening can be simulated by rod or beam elements, as indicated in Figure 1.5.6.6(3). The allowable stress is to be as follows:

$$[\sigma_e] = 1.6 \times 235 / K \text{ N/mm}^2$$

where: K — material factor.

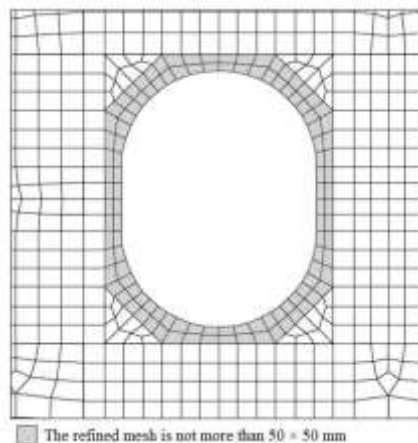


Figure 1.5.6.6(3) Refined Opening of Web Plate

1.5.7 Direct calculation of global strength of the ship

1.5.7.1 The flowchart of direct calculation of global strength of the ship is shown in Figure 1.5.7.1.

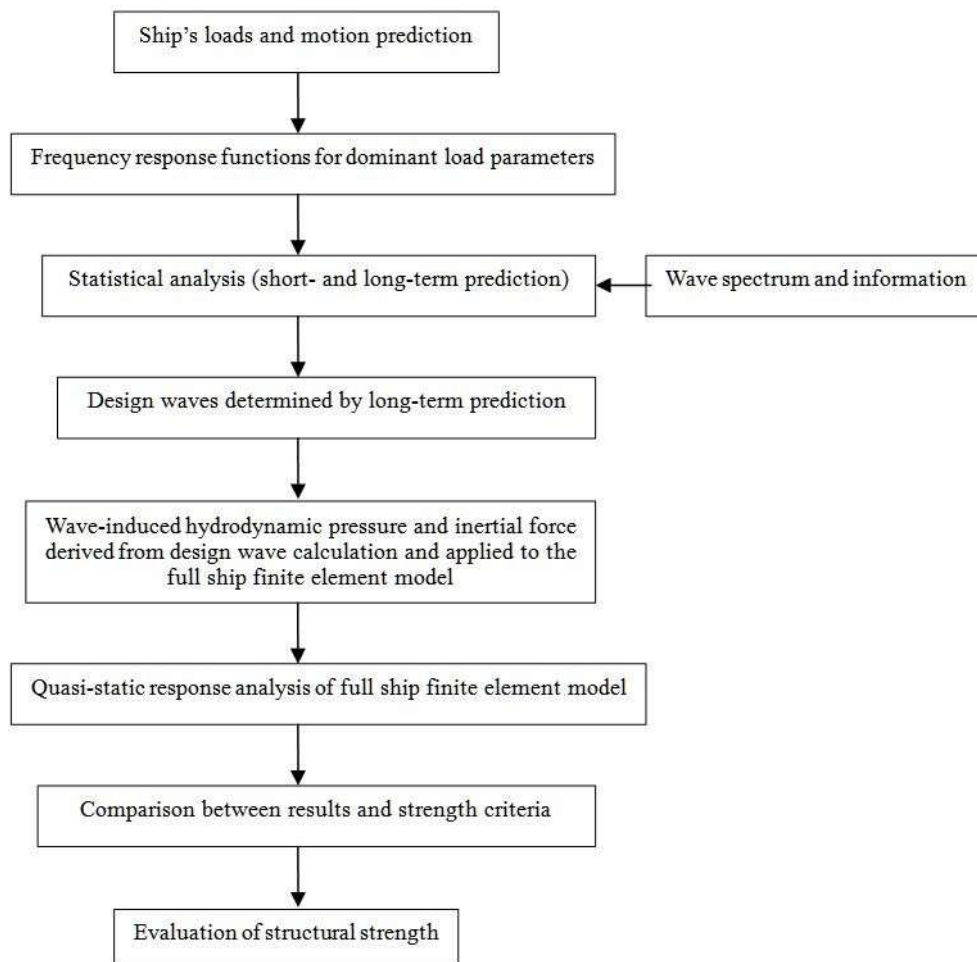


Figure 1.5.7.1 Flowchart of Direct Calculation of Global Strength of the Ship

1.5.7.2 The wave loads are to be determined by the equivalent design wave method, and in compliance with the following requirements:

- (1) Ship motion and wave load are to be calculated based on the two-dimensional linear strip theory, the three-dimensional linear theory (considering non-linear corrections) or the non-linear wave theory.
- (2) To calculate the ship motions and loads under design waves for each loading condition, the input data are considered as follows:
 - ① the number of wave frequency (or wave length) is not to be less than 20, range of wave frequency taken as 0.2 to 3 according to the ratio of wave length to ship's length (λ/L), and the increments taken as 0.1;
 - ② not less than 7 wave heading angles are to be taken, including 0° (head sea), 30°, 60°, 90°, 120°, 150°, 180° (following sea);
 - ③ ship speed is taken as 0.

1.5.7.3 Statistical analysis is to be carried out according to the following requirements:

- (1) *P-M* wave spectrum is used for calculation of ship's motion on irregular waves, wave load response and its short- and long-term prediction:

$$S(\omega, H_{1/3}, T_2, \theta) = \begin{cases} \frac{2}{\pi} 124 H_{1/3}^2 T_2^{-4} \omega^{-5} \exp\left(-\frac{496}{T_2^4 \omega^4}\right) \cos^2 \theta, & |\theta| \leq \frac{\pi}{2} \\ 0, & \theta \text{ as other values} \end{cases}$$

where: ω — circular frequency of waves, in rad/s;
 $H_{1/3}$ — significant wave height, in m;
 T_2 — zero-crossing wave period, in sec.;
 $\frac{2}{\pi} \cos^2 \theta$ — energy spread function;
 θ — included angle between complex wave and main sea direction, in rad.

- (2) In the wave scatter diagram used in the calculations, the worst wave data of the ship navigating in service areas are used.

1.5.7.4 The design waves are to be calculated as follows:

- (1) The design wave parameters are defined as shown in Figure 1.5.7.4(1):

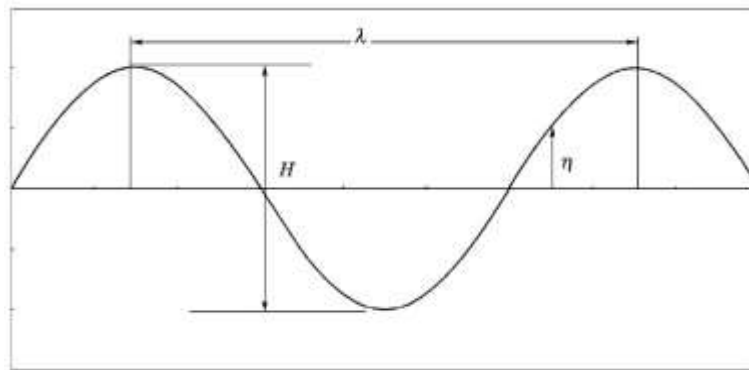


Figure 1.5.7.4(1) Design Wave Parameters

where:

λ — wave length, minimum distance between two adjacent wave crests, in m;
 H — wave height, minimum distance from wave crest to wave trough, in m;
 η — wave surface, as sine equation.

- (2) The probability level of long-term prediction values is to be selected according to the dominant load parameters.
- (3) To calculate the curve of frequency response functions of dominant load parameters under different heading angles of regular waves, as shown in Figure 1.5.7.4(2).

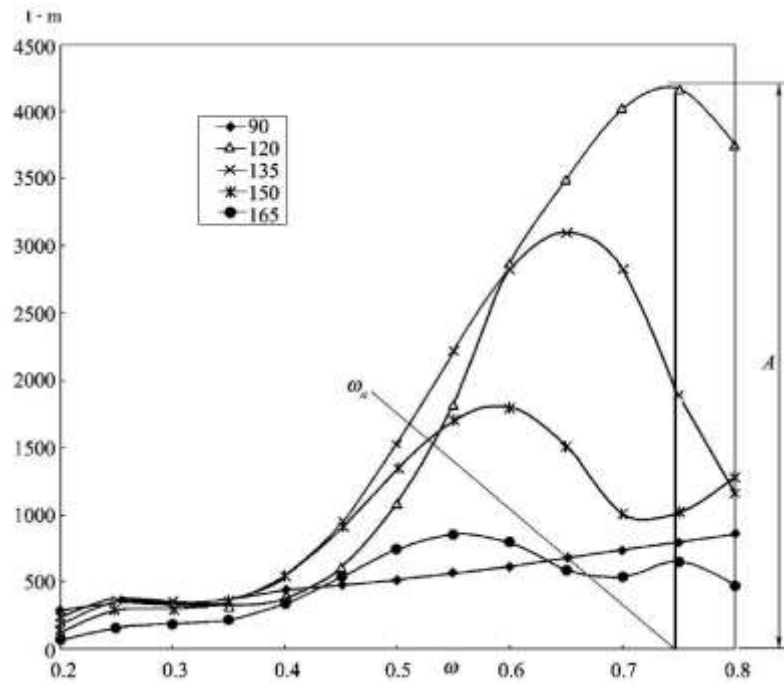


Figure 1.5.7.4(2) Frequency Response Functions

- (4) The wave frequency ω_a where dominant load parameters are at the maximum amplitude are determined according to frequency response functions.
- (5) Design wave length λ is to be calculated as follows:

$$\lambda = (2\pi g) / \omega_a^2 \quad \text{m}$$

where:

g — gravitational acceleration;

ω_a — wave frequency corresponding to dominant load parameters exceeding the maximum amplitude, to be determined by 1.5.7.4(4), in rad/s.

- (6) Amplitude of design waves is to be calculated as follows:

$$a_w = \frac{L_j}{A_j}$$

where:

a_w — amplitude of design waves;

A_j — maximum amplitude of dominant load parameters;

L_j — long-term extreme value of dominant load parameter at the probability level according to 1.5.7.4(2);

J — dominant load parameter number.

- (7) The time t_j instant where the dominant load parameter reaches maximum is to be determined as follows:

$$t_j = (n\pi + \pi/2 - \varepsilon_j) / \omega_a$$

where:

ω_a — wave frequency corresponding to dominant load parameters exceeding the maximum amplitude, to be determined by 1.5.7.4(4), in rad/s;

ε_j — phase angle corresponding to dominant load parameters exceeding the maximum amplitude, in rad;

j — as in 1.5.7.4(6);

$n = 0$ or 1 .

(8) Wave pressure and other load components under design waves are to be calculated as follows:

$$P_i = A_i a_w \sin(\omega_a t_j + \varepsilon_i)$$

where:

P_i — wave pressure or other load components at arbitrarily considered position of hull;

A_i — amplitude of frequency response function of wave pressure or other load component P_i ;

ε_i — phase corresponding to wave pressure or other load component P_i ;

t_j — time instant where dominant load parameter reaches maximum, determined according to 1.5.7.4(7).

1.5.7.5 Load components and applying

- (1) The ship's light weight: the masses of steel materials, outfits and small equipment are to be simulated by regulating the material density of each component. Large equipment and ballast water are to be simulated by mass elements, which may be established on the corresponding structures, and also may be connected to the actual structures through the simulated structures.
- (2) The weight of cargo in hold and on deck is to be simulated by appropriate mass elements.
- (3) External hydrostatic pressure, which acts, according to draft under the considered condition, on external wet surface of hull.
- (4) Wave pressure is to be calculated according to the equivalent design wave method, acting on external wet surface of hull.
- (5) Inertial load is to be based on the initial acceleration obtained by the equivalent design wave method, acting on the whole model.

1.5.7.6 The mass model of whole ship is to be matched with ship's hydrostatic buoyancy. The error between the total weight and total buoyancy is not to be more than 0.0001Δ , where Δ is the moulded displacement, in t, at the corresponding draught; the error of longitudinal coordinate for centers of mass and buoyancy is not to be more than $0.0025L$, where L is the length of ship, in m; the error of horizontal coordinate is not to be more than $0.001B$, where B is the breadth of ship, in m.

1.5.8 Yield strength evaluation

1.5.8.1 The stress of members is not to exceed the relevant allowable stress criteria.

1.5.8.2 Membrane stress, i.e. median stress at center of bending plate element is to be taken for plate element.

1.5.8.3 For corrugated bulkheads, the stress in way of corrugation end may be obtained by extrapolation of average stresses of bulkhead plating.

1.5.8.4 For those elements of concentrated stress and poor shape, the stresses are not to be

taken into consideration.

1.5.9 Buckling strength evaluation

1.5.9.1 The buckling safety factor ϕ of plate panel is not to be less than the related minimum one.

1.5.9.2 The buckling strength evaluation of plate panel is to be carried out for all primary members. During the evaluation, the appropriate standard thickness deduction is to be taken into consideration for the critical buckling compressive stresses.

1.5.9.3 The biaxial compressive stress and shear stress are to be taken into account for the buckling strength evaluation and membrane stress of plate panel is to be used for the buckling strength evaluation.

1.5.9.4 Critical buckling stress and plastic correction

(1) The elastic critical buckling stress σ_{xcr_e} of the plate panel, of which the shorter side is subjected to compression and bending, is defined as follows:

$$\sigma_{xcr\_e} = k_x C_1 \frac{\pi^2 E}{12(1-\nu^2)} \left(\frac{t}{s} \right)^2 \quad \text{N/mm}^2$$

where:

k_x — buckling coefficient for shorter side subjected to compression and bending, to be calculated according to Table 1.5.9.4(1);

C_1 — boundary constraint coefficient, see Table 1.5.9.4(2);

T — thickness of plate panel, in mm;

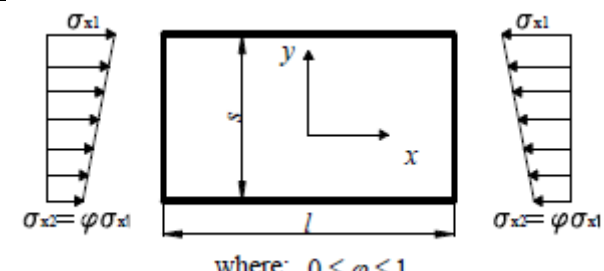
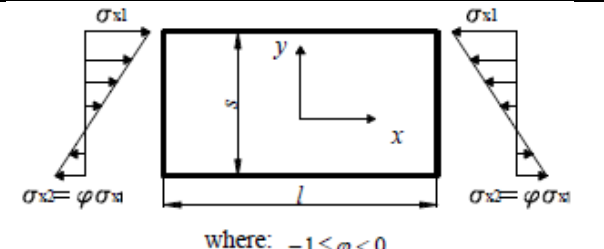
S — length of shorter side of plate panel, in mm, taken as spacing of stiffeners;

E — material's elastic modulus, in N/mm²;

ν — Poisson's ratio, $\nu = 0.3$ for steel;

x — axial direction of longer side of plate panel.

Table 1.5.9.4(1)-Buckling Coefficient of Plate Panel

	Buckling load condition	Buckling coefficient
Shorter side subject to stress	 where: $0 \leq \phi \leq 1$	$k_x = \frac{8.4}{\phi + 1.1}$
	 where: $-1 \leq \phi < 0$	$k_x = 7.6 - 6.4\phi + 10\phi^2$

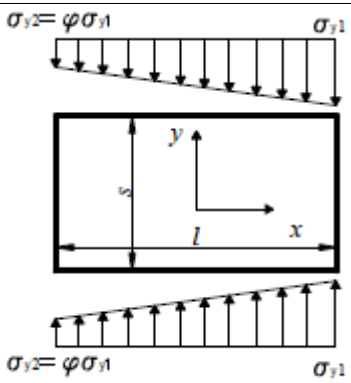
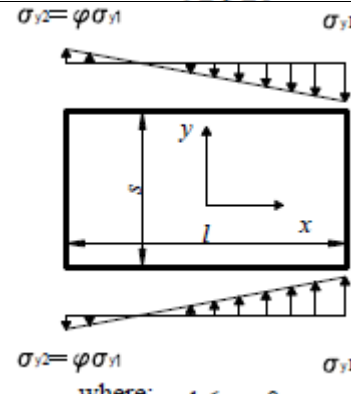
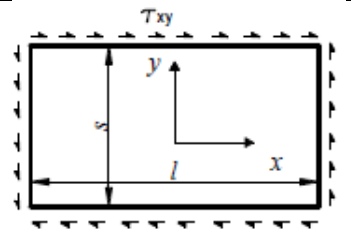
Longer side subject to stress	 where: $0 \leq \phi \leq 1$	$k_y = \left[1 + \left(\frac{s}{l} \right)^2 \right]^2 \frac{2.1}{\phi + 1.1}$
	 where: $-1 \leq \phi < 0$	$k_y = 1.909(1 + \phi) \left[1 + \left(\frac{s}{l} \right)^2 \right]^2 - k_p \phi + 10\phi(1 + \phi) \left(\frac{s}{l} \right)^2$ where: $k_p = \begin{cases} 24 \left(\frac{s}{l} \right)^2 & \frac{l}{s} \leq \frac{3}{2} \\ 2 + 16 \left(\frac{s}{l} \right)^2 + 8 \left(\frac{s}{l} \right)^4 & \frac{l}{s} > \frac{3}{2} \end{cases}$
Edges subject to shear stress		$k_t = 5.34 + 4 \left(\frac{s}{l} \right)^2$

Table 1.5.9.4(2)-Plate Panel Boundary Restraint Coefficients C1 and C2

Boundary	C ₁	C ₂	
		In double bottom or between double sides	Elsewhere
Angles or T-stiffeners	1.1	1.3	1.2
Flat bars or bulb flats	1.0	1.2	1.1

- (2) The elastic critical buckling stress σ_{xcr_e} of the plate panel, of which the longer side is subjected to compression and bending, is defined as follows:

$$\sigma_{xcr\_e} = k_y C_2 \frac{\pi^2 E}{12(1-\nu^2)} \left(\frac{t}{s} \right)^2 \quad \text{N/mm}^2$$

where:

k_y — buckling coefficient for longer side subjected to compression and bending, to be calculated according to Table 1.5.9.4(1);

C_2 — boundary restraint coefficient, see Table 1.5.9.4(2);

y — axial direction of shorter side of plate panel; other symbols are the same as in 1.5.9.4(1).

- (3) The elastic critical buckling stress σ_{yxr_e} of plate panel subject to shear force is defined as follows:

$$\tau_{cr\_e} = k_t C_1 \frac{\pi^2 E}{12(1-\nu^2)} \left(\frac{t}{s}\right)^2 \quad \text{N/mm}^2$$

where:

k_t — shear buckling coefficient, to be calculated according to Table 1.5.9.4(1);

other symbols are the same as in 1.5.9.4(1) and (2).

1.5.9.5 The elastic critical buckling stress of plate panel is to be corrected as follows:

$$\sigma_{scr} = \begin{cases} \sigma_{scr\_e} & \text{when } \sigma_{scr\_e} \leq \frac{R_{eff}}{2} \\ R_{eff} \left(1 - \frac{R_{eff}}{4\sigma_{scr\_e}} \right) & \text{when } \sigma_{scr\_e} > \frac{R_{eff}}{2} \end{cases}$$

$$\tau_{cr} = \begin{cases} \tau_{cr\_e} & \text{when } \tau_{cr\_e} \leq \frac{\tau_s}{2} \\ \tau_s \left(1 - \frac{\tau_s}{4\tau_{cr\_e}} \right) & \text{when } \tau_{cr\_e} > \frac{\tau_s}{2} \end{cases}$$

where:

σ_{scr_e} 、 σ_{scr} 、 τ_{cr_e} — respectively as elastic critical buckling compressive stress along axes x and y under uniaxial stress and critical buckling shear stress of plate panel, see 1.5.9.4 of this Section;

R_{eff} — yield stress of material, in N/mm²;

$$\tau_s = \frac{R_{eff}}{\sqrt{3}}$$

1.5.9.6 In the buckling strength evaluation, the buckling safety factor λ is to be the ratio of the critical buckling stress of plate panel to actual compressive stress, see Table 1.5.9.6. The

σ_x 、 σ_y 、 τ_{xy} are considered in their absolute values in calculation. Where the working stress along axes x and y is of tension stress, such stress component is to be taken as zero.

Table 1.5.9.6-Calculation of λ

Aspect ratio of plate panel	$1 \leq \frac{l}{s} \leq \sqrt{2}$	$\sqrt{2} < \frac{l}{s} \leq 8$
Stress condition		
Biaxial compression	$\frac{1}{(1+k_1)} \frac{\sigma_{xy}}{\sigma_x}$	$\frac{1}{\sqrt{(1+k_1^2)}} \frac{\sigma_{scr}}{\sigma_x}$
Compression along x axis + edge shear		$\frac{1}{\sqrt{(1+k_1^2)}} \frac{\sigma_{scr}}{\sigma_x}$
Compression along y axis + edge shear		$\frac{1}{\sqrt{(1+k_2^2)}} \frac{\sigma_{scr}}{\sigma_y}$
Biaxial compression + edge shear		$\frac{1}{\sqrt{(1+k_1^2+k_2^2)}} \frac{\sigma_{scr}}{\sigma_x}$
where: $k_1 = \frac{\sigma_y / \sigma_{scr}}{\sigma_x / \sigma_{scr}}$, $k_2 = \frac{\tau_{xy} / \tau_{cr}}{\sigma_x / \sigma_{scr}}$, $k_3 = \frac{\tau_{xy} / \tau_{cr}}{\sigma_y / \sigma_{scr}}$		

Notes:

- ① σ_{x1} and σ_{y1} are greater values of working stress acting on sides of plate panel along axes x and y, σ_{x2} and σ_{y2} are the lesser values of such stress, and x are to be taken as the average values of y σ_{x1} 、 σ_{x2} and σ_{y1} 、 σ_y respectively; τ_{xy} is the average shear stress, σ_{x1} 、 σ_{x2} 、 σ_{y1} 、 σ_{y2} 、 τ_{xy} are as shown in Table 1.5.9.4(1) of this Section.
- ② σ_{scr} 、 σ_{scr} and σ_{cr} are the elastically corrected critical buckling compressive stresses under uniaxial stress and critical buckling shear stress of plate panel along axes x and y respectively.

SECTION 6 - CORROSION CONTROL FOR HULL STRUCTURES

1.6.1 General requirements

1.6.1.1 Effective means are to be taken for all ships to prevent excessive corrosion of hull members.

1.6.1.2 All seawater ballast tanks having boundaries formed by the hull envelope plating are to have an efficient protective coating, epoxy or equivalent, applied in accordance with the coating manufacturer's recommendation. Dedicated seawater ballast tanks of all types of ships of not less than 500 gross tonnage and double-side skin spaces arranged in bulk carriers of 150 m and over in length, as specified in SOLAS regulation II-1/3-2, are to be coated in accordance with IMO resolution MSC.215(82) on Performance Standard for Protective Coatings for Dedicated Seawater Ballast Tanks in All Types of Ships and Double-Side Skin Spaces of Bulk Carriers (PSPC).

1.6.1.3 For bulk carriers, all internal and external surfaces of hatch coamings and hatch covers, and all internal surfaces of cargo holds, excluding the flat tank top areas and the hopper tanks sloping plating approximately 300 mm below the side shell frame and brackets, are to use an efficient protective coating (epoxy coating or equivalent) recommended by the coating manufacturer. In the selection of coatings, due consideration is to be given by the Owner to the intended cargo conditions expected in service.

1.6.1.4 Right before application of coatings to any structure, surface preparation is to be made in accordance with coating manufacturer's workmanship requirements and the surfaces are to be thoroughly cleaned to a corresponding degree. The number of coatings and total dry film thickness are to comply with the design requirements.

1.6.1.5 Where bimetallic connections are made, measures are to be incorporated to preclude galvanic corrosion.

1.6.1.6 Impressed current systems are not permitted in oil cargo tanks.

1.6.2 Primers or coatings

1.6.2.1 Where a primer is used to coat steel during construction, the primer is to be applied right after surface preparation. The composition of the primer is to be such that it will have no significant deleterious effect on subsequent welding work and that it is compatible with the paints or other coatings subsequently applied in association with an approved system of corrosion control for structures. Primers are subject to approval in accordance with the relevant ISC requirements.

1.6.3 Internal cathodic protection in tanks

1.6.3.1 Where a cathodic protection system is to be fitted in tanks or adjacent tanks carrying liquid cargoes having a flash point not exceeding 60°C, a plan showing details of the locations and attachment of anodes is to be submitted for information.

1.6.3.2 When cathodic protection requirements are assessed, the effects of uncoated surfaces (e.g. tank fittings) adjacent to those which require protection are to be taken into account.

1.6.3.3 Aluminum alloy sacrificial anodes, magnesium alloy sacrificial anodes, zinc and zinc alloy sacrificial anodes of oil tankers

- (1) Aluminum alloy sacrificial anodes are permitted in tanks used for the carriage of oil and adjacent tanks, but only at locations where the potential energy does not exceed 28 kg•m (200 lb•ft). The weight of the anode is to be taken as the weight at the time of fitting, including any inserts and fitting devices.
- (2) The height of the anode is, in general, to be measured from the bottom of the tank to the centre of the anode. Where the anode is located on horizontal surfaces (such as bulkhead girders and stringers) not less than 1 m wide, provided with an upstanding flange or face plate projecting not less than 75 mm above the horizontal surface, the height of the anode may be measured above that surface.
- (3) Aluminum anodes are not to be located under tank hatches or Butterworth openings (in order to avoid any metal parts falling on the fitted anodes), unless protected by adjacent structure.
- (4) Magnesium alloy sacrificial anodes are not permitted in oil cargo tanks and tanks adjacent to cargo tanks.
- (5) Zinc and zinc alloy sacrificial anodes may be located in any position without restriction.

1.6.3.4 Arrangement of sacrificial anodes

- (1) Anodes are to be reasonably located in relation to the structural features of the surfaces protected, and particular attention is to be given to the effects of adjacent structures and openings of the tank.
- (2) Anodes are to be fitted with steel cores which are to be so designed as to retain the anode even when the latter is wasted. Anodes are to be sufficiently rigid to avoid resonance in the anode support.
- (3) Anodes are to be efficiently attached to the structure. The following methods of attachment would be acceptable:
 - ① steel core connected to the structure by continuous welding of adequate section;
 - ② steel core bolted to separate supports, provided that a minimum of two bolts with lock nuts is used at each support;
 - ③ approved means of mechanical clamping.
- (4) Sacrificial anodes in tanks are not to be attached to the shell. The two ends are not to be attached to separate members which are capable of relative movement.
- (5) Sacrificial anodes are to be attached to stiffeners, or may be aligned in way of stiffeners on plane bulkhead plating. Where cores or supports are welded to the structure, they are to be arranged so that the welds are clear of stress raisers. Where they are welded to asymmetrical stiffeners, they are to be connected to the web with the welding kept at least 25 mm away from the edge of the web. In the case of stiffeners or girders with symmetrical face plates, the connection may be made to the web or to the centreline of the face plate but well clear of the free edges. However, it is recommended that anodes be not fitted to face plates of higher tensile steel longitudinals in so far as practicable.

1.6.4 External hull protection

1.6.4.1 Shell plating, particularly the portion between light and loaded load lines, weather decks and hatch covers are to be provided with suitable corrosion protection.

1.6.4.2 Where an impressed current cathodic protection system is fitted, plans or information showing the proposed layout of anodes, reference electrodes, wiring and methods of attaching to the rudder and propeller, are to be submitted.

1.6.4.3 A small cofferdam is to be included in the arrangements for glands, where cables pass through the shell. Cables to anodes are not to be led through tanks intended for the carriage of low flash point oils. Where cables are led through cofferdams or clean ballast tanks of tankers, they are to be enclosed in a substantial steel tube of at least 10 mm thickness.

1.6.4.4 For ships subject to in-water survey instead of drydocking survey, the underwater portion of the hull is to be coated with a high resistant paint. Details of the high resistant paint are to be submitted to ISC for information.

1.6.5 Corrosion allowance

1.6.5.1 Unless otherwise stated in this PART, the scantlings of hull structural members calculated in accordance with this PART are to include the values of corrosion allowance t_c as specified here.

1.6.5.2 Corrosion allowances t_c of hull structural members, including plating and framing, are to be obtained as in Table 1.6.5.2.

Table 1.6.5.2-Value of Corrosion Allowance t_c

Thickness, t (mm)	Corrosion Allowance, t_c (mm)
≤ 10	1.5
> 10	$0.1 t + 0.5$ (<i>maximum 3.2</i>)

1.6.5.3 For boundaries of ballast spaces or cargo tanks, the corrosion allowance is not to be less than 2.5 mm.

1.6.5.4 For dry spaces (cargo spaces in bulk carriers excluded), the corrosion allowances is to be $0.5 t_c$ (see Table 1.6.5.2), but not less than 1.0 mm.

SECTION 7 - FORE DECK FITTINGS

1.7.1 Strength requirements for fore deck fittings and equipment

1.7.1.1 This Section provides strength requirements for the following items located within the forward 0.25L: air pipes, ventilator pipes and their closing devices. However, these requirements do not apply to the cargo tank venting systems and the inert gas systems of oil tankers.

1.7.1.2 All ships of 80 m or over in length, where the height of the exposed deck in way of the items as defined in 1.7.1.1 of this Section is less than 0.1L or 22 m above the summer load waterline, whichever is the lesser, are to comply with the relevant requirements of 1.7.1 of this Section.

1.7.1.3 The pressures p , acting on air pipes, ventilator pipes and their closing devices may be calculated from:

$$p = 0.5 \rho V^2 C_d C_s C_p \text{ kN/m}^2$$

where:

ρ — density of seawater, taken as 1.025 t/m³;

V — velocity of water over the fore deck, in m/s;

= 13.5 m/s, for $h \leq 0.5h_1$;

= $13.5 \sqrt{2(1 - \frac{h}{h_1})}$ m/s, for $0.5h_1 < h < h_1$;

h — distance from summer load waterline to exposed deck, in m;

h_1 — 0.1L or 22 m, whichever is the lesser;

C_d — shape coefficient, taken as 0.5 for pipes, 1.3 for air pipe or ventilator heads in general, 0.8 for an air pipe or ventilator head of cylindrical form with its axis in the vertical direction;

C_s — slamming coefficient, taken as 3.2;

C_p — protection coefficient, taken as 0.7 for pipes and ventilator heads located immediately behind a breakwater or forecastle, 1.0 elsewhere and immediately behind a bulwark.

1.7.1.4 Forces acting in the horizontal direction on the pipe and its closing device may be calculated from 1.7.1.3 of this Section using the largest projected area of each component.

1.7.1.5 The requirements of 1.7.1.5 to 1.7.1.12 are additional to IACS UR P3 and UI LL36. This does not mean that closing devices of air pipes on all existing ships need to be upgraded to comply with UR P3.

1.7.1.6 Bending moments and stresses in air and ventilator pipes are to be calculated at critical positions: at penetration pieces, at weld or flange connections, at toes of supporting brackets. Bending stresses in the net section are not to exceed 0.8 R_{eH} , where R_{eH} is the specified minimum yield stress or 0.2% proof stress of the steel at room temperature. Irrespective of corrosion

protection, a corrosion addition to the net section of 2.0 mm is then to be applied.

1.7.1.7 For standard air pipes of 760 mm height closed by heads of not more than the tabulated projected area, pipe thicknesses and bracket heights are specified in Table 1.7.1.7. Where brackets are required, three or more radial brackets are to be fitted. Brackets are to be of gross thickness 8 mm or more, of minimum length 100 mm, and height according to Table 1.7.1.7 but need not extend over the joint flange for the head. For air pipes of other heights, relevant requirements specified in 1.7.1.5 to 1.7.1.8 of this Section are to be met. Bracket toes at the deck are to be suitably supported.

Table 1.7.1.7 - 760 mm Air Pipe Thickness and Bracket Standards

Nominal pipe diameter (mm)	Minimum fitted gross thickness (mm)	Maximum projected area of head (cm ²)	Height ^① of brackets (mm)
40 ^③	6	–	520
50 ^③	6	–	520
65	6	–	480
80	6.3	–	460
100	7	–	380
125	7.8	–	300
150	8.5	–	300
175	8.5	–	300
200	8.5 ^②	1,900	300 ^②
250	8.5 ^②	2,500	300 ^②
300	8.5 ^②	3,200	300 ^②
350	8.5 ^②	3,800	300 ^②
400	8.5 ^②	4,500	300 ^②

Notes:

- ① Brackets (see 1.7.1.7) need not extend over the joint flange for the head.
- ② Brackets are required where the as-fitted (gross) thickness is less than 10.5 mm, or where the tabulated projected head area is exceeded.
- ③ Not permitted for new ships.
- ④ For air pipes of other heights, requirements specified in 1.7.1.5 to 1.7.1.12 of this Section are to be met.

1.7.1.8 For other configurations, loads according to 1.7.1.3 and 1.7.1.4 of this Section are to be applied, and means of support determined in order to comply with the requirements of 1.7.1.6 of this Section. Brackets, where fitted, are to be of suitable thickness and length according to their height. Pipe thickness is not to be taken less than as indicated in IACS UI LL36.

1.7.1.9 For standard ventilators of 900 mm height closed by heads of not more than the tabulated projected area, pipe thicknesses and bracket heights are specified in Table 1.7.1.9. Brackets, where required, are to be as specified in 1.7.1.7 of this Section.

Table 1.7.1.9 - 900 mm Air Pipe Thickness and Bracket Standards

Nominal Pipe Diameter (mm)	Minimum Fitted Gross Thickness (mm)	Maximum Projected Area of Head (cm ²)	Height of Brackets (mm)
80	6.3	–	460
100	7	–	380
150	8.5	–	300
200	8.5	550	–
250	8.5	880	–
300	8.5	1200	–
350	8.5	2000	–
400	8.5	2700	–
450	8.5	3300	–
500	8.5	4000	–

Note: For ventilators of other heights, requirements specified in 1.7.1.5 to 1.7.1.12 of this Section are to be met.

1.7.1.10 For ventilators of height greater than 900 mm, brackets or alternative means of support are to be fitted. Pipe thickness is not to be taken less than as indicated in IACS UI LL36.

1.7.1.11 All component parts and connections of the air pipe or ventilator are to be capable of withstanding the loads defined in 1.7.1.3 and 1.7.1.4 of this Section.

1.7.1.12 Rotating type mushroom ventilator heads are unsuitable for application in the areas defined in 1.7.1.1 and 1.7.1.2 of this Section.

1.7.2 Strength and securing of small hatches on the exposed fore deck

1.7.2.1 The provisions of this Section apply to the strength of, and securing devices for, small hatches fitted on the exposed deck over the forward 0.25 L , where the height of the exposed deck in way of the hatch is less than 0.1 L or 22 m above the summer load waterline, whichever is the lesser, for all ships of 80 m or over in length. This regulation does not apply to small hatches on container ship giving access to a cargo hold which comply with UI LL64 except the requirement of clauses 4 & 5. Such hatch covers are considered non-weather-tight regardless of whether it is actually weather-tight or not. However, for scantlings of small hatches, the strength requirements in 1.7.2.4-1.7.2.7 of this Section could be applied instead of clause 6 of UI LL64.

1.7.2.2 Small hatches are hatches designed for access to spaces below the deck and capable of being closed weather-tight or watertight, as applicable. Their opening is normally 2.5 m² or less.

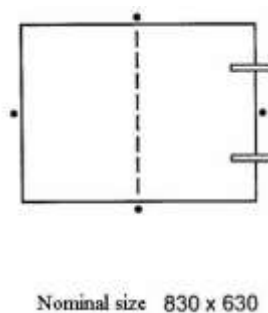
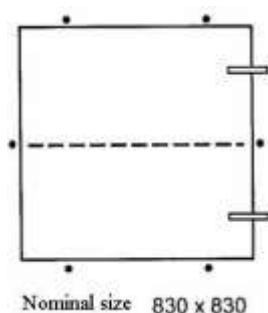
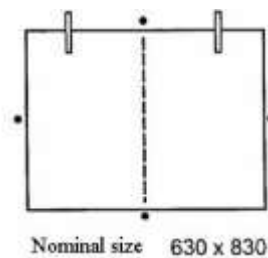
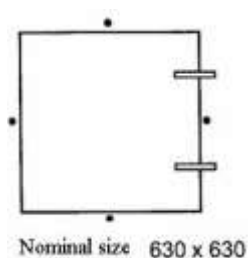
1.7.2.3 Hatches designed for emergency escape need not comply with the requirements of 1.7.2.8(1), 1.7.2.8(2), 1.7.2.9(3) and 1.7.2.10 of this Section. Securing devices of hatches designed for emergency escape are to be of a quick-acting type (e.g., one action wheel handles are provided as central locking devices for latching/unlatching of hatch cover) operable from both sides of the hatch cover. The maximum force needed to open the securing device is not to exceed 150 N, and the use of a spring equalizing, counterbalance or other suitable device on the hinge side to reduce the force needed for opening such hatch covers is acceptable. These requirements apply to new vessels, contracted for construction on or after 1 July 2007, by the time of delivery; to vessels

contracted for construction prior to 1 July 2007, by the compliance date specified in 5.3.5 of Chapter 5, PART ONE of the Rules, or by the due date of the first special survey after 1 July 2007, whichever is later. Completion prior to 1 July 2007 of a special survey with a due date after 1 July 2007 cannot be used to postpone compliance.

1.7.2.4 For small rectangular steel hatch covers, the plate thickness, stiffener arrangement and scantlings are to be in accordance with Table 1.7.2.4 and Figure 1.7.2.4. Stiffeners, where fitted, are to be aligned with the metal-to-metal contact points, as required in 1.7.2.9(1) of this Section, see Figure 1.7.2.4. Primary stiffeners are to be continuous. All stiffeners are to be welded to the inner edge stiffener, see Figure 1.7.2.9.

Table 1.7.2.4 - Scantlings for Small Steel Hatch Covers on Fore Deck

Nominal Size (mm × mm)	Cover Plate Thickness (mm)	Primary Stiffeners	Secondary Stiffeners
630 × 630	8	–	–
630 × 830	8	100 × 8; 1	–
830 × 630	8	100 × 8; 1	–
830 × 830	8	100 × 10; 1	–
1030 × 1030	8	120 × 12; 1	80 × 8; 2
1330 × 1330	8	150 × 12; 2	100 × 10; 2



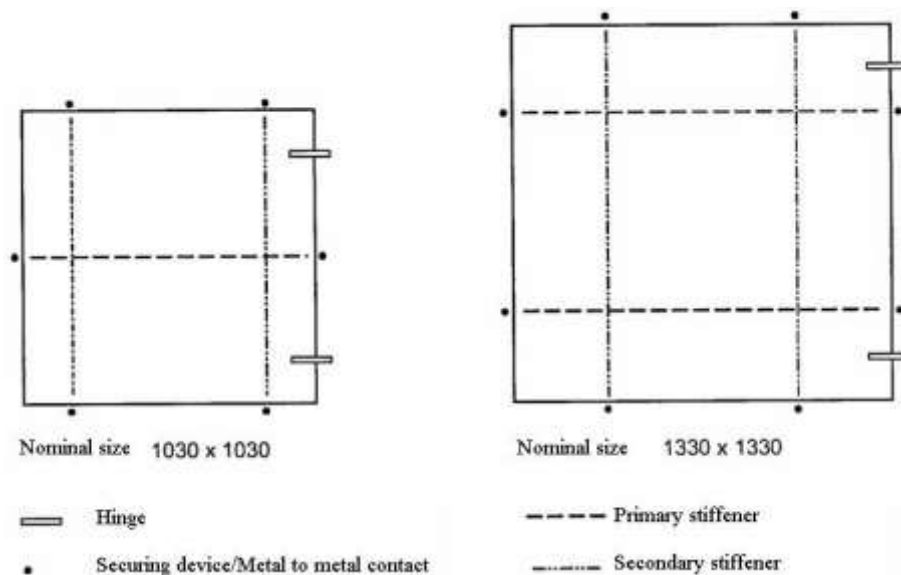


Figure 1.7.2.4 (Unit: mm × mm)

1.7.2.5 The upper edge of the hatchway coamings is to be suitably reinforced by a horizontal section, normally not more than 170 to 190 mm from the upper edge of the coamings.

1.7.2.6 For small hatch covers of circular or similar shape, the cover plate thickness and reinforcement is to provide strength equivalent to that of the surrounding structure.

1.7.2.7 For small hatch covers constructed of materials other than steel, the required scantlings are to provide equivalent strength.

1.7.2.8 Small hatches located on exposed fore deck are to be fitted with any one of the following primary securing devices:

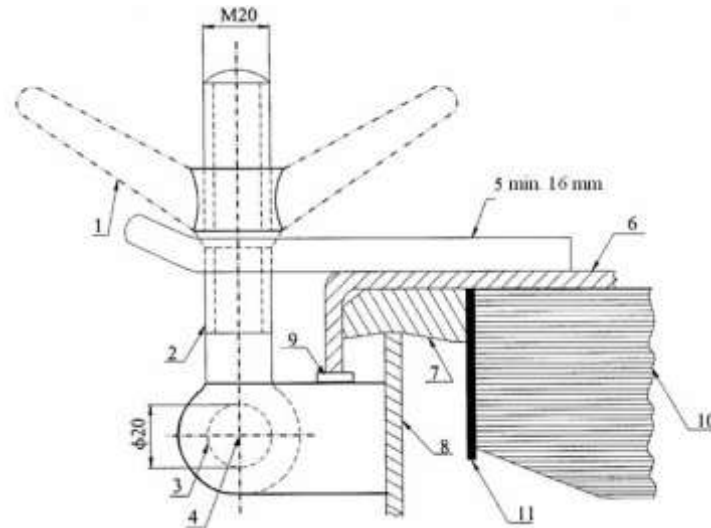
- (1) butterfly nuts tightening onto forks (clamps); (2) quick acting cleats; or
- (2) central locking device.
- (3) Dogs (twist tightening handles) with wedges are not acceptable.

1.7.2.9 The following requirements are to be complied with for primary securing devices:

- (1) The hatch cover is to be fitted with a gasket of elastic material. The metal-to-metal contacts are to be arranged close to each securing device in accordance with Figure 1.7.2.4, and of sufficient capacity to withstand the bearing force. This is to be designed to allow a metal to metal contact at a designed compression and to prevent over compression of the gasket by green sea forces that may cause the securing devices to be loosened or dislodged.
- (2) The primary securing devices are to be designed and manufactured such that the designed compression pressure is achieved by one person without the need of any tools.
- (3) For a primary securing device using butterfly nuts, the forks (clamps) are to be of robust design. They are to be designed by means of curving the forks upward, a raised surface on the free end, or a similar method. The plate thickness of forks is not to be less than 16 mm. An example arrangement is shown in Figure 1.7.2.9.
- (4) For small hatch covers located on the exposed deck forward of the fore-most cargo hatch, the

hinges are to be fitted such that the predominant direction of green sea will cause the cover to close, which means that the hinges are normally to be located on the fore edge.

- (5) On small hatches located between the main hatches, for example between No.1 and No. 2, the hinges are to be placed on the fore edge or outboard edge, whichever is practicable for protection from green water in beam sea and bow quartering conditions.



1. butterfly nut; 2. bolt; 3. pin; 4. center of pin; 5. fork (clamp) plate; 6. hatch cover; 7. gasket; 8. hatch coaming; 9. bearing pad welded on the bracket of a toggle bolt for metal to metal contact; 10. stiffener; 11. inner edge stiffener Figure 1.7.2.9

1.7.2.10 Small hatches on the fore deck are to be fitted with an independent secondary securing device e.g. by means of a sliding bolt, a hasp or a backing bar of slack fit, which is capable of keeping the hatch cover in place, even in the event that the primary securing device became loosened or dislodged. It is to be fitted on the side opposite to the hatch cover hinges.

SECTION 8 - TANK SLOSHING

1.8.1 General requirements

1.8.1.1 For partially loaded tank, a strength assessment of tank structure under sloshing loads (hereinafter referred to as 'Sloshing Assessment') is to be carried out according to the requirements of this Section.

1.8.1.2 For those not covered by this Section, the requirements of ISC Guidelines for Assessment of Sloshing Loads and Structural Scantling of Tanks are to be met.

1.8.1.3 Unless otherwise specified, for tanks with internal members, partial filling generally means the liquid filling height is greater than 10% of the tank depth but less than 90% of the tank depth. For smooth tank, partial filling generally means the liquid filling height is greater than 5% of the tank depth but less than 95% of the tank depth.

1.8.1.4 Unless specially specified, the sloshing assessment specified in this Section includes both transverse and longitudinal sloshing motions.

1.8.1.5 According to the judgment of the sloshing resonance of ship and tank, the sloshing motion and loads are divided into levels 1, 2 and 3. For tanks complying with sloshing motion level 1, sloshing loads at sloshing motion level 1 are to be calculated. For tanks complying with sloshing motion level 2, sloshing loads at sloshing motion levels 1 and 2 are to be calculated. For tanks complying with sloshing motion level 3, sloshing loads at sloshing motion levels 1, 2 and 3 are to be calculated.

1.8.1.6 In order to reduce sloshing motion level, internal members may be added for swash or limit on the filling may be taken to avoid sloshing resonance.

1.8.2 Application

1.8.2.1 This Section is applicable to tankers such as oil tankers, chemical tankers, liquefied gas carriers, and bulk carriers, ore carriers and dry cargo carriers etc.

1.8.2.2 This Section is applicable to all cargo tanks, ballast tanks and other tanks where free surface motion is allowed.

1.8.2.3 For ships the length of which is less than 100 m, the level 3 longitudinal sloshing assessment is not to be considered if the tank effective sloshing length does not exceed $0.16 L$ during the sloshing assessment. If the tank effective sloshing breadth does not exceed $0.6B$ (B is the ship breadth), level 3 transverse sloshing assessment is not to be considered.

1.8.2.4 Longitudinal sloshing assessment may not be required for tanks meeting one of the following conditions:

- (1) the length of ship is less than 65 m and the effective sloshing length does not exceed $0.13L$;
- (2) the effective sloshing length is less than $0.03L$.

1.8.2.5 Transverse sloshing assessment may not be required for tanks meet one of the following conditions:

- (1) the length of ship is less than 65 m and the effective sloshing breadth does not exceed $0.56B$;
- (2) the effective sloshing breadth is less than $0.32B$.

1.8.2.6 Sloshing assessment may not be required for tanks meet one of the following conditions:

- (1) tank capacity is not greater than 100 m^3 ;
- (2) tanks fitted in double bottom or double skin or other tanks of cellular construction; (3) dry cargo holds used for ballasting of bulk carriers.

1.8.3 Plans and documents

1.8.3.1 Plans approved by ISC including tank boundary structure plan, internal member structure plan of tank (if any) are to be submitted during the sloshing assessment carried out in accordance with the requirements of this Section.

1.8.3.2 Sloshing loads and hull structural strength assessment report are to be submitted to ISC for information.

1.8.4 Sloshing loads calculation

1.8.4.1 Unless otherwise specified, the sloshing motion and the calculation of the loads specified in this Section are to meet the requirements of ISC Guidelines for Assessment of Sloshing Loads and Structural Scantling of Tanks.

1.8.4.2 The results of sloshing model test may be taken as the alternative for sloshing design loads when approved by ISC.

1.8.5 Strength assessment

1.8.5.1 Scantling assessment under sloshing loads are to be carried out to the following structural members:

- (1) plating forming tank boundaries, stiffeners;
- (2) plating and stiffeners on wash bulkheads in the tank;
- (3) web of primary support members, web stiffeners in the tank.

1.8.5.2 Unless otherwise specified, scantling assessment under sloshing loads is to meet the requirements of ISC Guidelines for Assessment of Sloshing Loads and Structural Scantling of Tanks.

SECTION 9- INTACT STABILITY

1.9.1 General requirements

1.9.1.1 Compliance with the requirements for intact stability is a condition for classification of ships.

1.9.1.2 The intact stability of ships is to comply with the requirements of this Section, or it is to be demonstrated that their intact stability is in compliance with the requirements of the flag State Administration.

1.9.1.3 All bulk carriers of less than 150 m in length are to be fitted with loading instruments capable of providing intact stability information and are to comply with the requirements of Appendixes 1 and 2 of Chapter 2 of this PART.

1.9.1.4 Onboard computers for stability calculation, where fitted, for all ships are to comply with the requirements of Appendixes 1 and 2 of Chapter 2 of this PART.

1.9.1.5 If class notation SGISC(X) is applied for, the provisions of 1.9.6 in this Section are to be complied with, where X means one or more suffixes, the meanings of which are as follows:

P_{RN}—parametric rolling failure mode;

P_{LN}—pure loss of stability failure mode;

EA_N—excessive acceleration failure mode;

DS_N —dead ship condition failure mode;

SRB_N —surf-riding/broaching failure mode.

Where: $N=1$, meaning all loading conditions in compliance with Level 1 vulnerability criteria; $N=2$, meaning all loading conditions in compliance with Level 2 vulnerability criteria; $N=M$, meaning that there are loading conditions which do not meet the vulnerability criteria, and information on the stability of ship in waves has been prepared for the master.

1.9.2 Application

1.9.2.1 Unless otherwise stated, this Section applies to ships of 24 m and over in length, the types of which are covered by 1.9.4 and 1.9.6 of this Section.

1.9.2.2 For ships of less than 24 m in length, reference may be made to 1.9.2.1 of this Section.

1.9.2.3 For other ship types not covered by 1.9.4 and 1.9.6 of this Section, the criteria acceptable to ISC may be used.

1.9.3 Plans and documents

1.9.3.1 The following plans and documents are to be submitted for approval or confirmation:

- (1) Stability calculations for loading conditions or loading manual;
- (2) Curves or table of allowable height of center of gravity or allowable initial metacentric height;
- (3) Coordinates of opening of flooding angles and curves or table of flooding angles;
- (4) Stability information for carriage of grain (capacity of fully and partially filled compartments, curves or table of assumed volumetric heeling moment, curves or table of maximum permissible heeling moment) and stability calculations for loading conditions or loading manual (if applicable);
- (5) Operational guidance for ships in high sea conditions (may be included in the loading manual) (if applicable).

1.9.3.2 The following plans and documents are to be submitted for information:

- (1) General arrangement;
- (2) Lines and offsets;
- (3) Hydrostatic curves or table;
- (4) Stability cross curves or table;
- (5) Capacity curves or table;
- (6) Arrangement of bilge keels;
- (7) Plan of subdivision draught and load line marks;
- (8) Auxiliary calculations for windage area and moment of area, crowding of all passengers towards one side, icing, etc.;
- (9) Cross-sectional area (if applicable);
- (10) Approved inclining test report or light ship survey report;
- (11) Assessment calculations of operational guidance for ships in high sea conditions (if applicable).

1.9.3.3 The above information may be reduced as appropriate for ships of which the intact stability

has been approved, except for those of which service has been changed.

1.9.4 Requirements for intact stability

1.9.4.1 The intact stability of ships is to comply with the relevant requirements of IMO resolution MSC.267(85) – International Code on Intact Stability, 2008 (2008 IS Code) and its amendments. For ships with $B/D \geq 2.5$, the requirements of 2.2.3 of Part A of the Code may be substituted by the following criteria:

- (1) The heeling angle $\vartheta_{\max}$ corresponding to the maximum righting lever GZ is not to be less than 15° .
- (2) The area under the curve of righting levers (GZ curve) is not be less than 0.07 m·rad up to an angle of 15° when the maximum righting lever (GZ) occurs at 15° and 0.055 m·rad up to an angle of 30° when the maximum righting lever (GZ) occurs at 30° or above. Where the maximum righting lever (GZ) occurs at angles of between 15° and 30° , the corresponding area under the righting lever curve is to be: $0.055 + 0.001 (30^\circ - \vartheta_{\max})$ m·rad

1.9.4.2 The intact stability of oil tankers of 5,000 deadweight ton and above is also to comply with the relevant requirements of Regulation 27 of MARPOL Annex I.

1.9.4.3 The intact stability of open-top container ships is to comply with the relevant requirements of MSC/Circ.608/Rev. 1 – Interim Guidelines for Open-Top Container Ships.

1.9.4.4 The intact stability of polar ships having class notation PC and ships intended for navigation in ice and having class notation B1* or B1 are also to comply with the relevant requirements of resolution MSC.385(94) – International Code for Ships Operating in Polar Waters (Polar Code).

1.9.5 Second generation intact stability criteria

1.9.5.1 Ships are to comply with the relevant requirements of ISC Guidelines on Assessment of Ship Second Generation Intact Stability Criteria.

1.9.5.2 Second generation intact stability calculations are to be submitted for information.

1.9.6 Operational guidance for ships in high sea conditions

1.9.6.1 Hydrodynamic-based methods are to be used to analyze the performance and characteristics of the ship, assess the sailing conditions that may affect safety, and prepare operational guidance for ships in potential high sea conditions for the master's reference.

1.9.6.2 Due to the influences of environmental conditions, the ship's own state, human factors and other factors, operating the ship according to the ship's operational guidance in high sea conditions cannot ensure that the ship can completely avoid loss of stability, excessive movement and capsizing accidents when sailing in adverse sea conditions, nor can the master be released from the responsibility of the ship's navigation safety.

1.9.6.3 The likelihood of different modes of navigation safety failures under the combined or separate action of wind and waves is to be assessed, and operational guidance for ships in high sea conditions is to be developed accordingly. Modes of navigation safety failures that are to be assessed include:

- (1) excessive roll or excessive acceleration caused by parametric rolling;
- (2) excessive roll or excessive acceleration caused by synchronous rolling motion during navigation;
- (3) loss of stability caused by pure loss of stability;
- (4) excessive roll/capsizing or insufficient stability caused by the combined action of wind and waves in the dead ship condition.

1.9.6.4 Navigation safety assessments are to be carried out for typical loading conditions in sailing conditions as a minimum and operational guidance for ships in high sea conditions is to be developed.

1.9.6.5 The level 2 criteria for parametric rolling in IMO MSC.1/Circ.1627 is to be used to calculate the amplitude of parametric rolling and the resultant lateral acceleration at the bridge when the ship is sailing at typical speed in head waves and following waves. Operational guidance for ships in high sea conditions is to include sailing and sea conditions where the calculated roll amplitude is greater than 25° or lateral acceleration is greater than 4.64 m/s^2 .

1.9.6.6 The level 2 criteria for pure loss of stability in IMO MSC.1/Circ.1627 is to be used to calculate the vulnerability index of ship's pure loss of stability. Operational guidance for ships in high sea conditions is to include sea conditions with a calculated vulnerability index of 1.0.

1.9.6.7 The potential flow theory is to be used to calculate the amplitude of parametric rolling and the resultant lateral acceleration at the bridge when the ship is sailing at typical speed in typical waves. Operational guidance for ships in high sea conditions is to include sailing and sea conditions where the calculated roll amplitude is greater than 25° or lateral acceleration is greater than 4.64 m/s^2 .

1.9.6.8 The meteorological criteria of the International Code for Intact Stability, 2008, adopted by IMO resolution MSC.267(85), is to be used to calculate the steady wind speed value (beam wind) that meets the requirements of the meteorological criteria, assuming that the ship is in a dead ship condition and that the roll angle caused by wave action is 25° . Operational guidance for ships in high sea conditions is to include the steady wind speed value (beam wind).

1.9.6.9 The potential flow theory is to be used to calculate the amplitude of parametric rolling and the resultant lateral acceleration at the bridge when the ship is in the dead ship conditions in typical waves. Operational guidance for ships in high sea conditions is to include sailing and sea conditions where the calculated roll amplitude is greater than 25° or lateral acceleration is greater than 4.64 m/s^2 .

1.9.6.10 Other numerical simulations or model tests may be used as alternatives to navigation safety assessment subject to ISC agreement.

1.9.6.11 Operational guidance for ships in high sea conditions is to be provided in a loading manual or onboard computer-based system in a simple and clear form.

SECTION 10 - DAMAGE STABILITY

1.10.1 General requirements

1.10.1.1 Compliance with the applicable requirements for damage stability is a condition for classification of ships.

1.10.1.2 The damage stability of ships is to comply with the requirements of this Section, or it is to be demonstrated that their damage stability is in compliance with the requirements of the flag State Administration.

1.10.2 Plans and documents

1.10.2.1 The following plans and documents are to be submitted for approval or confirmation:

- (1) Calculations of damage stability;
- (2) Damage control plan and damage control booklet (for passenger ships and dry cargo ships);
- (3) Curves or table of allowable height of center of gravity or allowable initial metacentric height for damage stability (if applicable);
- (4) Arrangement of cross-flooding fittings and calculations of cross-flooding duration (if applicable).

1.10.2.2 The following plans and documents are to be submitted for information:

- (1) General arrangement of doors and windows;
- (2) General arrangement of scuttles, ventilators and air pipes;
- (3) Plans and documents stated in 1.9.3 of this Chapter.

1.10.3 Requirements for damage stability

1.10.3.1 The damage stability of ships is to comply with the relevant requirements of applicable regulations as shown in Table 1.10.3.1.

1.10.3.2 The stability of ships carrying timber deck cargo is to comply with the relevant requirements of IACS UI SC 161.

Table 1.10.3.1-List of Applicable Regulations for Damage Stability

Ship type	Applicable regulation
Passenger ship, type B freeboard dry cargo ship and combination carrier*, type B-60 and type B-100 freeboard cargo ships intended for carriage of deck cargo	Part B-1, Chapter II-1 of the International Convention for the Safety of Life at Sea (SOLAS)
Bulk carrier (additional requirements)	Reg. XII/4 of the International Convention for the Safety of Life at Sea (SOLAS)
Type B-60, type B-100 and type A freeboard ships	Reg. 27 of the International Convention on Load Lines, 1966 (ICLL), as revised by the 1988 Protocol
Chemical tanker	International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC Code)
Oil tanker (including combination carrier*)	Reg. 28 of Annex I of the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the 1978 Protocols (MARPOL)
Offshore supply vessel of not more than 100 m in length	Guidelines for the Design and Construction of Offshore Supply Vessels, 2006 (2006 OSV Guidelines)
Open-top container ship	MSC/Circ.608/Rev.1
Offshore support vessels transporting and handling hazardous and noxious liquid substances in bulk	Code for the Transport and Handling of Hazardous and Noxious Liquid Substances in Bulk on Offshore Support Vessels (OSV Chemical Code)
Ships using gases or other low-flashpoint fuels	International Code of Safety for Ships Using Gases or Other Low-flashpoint Fuels (IGF Code)

* Note: Combination carrier is a cargo ship designed to carry both oil and solid cargoes in bulk (see definition of SOLAS Reg.II-2/3.14).

SECTION 11 - LOAD LINE MARKS AND MARKING

1.11.1 Application

1.11.1.1 The requirements of this Section apply to ships engaged on international voyages.

1.11.2 Load line marks

1.11.2.1 The load line mark for ships not carrying timber deck cargoes is shown in Figure 1.11.2.1.

1.11.2.2 The load line mark for ships carrying timber deck cargoes is shown in Figure 1.11.2.2.

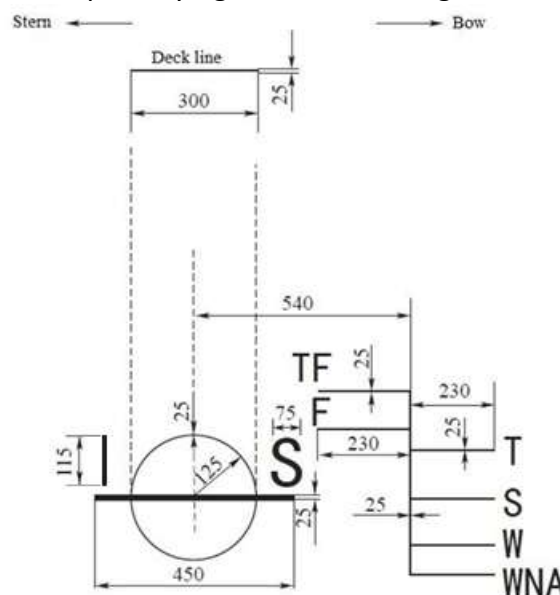


Figure 1.11.2.1 Freeboard Mark for Ships not Carrying Timber Deck Cargoes (in mm)

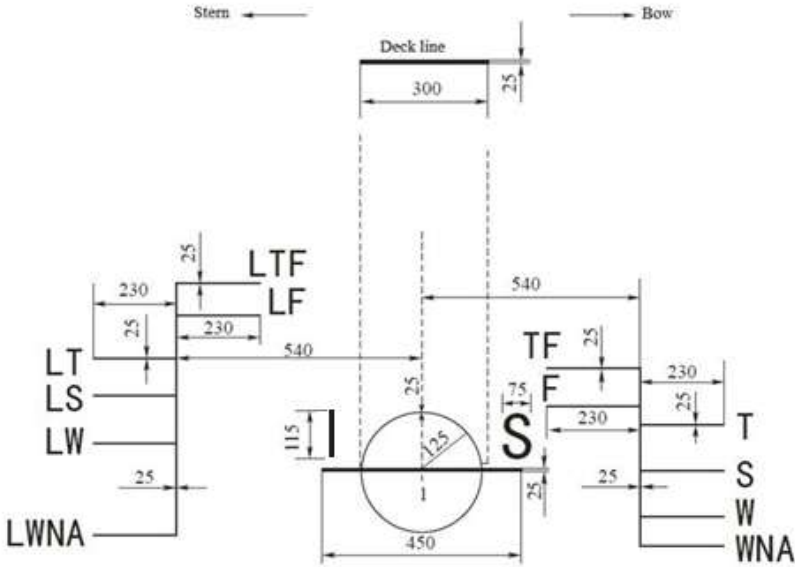


Figure 1.11.2.2 Freeboard Mark for Ships Carrying Timber Deck Cargoes (in mm)

1.11.2.3 Where a ship is assigned a greater than minimum freeboard so that the load line is marked at a position corresponding to, or lower than, the lowest seasonal load line assigned at minimum freeboard as specified in Annex B to the Protocol of 1988 Relating to the International Convention on Load Lines, 1966, only the Fresh Water Load Line need be marked. In such a case, the load line mark is as shown in Figure 1.11.2.3.

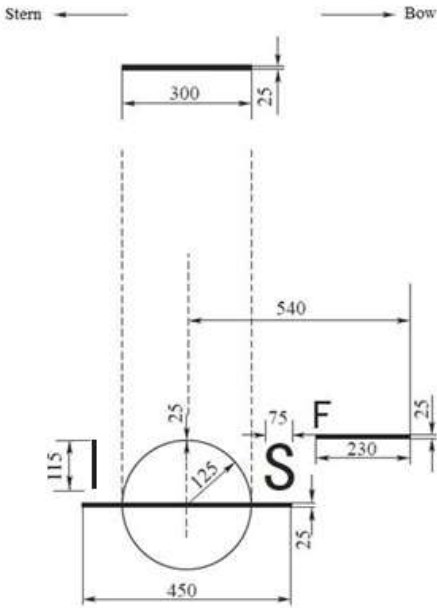


Figure 1.11.2.3 Fresh Water Load Line Only (in mm)

1.11.2.4 The subdivision load line mark for passenger ships is shown in Figure 1.11.2.4.

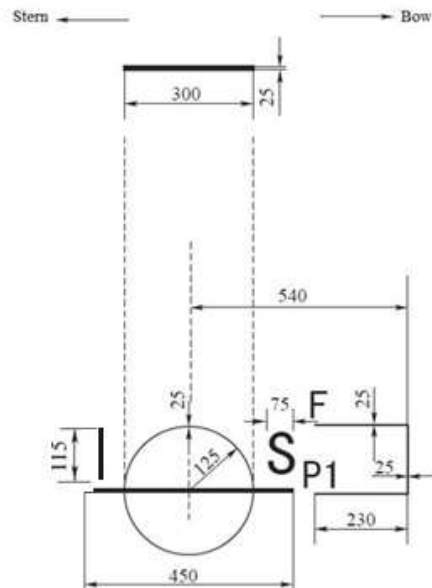


Figure 1.11.2.4 Subdivision Load Line Mark for Passenger Ships (in mm)

The symbols in Figures 1.11.2.1 to 1.11.2.4 are defined as follows:

- I, S — International Classification Society;
- TF — Tropical Fresh Water Load Line;
- F — Summer Fresh Water Load Line;
- T — Tropical Load Line;
- S — Summer Load Line;
- W — Winter Load Line;
- WNA — Winter North Atlantic Load Line;
- LTF — Tropical Fresh Water Timber Load Line;
- LF — Summer Fresh Water Timber Load Line;
- LT — Tropical Timber Load Line;
- LS — Summer Timber Load Line;
- LW — Winter Timber Load Line;
- LWNA — Winter North Atlantic Timber Load Line;
- P1 — Passenger Ship Subdivision Load Line.

1.11.3 Marking

1.11.3.1 The Load line mark is to consist of a ring 300 mm in outside diameter and 25 mm wide which is intersected by a horizontal line 450 mm in length and 25 mm in breadth, the upper edge of which passes through the center of the ring. The center of the ring is to be placed on each side of the ship at the middle of the length as defined in the Annex B to the Protocol of 1988 Relating to the International Convention on Load Lines, 1966, and at a distance equal to the assigned summer freeboard measured vertically below the upper edge of the deck line. The ring, lines and letters are to be painted in white or yellow on a dark ground or in black on a light ground. They are to be permanently marked on both sides of the ship and clearly visible.

SECTION 12 - STRUCTURAL ARRANGEMENT**1.12.1 General requirements**

1.12.1.1 This Section specifies the requirements for the structural arrangement of hull structures of ships engaged in unrestricted service.

1.12.1.2 Unless stated otherwise, this Section applies to mechanically self-propelled ships engaged on international voyages.

1.12.2 Arrangement of watertight bulkheads

1.12.2.1 All ships are to be fitted with at least the following watertight bulkheads:

- (1) one collision bulkhead;
- (2) one after peak bulkhead;
- (3) one bulkhead at both ends of the machinery space;
- (4) the number of watertight bulkheads and their distribution along the ship's length for both passenger and cargo ships are to comply with the requirements for subdivision and stability contained in Sections 9 and 10 of this Chapter, in addition to the requirements of (1) to (3) above;
- (5) the number of watertight bulkheads and their distribution along the ship's length for oil tankers of 600 deadweight tons and above are to comply with the requirements of Chapters 3 and 4 of MARPOL Annex I, in addition to the requirements of (1) to (3) above.

1.12.3 Arrangement of collision bulkhead

1.12.3.1 A collision bulkhead is to be fitted which is to be watertight up to the bulkhead deck of passenger ships and the freeboard deck of cargo ships. This bulkhead is to be located at a distance from the forward perpendicular (the perpendicular at the intersection of the load waterline LL with the fore side of the stem) of not less than $0.05 LL$ or 10m, whichever is the less, and, except as may be permitted by the Administration, not more than $0.08 LL$ or $0.05 LL + 3$ m, whichever is the greater.

1.12.3.2 Where any part of the ship below the waterline extends forward of the forward perpendicular referred to in 1.12.3.1 of this Section, e.g., a bulbous bow, the distances specified in

1.12.3.1 of this Section are to be measured from a point either:

- (1) at the mid-length of such extension;
- (2) at a distance $0.015 L_L$ forward of the forward perpendicular; or
- (3) at a distance 3m forward of the forward perpendicular, whichever gives the smallest measurement.

1.12.3.3 The collision bulkhead may have steps or recesses, provided that they are within the limits specified in 1.12.3.1 and 1.12.3.2 of this Section.

1.12.3.4 Where a long forward superstructure is fitted, the collision bulkhead is to be extended weathertight to the deck next above the bulkhead deck of passenger ships and the freeboard deck of cargo ships. The extension need not be fitted directly above the bulkhead below provided it is located within the limits prescribed in 1.12.3.1 and 1.12.3.2 of this Section with the exception permitted by 1.12.3.5 of this Section and that the part of the deck which forms the step is made effectively weathertight.

1.12.3.5 Where bow doors are fitted and a sloping loading ramp forms part of the extension of the collision bulkhead above the bulkhead deck of passenger ships and the freeboard deck of cargo ships, the ramp is to be weathertight over its complete length. In cargo ships the part of the ramp which is more than 2.3 m above the freeboard deck may extend forward of the limit specified in 1.12.3.1 and 1.12.3.2 of this Section. Ramps not meeting the above requirements are to be disregarded as an extension of the collision bulkhead.

1.12.3.6 The number of openings in the extension of the collision bulkhead above the freeboard deck is to be restricted to the minimum compatible with the design and normal operation of the ship. All such openings are to be capable of being closed weathertight.

1.12.4 Arrangement of after peak and machinery space bulkheads and stern tube

1.12.4.1 Bulkheads are to be fitted separating the machinery space from cargo and accommodation spaces forward and after and made watertight up to the bulkhead deck of passenger ships and the freeboard deck of cargo ships. An aft peak bulkhead is also to be fitted and made watertight up to the bulkhead deck or the freeboard deck. The aft peak bulkhead may, however, be stepped below the bulkhead deck or the freeboard deck, provided the degree of safety of the ship as regards subdivision is not thereby diminished.

1.12.4.2 In all cases, stern tubes are to be enclosed in watertight spaces of moderate volume. In passenger ships the stern gland is to be situated in a watertight shaft tunnel or other watertight space separate from the stern tube compartment and of such volume that, if flooded by leakage through the stern gland, the bulkhead deck will not be immersed. In cargo ships, other measures to minimize the danger of water penetrating into the ship in case of damage to stern tube arrangements may be taken upon approval.

1.12.5 Arrangement and watertightness of openings and trunks in watertight bulkheads and internal decks

1.12.5.1 The number of openings in watertight bulkheads is to be reduced to the minimum compatible with the design and proper working of the ship.

1.12.5.2 Where pipes, scuppers, electric cables, etc., are carried through watertight bulkheads, arrangements are to be made to ensure the watertight integrity of the bulkheads. Valves not forming part of a piping system are not to be permitted in watertight bulkheads. Lead or other heat-sensitive materials are not to be used in systems which penetrate watertight bulkheads.

1.12.5.3 For passenger ships, no doors, manholes or access openings are permitted in watertight transverse bulkheads dividing a cargo space from an adjoining cargo space, except those agreed. For cargo ships, ISC may permit relaxation of the watertightness requirements for openings above the freeboard deck, where it is demonstrated that any progressive flooding can be easily controlled and that the safety of the ship will not be thereby impaired.

1.12.5.4 No doors, manholes, ventilation ducts or any other openings are to be fitted in the collision bulkhead below the bulkhead deck for passenger ships (except the pipes, provided that the relevant requirements of the Administration are complied with).

1.12.5.5 Watertight ventilators and trunks are to be carried at least up to the bulkhead deck in passenger ships and up to the freeboard deck in cargo ships.

1.12.5.6 The arrangement and watertightness of accesses to spaces below the ro-ro deck (bulkhead deck) in ro-ro passenger ships are to comply with the following requirements:

- (1) Subject to (2) and (3) of this paragraph, all accesses that lead to spaces below the bulkhead deck are to have a lowest point which is not less than 2.5 m above the bulkhead deck.
- (2) Where vehicle ramps are installed to give access to spaces below the bulkhead deck, their openings are to be able to be closed weathertight to prevent ingress of water below, alarmed and indicated to the navigation bridge.
- (3) ISC may permit the fitting of particular accesses to spaces below the bulkhead deck provided they are necessary for the essential working of the ship, e.g. the movement of machinery and stores, subject to such accesses being made watertight, alarmed and indicated to the navigation bridge.

1.12.6 Openings in the shell plating below bulkhead deck of passenger ships and the freeboard deck of cargo ships and their watertightness

1.12.6.1 The number of openings in the shell plating is to be reduced to the minimum compatible with the design and proper working of the ship.

1.12.6.2 Freeing ports are to be capable of rapidly freeing the decks of water and draining them. The freeing port area in bulwarks is to be in accordance with Regulation 24 of the Amendments to Annex I of Annex B to the Protocol of 1988 Relating to the International Convention on Load Lines, 1966.

1.12.6.3 Moving parts penetrating the shell plating below the deepest subdivision draught are to be fitted with an acceptable watertight sealing arrangement. The inboard gland is to be located within a watertight space of such volume that, if flooded, the bulkhead deck of passenger ships and the freeboard deck of cargo ships will not be submerged.

1.12.7 Other openings and their closing appliances

1.12.7.1 All access openings in bulkheads at ends of enclosed superstructures are to comply with the following requirements:

- (1) Doors of steel or other equivalent material are to be fitted, permanently and strongly attached to the bulkhead, and framed, stiffened and fitted so that the whole structure is of equivalent strength to the un-pierced bulkhead and weathertight when closed.
- (2) Unless otherwise permitted by the flag Administration, doors are to open outwards so as to be protected against wave impact.
- (3) The height of doorsills is to be at least 380 mm above the deck.

1.12.7.2 Cargo and other hatchways, miscellaneous openings in freeboard and superstructure decks are to comply with the following requirements:

- (1) The height of coamings of hatchways above the deck is to be at least as follows:
 - ① 600 mm if in Position 1; and
 - ② 450 mm if in Position 2.
- (2) The structure of cargo and other hatchways in Positions 1 and 2 and the means for keeping them weathertight are to comply with the relevant requirements of Regulation 15 or 16 of the Amendments to Annex I of Annex B to the Protocol of 1988 Relating to the International Convention on Load Lines, 1966.
- (3) Openings in freeboard and superstructure decks are to comply with the relevant requirements of Regulation 18 of the Amendments to Annex I of Annex B to the Protocol of 1988 Relating to the International Convention on Load Lines, 1966.

1.12.7.3 Machinery space openings are to comply with the following requirements:

- (1) Machinery space openings are to be efficiently enclosed by steel casings. Access openings in such casings are to be fitted with weathertight doors, the sills of which are to be at least 600 mm above the deck if in Position 1, and at least 380 mm above the deck if in Position 2. Other openings in such casings are to be fitted with covers, permanently attached in their proper positions.
- (2) Where machinery casings are not protected by other structures, double doors are to be required for ships assigned freeboards less than those based on relevant requirements. An inner sill of 230 mm in conjunction with the outer sill of 600 mm is to be provided.
- (3) Coamings of any machinery space ventilator, the height of which complies with the requirements of 1.12.7.4(6) of this Section, need not be fitted with weathertight closing appliances. Ventilators necessary to continuously supply the emergency generator room, if this is considered buoyant in the stability calculation or protecting opening leading below, are to have coamings of sufficient height to comply with 1.12.7.4(6) of this Section, without having to

fit weathertight closing appliances.

- (4) Where the height of machinery space and emergency generator room ventilator coamings is less than that required by 1.12.7.4(6) of this Section, weathertight closing appliances are to be fitted.
- (5) Engine/boiler openings are to be fitted with strong covers of steel or other equivalent material permanently attached in their proper positions and capable of being secured weathertight.
- (6) Machinery casings on type “A” ships are to comply with the relevant requirements of Regulations 26(1) and (2) of the Amendments to Annex I of Annex B to the Protocol of 1988 Relating to the International Convention on Load Lines, 1966.

1.12.7.4 Ventilators are to comply with the following requirements:

- (1) Ventilators in Position 1 or 2 to spaces below freeboard deck or decks of enclosed superstructures are to have coamings of steel or other equivalent material, substantially constructed and efficiently connected to the deck. Where the coaming of any ventilator exceeds 900 mm in height, it is to be specially supported.
- (2) Ventilators passing through superstructures other than enclosed superstructures are to have substantially constructed coamings of steel or other equivalent material at the freeboard deck.
- (3) Ventilators in Position 1 are to have coamings of a height of at least 900 mm above the deck.
- (4) Ventilators in Position 2 are to have coamings of a height of at least 760 mm above the deck.
- (5) The thickness of ventilator coamings may be taken from Table 1.12.7.4(5), but need not exceed that of the deck.

Table 1.12.7.4(5) - Thickness of Ventilator Coamings

Internal diameter of coaming (mm)	Thickness of coaming (mm)	Internal diameter of coaming (mm)	Thickness of coaming (mm)
≤ 200	7.5	350	9
250	8	400	9.5
300	8.5	≥ 450	10

- (6) Ventilators in Position 1 the coamings of which extend to more than 4.5 m above the deck, and in Position 2 the coamings of which extend to more than 2.3 m above the deck, need not be fitted with closing arrangements.
- (7) Except as provided in (6) above, ventilator openings are to be provided with efficient weathertight closing appliances. In ships of not more than 100 m in load line length LL , the closing appliances are to be permanently attached; in ships of more than 100 m in load line length LL , they may be conveniently stowed near the ventilators to which they are to be fitted.

1.12.7.5 Air pipes are to comply with the following requirements:

- (1) Air pipes are to comply with the requirements of this Section and in addition, the relevant requirements of Chapter 3 of PART THREE of the Rules.
- (2) Where air pipes to ballast and other tanks extend above the freeboard or superstructure decks, the height from the deck to the point where water may have access below is to be at least 760 mm on the freeboard deck and 450 mm on the superstructure deck. Where these heights may interfere with the working of the ship, a lower height may be approved, provided that ISC is satisfied that the closing arrangements and other circumstances justify a lower height. The

exposed parts of the pipes are to be of substantial construction

(3) The minimum wall thickness of air pipes above weather deck is to be:

6.0 mm for pipes of 80 mm external diameter or smaller;

8.5 mm for pipes of 165 mm external diameter or greater.

Intermediate minimum thicknesses are to be determined by linear interpolation.

(4) Air pipes are to be fitted with automatic closing devices.

1.12.8 Arrangement of double bottoms (not of tankers)

1.12.8.1 For all passenger ships regardless of size and cargo ships of 500 gross tonnage and over, a double bottom is to be fitted and is to extend from the collision bulkhead to the after peak bulkhead, as far as this is practicable and compatible with the design and proper working of the ship.

1.12.8.2 Where a double bottom is required to be fitted, the inner bottom is to be continued out to the ship's side in such a manner as to protect the bottom to the turn of the bilge. The vertical distance h measured from the keel line is in no case to be less than $B/20$, or less than 760 mm, whichever is the greater, and need not be greater than 2,000 mm.

1.12.8.3 Small wells constructed in the double bottom in connection with drainage arrangements are not to extend downward more than necessary. The vertical distance from the bottom of such a well to a plane coinciding with the keel line is not to be less than $h/2$ or 500 mm, whichever is greater. Other wells (e.g. for lubricating oil under main engines) may be permitted if satisfied that the arrangements give protection equivalent to that afforded by a double bottom complying with this regulation.

1.12.8.4 A double bottom need not be fitted in way of watertight tanks (including dry tanks) of moderate size, provided the safety of the ship is not impaired in the event of bottom or side damage.

1.12.8.5 Any part of a passenger ship regardless of size and a cargo ship of 500 gross tonnage and over that is not fitted with a double bottom in accordance with 1.12.8.1 or 1.12.8.4 of this Section is to satisfy the requirements for bottom damages, as specified in SOLAS II-1, in that part of the ship.

1.12.8.6 In case of large lower holds in passenger ships, the double bottom height is to be increased to not more than $B/10$ or 3 m, whichever is less, measured from the keel line. Alternatively, bottom damages may be calculated for these areas, in accordance with 1.12.8.5 of this Section, but assuming an increased vertical extent.

1.12.9 Arrangement of cofferdams

1.12.9.1 A cofferdam means an empty space arranged so that compartments on each side have no common boundary; a cofferdam may be located vertically or horizontally. A cofferdam is to be properly ventilated and of sufficient size to allow for inspection, maintenance and safety evacuation.

1.12.9.2 Cofferdams are to be provided between compartments intended for fuel oil or lubricating oil and those intended for fresh water (drinking water, water for propelling machinery and boilers).

Cofferdams are to be provided between compartments intended for fuel oil or lubricating oil and tanks intended for the carriage of liquid foam for fire extinguishing.

Cofferdams are only required between fuel oil tanks in double bottom and tanks immediately above where the inner bottom plating is subjected to the head of fuel oil contained therein, as in the case of a double bottom with its top raised at the sides. Where a corner to corner situation occurs for such tanks, they are not considered to be adjacent.

1.12.9.3 In addition to the requirements of 1.12.9.2 of this Section, the oil fuel tank protection by means of cofferdams in ships is to comply with Regulation 12A of MARPOL Annex I.

1.12.9.4 The separation of cargo oil tanks in tankers is to be arranged in accordance with the requirements of SOLAS Reg. II-2/4.5 regarding cargo areas of tankers.

1.12.9.5 The arrangement of cofferdams is also to comply with 2.8.2 of Section 8, Chapter 2 of PART THREE of the Rules.

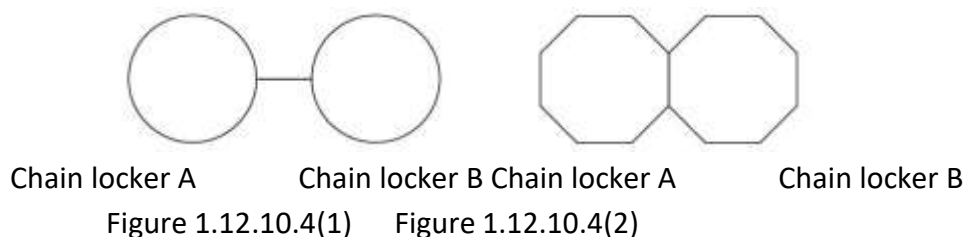
1.12.10 Arrangement of bow freeboard deck and compartments forward of collision bulkhead

1.12.10.1 The arrangement of bow freeboard deck and enclosed superstructures (if fitted) is to comply with the requirements for minimum bow height as specified in Regulation 39 of the Amendments to Annex I of Annex B to the Protocol of 1988 relating to the International Convention on Load Lines, 1966.

1.12.10.2 The arrangement of bow freeboard deck and enclosed superstructures (if fitted) of all ships assigned a type B freeboard, other than oil tankers, chemical tankers and gas carrier is to comply with 1.12.9.2 of this Section and in addition, the requirements for bow reserve buoyancy as specified in Regulation 39 of the Amendments to Annex I of Annex B to the Protocol of 1988 relating to the International Convention on Load Lines, 1966.

1.12.10.3 Fuel oil and other flammable oils are not to be carried in forepeak tanks and other compartments located forward of the collision bulkhead. Chain lockers of ships with a load line length of 24 m and above are to comply with the following requirements:

- (1) Spurling pipes and cable lockers are to be watertight up to the deck exposed to weather. However, the bulkhead between separate chain lockers (Figure 1.12.10.4(1)) or the common bulkhead between adjacent lockers (Figure 1.12.10.4(2)) need not be watertight.



- (2) Where means of access are provided, they are to be closed by a substantial cover and secured by closely spaced bolts.
- (3) Where a means of access to spurling pipes or cable lockers is located below the weather deck,

the manhole covers and securing appliances are to be in consistence with recognized standards^①, or equivalent to the watertight manhole covers. The use of butterfly nuts and/or hinged bolts as the securing appliances of manhole covers is prohibited.

- (4) Spurling pipes through which anchor cables are led are to be provided with permanently attached closing appliances (e.g. steel plates in halves hooked over the spurling pipe tops, or canvas covers lashed) to minimize water ingress.

1.12.11 Arrangement of passenger ships above the bulkhead deck

1.12.11.1 Measures are to be taken to limit the entry and spread of water above the bulkhead deck. Such measures may include partial bulkheads or webs. When partial watertight bulkheads and webs are fitted on the bulkhead deck, above or in the immediate vicinity of main subdivision bulkheads, they are to have watertight shell and bulkhead deck connections so as to restrict the flow of water along the deck when the ship is in a heeled damaged condition. Where the partial watertight bulkhead does not line up with the bulkhead below, the bulkhead deck between is to be made of effectively watertight.

1.12.11.2 All openings in the exposed weather deck are to have coamings of ample height and strength and are to be provided with efficient means for expeditiously closing them weathertight. Freeing ports, open rails and scuppers are to be fitted as necessary for rapidly clearing the weather deck of water under all weather conditions.

1.12.11.3 Air pipes terminating within a superstructure which are not fitted with watertight means of closure are to be considered as unprotected openings in damage stability calculation.

1.12.11.4 Side scuttles, gangway, cargo and coaling ports and other means for closing openings in the shell plating above the bulkhead deck are to be of efficient design and construction and of sufficient strength having regard to the spaces in which they are fitted and their positions relative to the deepest subdivision draught.

1.12.11.5 Efficient inside deadlights, so arranged that they can be easily and effectively closed and secured watertight, are to be provided for all side scuttles to spaces below the first deck above the bulkhead deck.

1.12.12 Arrangement of compartments of double hull oil tankers

1.12.12.1 Wing tanks or spaces are to extend either for the full depth of the ship's side or from the top of double bottom to the uppermost deck, disregarding a rounded gunwale where fitted. They are to be so arranged that all cargo tanks are located inboard of the moulded lines of the side shell plating in those tanks or spaces. The entire cargo tank (including slop tank) length of oil tankers of 5,000 tons deadweight and above are to be protected by ballast tanks or spaces other than tanks that carry oil, and the wing tanks and double bottom for such protection within the cargo tank length are to comply with the following requirements:

- (1) The vertical distance W between wing tank inner hull and side shell is not to be less than as calculated below:

$$W = 0.5 + DW/20000 \text{ m} \quad \text{or } W = 2.0 \text{ m}$$

whichever is the lesser. The minimum value of $W = 1.0 \text{ m}$.

where: DW (Deadweight) means the difference in tons between the displacement of a ship in water of a relative density of 1.025 t/m^3 at the load line corresponding to the assigned summer freeboard and the lightweight of the ship.

- (2) The depth of double bottom is not to be less than as calculated below:

$$h = B/15 \text{ m} \quad \text{or } h = 2.0 \text{ m}$$

whichever is the lesser. The minimum value of $h = 1.0 \text{ m}$.

1.12.12.2 The height of double bottom of oil tankers of less than 5,000 tons deadweight are to comply with the following requirements:

$$h = B/15 \text{ m}; \text{ the minimum value of } h = 0.76 \text{ m}$$

1.12.12.3 Every crude oil tanker of 20,000 tons deadweight and above and every product carrier of 30,000 tons deadweight and above are to be provided with segregated ballast tanks. The capacity of the segregated ballast tanks is to be so determined that the ship may operate safely on ballast voyages without recourse to the use of cargo tanks for water ballast. The capacity of segregated ballast tanks is to be at least such that, in any ballast condition at any part of the voyage, including the conditions consisting of lightweight plus segregated ballast only, the ship's draughts and trim can meet the following requirements:

- (1) the moulded draught amidship (dm), in m, (without taking into account any deformation of the ship) is not to be less than:

$$dm = 2.0 + 0.02LL \text{ m}$$

- (2) the draughts at the forward and after perpendiculars are to correspond to those determined by the draught amidships as specified in (1) above, in association with the trim by the stern of not greater than

$$0.015LL ; \text{ and}$$

- (3) the draught at the after perpendicular is not to be less than that which is necessary to obtain full immersion of the propeller(s).

1.12.12.4 Cargo tanks are to be of such size and arrangement that the hypothetical oil outflow from side and bottom damage, anywhere in the length of the ship, is limited. For oil tankers of less than 5,000 tons deadweight, the length of each cargo tank is not to exceed 10 m or one of the following values, whichever is the greater:

- (1) where no longitudinal bulkhead is provided inside the cargo tanks: $(0.5b_i/B + 0.1)LL$, but not to exceed $0.2LL$;
- (2) where a centerline longitudinal bulkhead is provided inside the cargo tanks: $(0.25b_i/B + 0.15)LL$;
- (3) where two or more longitudinal bulkheads are provided inside the cargo tanks:
 - ① for wing cargo tanks: $0.2LL$
 - ② for centre cargo tanks:

(a) if b_i/B is equal to or greater than $1/5$: $0.2 L_L$

(b) if b_i/B is less than $1/5$:

(i) where no centerline longitudinal bulkhead is provided: $(0.5b_i/B + 0.1)L_L$

(ii) where a centerline longitudinal bulkhead is provided: $(0.25b_i/B + 0.15)L_L$

b_i is the minimum distance from the ship's side to the outer longitudinal bulkhead of the tank in question measured inboard at right angles to the centerline at the level corresponding to the assigned summer freeboard.

For oil tankers of less than 5,000 tons deadweight, the capacity of each cargo tank is not to exceed 700 m^3 , unless wing tanks or spaces are arranged in accordance with 1.12.12.1(1), complying with the following:

$$W = 0.4 + 2.4DW/20000 \text{ m}; \text{ the minimum value of } W = 0.76 \text{ m.}$$

1.12.12.5 For oil tankers carrying oil having a flash point not exceeding 60°C , the separation of cargo tanks is to comply with the following requirements: Cargo pump-rooms, cargo tanks, slop tanks and cofferdams are to be positioned forward of machinery spaces. Main cargo control stations, control stations, accommodation and service spaces are to be positioned aft of cargo tanks, slop tanks, and spaces which isolate cargo or slop tanks from machinery spaces, but not necessarily aft of fuel oil tanks and ballast tanks.

1.12.12.6 Cofferdams are to be at least gastight. If applicable, means of access for internal inspection are to comply with 1.12.14 to 1.12.16 of this Section.

1.12.12.7 For oil tankers of 5,000 tons deadweight and above, the pump-room is to be provided with a double bottom such that at any cross-section the depth of each double bottom tank or space is to be such that the distance between the bottom of the pump-room and the ship's baseline measured at right angles to the ship's baseline is not less than specified below:

$$B/15 \text{ m or } 2 \text{ m, whichever is the lesser. The minimum value is } 1 \text{ m.}$$

In case of pump-rooms whose bottom plate is located above the baseline by at least the minimum height required above (e.g. gondola stern design), there will be no need for a double bottom construction in way of the pump-room.

1.12.13 Arrangement of compartments of single hull oil tankers

1.12.13.1 Oil tankers of 600 tons deadweight and above but less than 5,000 tons deadweight are to be fitted with double bottom tanks or spaces, the height of which is to comply with the requirement of 1.12.12.2 of this Section.

1.12.13.2 Oil tankers of less than 600 tons deadweight are not necessarily to be fitted with double bottom and double hull

1.12.13.3 The length of cargo tanks is to comply with the requirements of 1.12.12.4 of this Section for oil tankers of less than 5,000 tons deadweight.

1.12.13.4 The segregation of cargo tanks is to comply with the requirements of 1.12.12.5 of this Section.

1.12.14 Access and its openings and other requirements

1.12.14.1 Oil tankers as defined in Regulation II-1/2, chemical tankers as defined in Regulation VII/8.2 and gas carriers as defined in Regulation VII/11.2 of the International Convention for the Safety of Life at Sea, 1974, as amended are to be fitted with safe access to bow in accordance with Regulation II-1/3-3 of the Convention.

1.12.14.2 Oil tankers of 500 gross tonnage and over and bulk carriers (as defined in Regulation IX/1 of the International Convention for the Safety of Life at Sea, 1974, as amended) of 20,000 gross tonnage and over are to be fitted with access to and within spaces in, and forward of, the cargo area in accordance with Regulation II-1/3-6 of the Convention.

1.12.14.3 When implementing the provisions of 1.12.14.1 and 1.12.14.2 of this Section, for oil tankers of less than 5,000 tons deadweight, openings of smaller dimensions may be provided subject to the agreement of the flag State Administration, provided that the ability to traverse such openings or to remove an injured person can be proved. However in any case, the size of openings is not to be less than 400 mm × 600 mm or 450 mm × 550 mm.

1.12.14.4 In addition to the requirements of 1.12.14.1 to 1.12.14.3 of this Section, all ships are to be fitted with safe passage of crew in accordance with Regulation 25-1 of the Amendments to Annex I of Annex B to the Protocol of 1988 relating to the International Convention on Load Lines, 1966. Gangway and access fitted on type "A" ships are to be in accordance with Regulations 26(3) and (4) of Annex I. In addition, all ships are to be fitted with guard rails and bulwarks as means for protection of the crew in accordance with Regulations 25(2) and (3) of Annex I.

1.12.15 Arrangement of fuel oil tanks

1.12.15.1 Fuel oil tanks are to be arranged in accordance with the requirements of Regulation 12A of MARPOL Annex I.

SECTION 13 - MARKING OF OPERATING DRAFT OF WORKING SHIPS

1.13.1 General provisions

1.13.1.1 This Section applies to floating cranes, and to open hopper dredgers and barges fitted with means of opening at their bottom (these three types of ships are hereinafter referred to as working ship).

1.13.1.2 For working ships, the maximum operating draught may be assigned and such draught appropriately marked in accordance with this Section.

1.13.1.3 In operational areas defined by the limited sea conditions in 1.13.3 of this Section, the

process of hoisting and handling operations of floating cranes, that of dredging operations of dredgers and that of loading, carrying and discharging operations of dredgers and barges are considered as their operating conditions.

1.13.1.4 The intact stability of working ships in operating conditions is to comply with the requirements of 1.13.4 of this Section, or alternatively, their compliance with the requirements of the flag Administration for intact stability regarding assignment of operating draught is to be confirmed.

1.13.2 Assignment of operating draught

1.13.2.1 For working ships intended for assignment of operating draught, the maximum operating draught is to be assigned in accordance with this Chapter, based on the minimum summer freeboard corresponding to type B freeboard as specified in the amendments to the protocol of 1988 relating to the International Convention on Load Lines, 1966 (IMO resolution MSC.143(77)).

1.13.2.2 Where all requirements of this Section are complied with, the maximum draught of working ships in operation may correspond to a freeboard reduced by 2/3 of the minimum summer freeboard referred to in 1.13.2.1.

1.13.3 Limitations on sea conditions for operations

1.13.3.1 For working operations at the maximum operating draught assigned in accordance with this Section, limitations on sea conditions for areas, in which the working ship is to operate, are as follows:

- (1) For floating cranes, wind force is not to exceed Beaufort scale 5 and significant wave height is not to exceed 1 m.
- (2) For dredgers and barges, wind force is not to exceed Beaufort scale 6 and significant wave height is not to exceed 2 m.

1.13.3.2 Where the environmental limitations as required by design regarding wind and wave for sea areas, in which working ships are to operate, are beyond those specified in 1.13.3.1, relevant technical proof and calculations or model test information for ensuring safe operation are to be submitted for approval or agreement by ISC. And this is to be indicated in the operating draught marking instruction in accordance with 1.13.6.3 of this Section.

1.13.4 Intact stability in operating condition

1.13.4.1 The intact stability of floating cranes in operating condition is to comply with the following requirements:

- (1) The stability of floating cranes is to be checked for the following loading conditions:
 - ① maximum lifting load, necessary ballast and all fuels and stores, the ship being at the maximum operating draught;
 - ② maximum lifting load, necessary ballast and 10% of fuels and stores.
- (2) Initial metacentric height GM of floating cranes in operating condition:

$$GM \geq \frac{M_f + M_h}{0.1716 \theta_c \Delta} \quad \text{m}$$

where: GM — initial metacentric height, in m, taking into account the effects of free surface and suspended objects thereon;

M_f — heeling moment due to wind pressure on the floating crane, in $\text{kN} \cdot \text{m}$, calculated according to 1.13.4.2;

M_h — heeling moment due to maximum lifting load and heeling moment due to asymmetrical loading, if any, in $\text{kN} \cdot \text{m}$;

θ_c — permissible static limiting heeling angle, ($^\circ$), taken as 4/5 immersion angle of freeboard deck edge, 4/5 emersion angle of bilge or heeling angle corresponding to 0.3 m of residual freeboard, whichever is the least; not exceeding 5° for floating cranes with slewing booms, and not exceeding 3° for floating cranes with unslewing booms;

Δ — displacement in the loading condition under checking, in t.

(3) Stability criterion numeral K of floating cranes in operating condition:

$$K = \frac{9.81 l_q \Delta}{M_f + M_h} \geq 1$$

where: l_q — minimum capsizing lever, in m, without taking into account the effect of rolling;

Δ, M_f, M_h — the same as in (2).

1.13.4.2 The heeling moment M_f due to wind pressure on the floating crane in operating condition is to be calculated as follows:

$$M_f = 0.001 P \sum C_i A_{fi} Z_i \quad \text{kN} \cdot \text{m}$$

where: P — wind pressure calculated per unit, taken as 170 N/m^2 ;

C_i — coefficient for correction of height, as given in Table 1.13.4.3;

A_{fi} — windage area, in m^2 ;

Z_i — vertical distance, in m, from centre of windage area A_{fi} to half draught d in the loading condition under checking;

Δ — displacement in the loading condition under checking, in t.

Table 1.13.4.3 - Coefficient C_i for Correction of Height

$Z_i - d/2 \text{ (m)}$	0 ~ 15	15 ~ 30	30 ~ 45	45 ~ 60	60 ~ 75	75 ~ 90	90 ~ 105	105 ~ 120
C_i	1	1.16	1.32	1.44	1.53	1.61	1.68	1.74

1.13.4.3 The intact stability of dredgers and barges in operating condition is to comply with the following requirements:

(1) The stability of dredgers and barges in operating condition is to be checked for the following loading conditions:

- ① hopper fully loaded, with all fuels and stores;
- ② hopper fully loaded, with 10% of fuels and stores;
- ③ hopper partially loaded, with 10% of fuels and stores;

- ④ hopper unloaded, but being open to sea, with all fuels and stores;
- ⑤ hopper unloaded, but being open to sea, with 10% of fuels and stores.

When the hopper is fully loaded, spoil is to be loaded to the lower edge of the opening of the means for overflow specified in 1.13.5.2, and the least of the values obtained is to be taken.

When the hopper is partially loaded, an additional layer of seawater is to be assumed on the top of spoil to reach the lower edge of the opening of the means for overflow specified in 1.13.5.2, and the least of the values so obtained is to be taken.

(2) The density of spoil in hopper is to be taken as follows:

- ① the stability with the density of spoil ρ_{m1} , ρ_{m2} at the maximum operating draught according to (1)①, ② is to be checked;
- ② the stability is to be checked according to (1)②, density of spoil $\rho = 1.4 - 0.2 i$, in t/m^3 , ($i = 0, 1, 2$) whichever is the closest to and less than ρ_{m2} ;
- ③ the stability is to be checked according to (1)③, density of spoil $\rho = 2.2 - 0.2 i$, in t/m^3 , ($i = 0, 1 \dots 6$) whichever is the closest to and over ρ_{m2} ,
where at the maximum operating draught, an additional layer of seawater on the top of spoil is to be regarded as overload.

(3) Characteristic values of righting lever curves for dredgers and barges in operating condition:

- ① the initial metacentric height is not to be less than 0.15 m;
- ② the righting lever GZ is to be at least 0.2 m at heeling angles equal to or over 30° ;
- ③ the heeling angle ϑ_{max} corresponding to the maximum righting lever is to be not less than 15° ;
- ④ up to the heeling angle ϑ_{max} corresponding to the maximum righting lever, the area under the righting lever curve (GZ curve) is to be not less than $0.055 + 0.001 (30^\circ - \vartheta_{max}) \text{ m} \cdot \text{rad}$, and ϑ_{max} is taken as 30° if greater than 30° ;
- ⑤ the area under the righting lever curve (GZ curve) between the heeling angles of 30° and 40° , or between 30° and immersion angle ϑ_f (if this angle is less than 40°) is not to be less than $0.03 \text{ m} \cdot \text{rad}$.

(4) Weather criterion for dredgers and barges in operating condition: The weather criterion in 2.3, Chapter 2, Part A of the International Code on Intact Stability, 2008 (2008 IS Code) is to be complied with, where the wind pressure is taken as 215 N/m^2 and the angle of roll may be reduced by 20% but not less than 10° .

(5) For stability calculation, where the density of spoil in the hopper is equal to or less than 1.4 t/m^3 , the effects of free surface of spoil on the initial metacentric height and righting lever curves are to be calculated and in this case, the outflow of liquid spoil and inflow of seawater over the upper edge of the hopper coaming by ship's heeling may be taken into account. Where the density of spoil in the hopper is greater than 1.4 t/m^3 , the inflow and outflow of seawater

through the lower edge of the opening of the means for overflow specified in 1.13.5.2 (and the least of the values obtained is to be taken) by ship's heeling is to be taken into account. The righting lever curves are to be calculated according to the actual changes of displacement and of centre of gravity of spoil.

- (6) For dredgers and barges with bottom doors or similar opening means for the hopper, asymmetric discharging, which is possible due to failure of control mechanism of the door or other opening means, is to be taken into account. 20% of the total hopper load is to be assumed to be discharging only at one side of the longitudinal centre line of the hopper, horizontally and equally distributed at the discharging side, according to the loading condition and the density of spoil respectively specified in (1) ② and (2) ① above.

In this situation, the stability is to comply with the following requirements:

- ① the angle of equilibrium is not to exceed 25° ;
- ② the range of positive righting lever beyond the angle of equilibrium is not to be less than 30° ;
- ③ the righting lever GZ within the range of positive righting lever beyond the angle of equilibrium is to be at least 0.1 m.

- (7) Working ships intended for operations in icing areas are to comply with the relevant requirements in Chapter 6, Part B of the International Code on Intact Stability, 2008 (2008 IS Code).

1.13.5 Operating draught mark

1.13.5.1 The permissible maximum operating draught line is to be permanently marked on both sides of the working ship, placed 540 mm aft of the centre of the load line mark. The maximum operating draught mark is to be a line of 25 mm in width and 450 mm in length. The upper edge of the line is to be flush with the maximum operating draught line. The operating draught is indicated by the letter W above the left end and the letter D above the right end of that line, each measuring 115 mm in height and 75 mm in width, as shown in Figure 1.13.5.1.

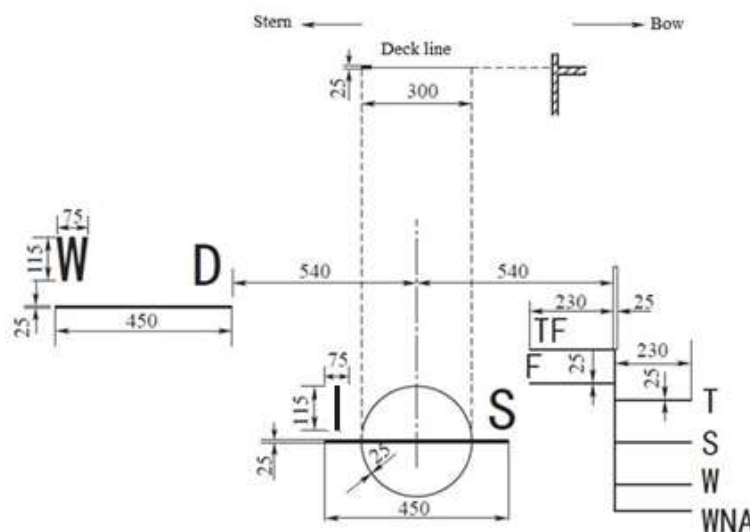


Figure 1.13.5.1 Operating Draught Mark (Starboard)

1.13.5.2 Prior to marking the maximum operating draught of a working ship, compliance of the ship with the stability requirements and other special requirements for operation of working ships is to be confirmed and indicated in the instruction for marking operating draught.

1.13.5.3 Limitations on sea conditions for operations of the working ship are to be clearly defined, compliance of the ship with the stability requirements and other special requirements for its operation summarized in the instruction for marking operating draught, and a marking sketch showing the maximum operating draught line is to be attached thereto.

CHAPTER 2

HULL STRUCTURES

SECTION 1 - GENERAL PROVISIONS

2.1.1 Application

2.1.1.1 This Chapter applies mainly to dry cargo ships. If not covered in this Chapter, the requirements of Chapter 1 of this PART are to be complied with.

2.1.1.2 This Chapter applies to the basic structural configuration of a multi-deck or a single deck hull which includes a double bottom, or a single bottom arrangement, and with the hatch openings of normal dimensions.

2.1.1.3 Longitudinal framing is in general to be adopted at the strength deck outside the line of openings and at the bottom.

2.1.1.4 For ships with self-unloading system, such system is to meet the relevant requirements of ISC Rules for Lifting Appliances of Ships and Offshore Installations.

2.1.2 Class notations

2.1.2.1 General dry cargo ships complying with the requirements of this Chapter will be assigned the class notation General Dry Cargo Ship.

2.1.2.2 Ships which have been strengthened for heavy cargoes and comply with the requirements of Section 22 of this Chapter will be assigned the class notation Strengthened for Heavy Cargoes.

2.1.2.3 Ships which have been strengthened for grabs and comply with the requirements of Section 23 of this Chapter will be assigned the class notation Grab*(X).

2.1.2.4 Ships which comply with the requirements of Section 14, Chapter 8 of this PART will be assigned the class notation Double Side Skin.

2.1.2.5 General dry cargo ships intended to carry cargoes in bulk may be assigned the notation Maximum cargo density x.y t/m³. When the maximum density of the bulk cargo designed under the bulk cargo loading condition is less than 3.0 t/m³, this notation is assigned to indicate the limitation and the maximum density value of the bulk cargo allowed to be loaded, see Section 12, Chapter 8 of this PART for detailed requirements.

2.1.2.6 General dry cargo ships intended to carry cargoes in bulk may be assigned the notation No MP. This notation is assigned to show the limitation when the bulk cargo loading condition of general dry cargo ships has not been designed for loading and unloading in multiple ports in accordance with the Rules, see Section 12, Chapter 8 of this PART for detailed requirements.

2.1.2.7 General dry cargo ships intended to carry cargoes in bulk may be assigned the notation Holds a, b, ...may be empty. This notation is assigned to specify the empty hold No. when specified empty holds are allowed in the design of bulk cargo loading condition of general dry cargo ships, see Section 12, Chapter 8 of this PART for detailed requirements.

2.1.3 Plans and documents

2.1.3.1 Plans and documents covering the following items are to be submitted to ISC for approval. In the case of special constructions and arrangements, additional plans and documents may be required if considered necessary by ISC:

- (1) Principal transverse sections;
- (2) Construction profile, including longitudinal sections, decks, inner bottom, superstructures and deckhouses;
- (3) Stem;
- (4) Stern frame;
- (5) Shell expansion;
- (6) Oiltight and watertight bulkheads;
- (7) Main engine seating and thrust bearing seating;
- (8) Propeller shaft bracket;
- (9) Hatch coamings;
- (10) Cargo hatch covers;
- (11) Arrangement of anchoring equipment including equipment number calculations;
- (12) Rudder, rudder stock and tiller;
- (13) Masts, derrick posts and crane pedestals, together with their support structures;
- (14) Ice strengthening with calculations;
- (15) Welding, including type and size of welds;
- (16) Preliminary and finished loading manuals.

2.1.3.2 The following plans and documents are to be submitted to ISC for information:

- (1) General arrangement;
- (2) Lines or offsets;
- (3) Body plan (frame lines);
- (4) Capacity plan;
- (5) Specifications for hull and equipment;
- (6) Longitudinal strength calculations (where applicable);
- (7) Direct strength calculation report (where applicable);
- (8) Fatigue strength assessment report (where applicable).

2.1.4 Direct strength calculation and fatigue strength assessment for hull structure

2.1.4.1 For general dry cargo ships of 150 m or over in length, FE direct strength calculation and verification are to be carried out for the strength of primary structural members within cargo area. When containers are carried, reference may be made to applicable requirements of Appendix 2, Chapter 7 of this PART. When bulk cargoes are carried, reference may be made to applicable requirements of Appendix 1, Chapter 8 of this PART.

2.1.4.2 For general dry cargo ships of 150 m or over in length, the fatigue strength check may be carried out for the following structural members in the cargo area. For check method, reference may be made to ISC Guidelines for Fatigue Strength of Ship Structure:

- (1) connections of longitudinals (bottom, side, deck and inner shell) to transverse web frames;
- (2) connections of longitudinals (bottom, side, deck and inner shell) to transverse bulkheads;
- (3) connections of hopper tank sloping plate or inner shell to inner bottoms (if any);
- (4) connections of transverse bulkheads to inner bottoms and girders.

SECTION 2 - LONGITUDINAL STRENGTH

2.2.1 General requirements

2.2.1.1 For ships of 65 m and over in length, their longitudinal strength is to be checked in accordance with the requirements of this Section. For ships of unusual type or special loading and less than 65 m in length, their longitudinal strength may also be checked in accordance with the requirements of this Section.

For container ships of 90 m and over in length or ships dedicated primarily to carry their load in containers, their longitudinal strength is to comply with the requirements of Section 2, Chapter 7 of this PART and of 2.2.5.1 of this Section.

2.2.1.2 For ships complying with the following conditions, special considerations are required for longitudinal strength:

- (1) For ships having one or more of the following characteristics, direct calculations are in general to be carried out, of which, direct calculation of wave loads is given in 2.2.9 of this Section:

$$L/B \leq 5$$

$$B/D \geq 2.5$$

$$L \geq 500 \text{ m}$$

$$Cb < 0.6$$

- (2) For ships having large deck openings, the longitudinal strength at combined bending and torque is to be checked according to the requirements in Section 10, Chapter 7 of this PART.
- (3) For ships having large flare, additional bending moment caused by slamming may be considered.
- (4) For ships intended for the carriage of special cargoes (e.g. heated cargoes), ships of unconventional type or ships of unconventional design, direct calculations are to be carried out in accordance with properties of cargoes or ship's type; where direct calculations are impracticable, design loads are to be determined by means of model test.

2.2.2 Design still water bending moment and shear force

2.2.2.1 The still water bending moment and shear force at each transverse section along the ship's length are to be calculated from the following conditions:

In loaded conditions: departure, arrival;

In ballast conditions: departure, arrival.

Various loading conditions included in the Loading Manual are also to be taken into account in the calculation.

2.2.2.2 In calculation of still water bending moments and shear forces, the downward loads are to be taken as positive values, the upward loads as negative values, and are to be integrated in the forward direction from the aft end of the length of the ship. The sign conventions of the still water bending moments M_s and shear forces F_s are as shown in Figure 2.2.2.2.

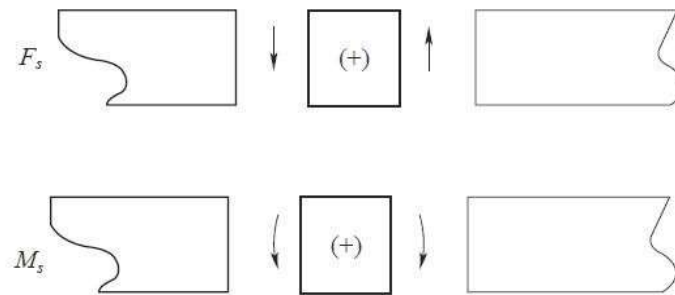


Figure 2.2.2.2

2.2.2.3 In general, the following design cargo and ballast loading conditions, based on amount of bunker, fresh water and stores at departure and arrival, are to be considered for the M_s and F_s calculations.

Where the amount and disposition of consumables at any intermediate stage of the voyage are considered more severe, calculations for such intermediate conditions are to be submitted for information. Also, where any ballasting and/or deballasting is intended during voyage, calculations of the intermediate condition just before and just after ballasting and/or deballasting any ballast tank are to be submitted and where reviewed included in the loading manual for guidance.

- (1) General cargo ships, container ships, roll-on/roll-off and refrigerated cargo carriers, bulk carriers, ore carriers:
 - ① homogeneous loading conditions at maximum draught;
 - ② ballast conditions;
 - ③ special loading conditions, e.g. container or light load conditions at less than the maximum draught, heavy cargo, empty holds or non-homogeneous cargo conditions, deck cargo conditions, etc., where applicable;
 - ④ short voyage or harbor conditions, where applicable;
 - ⑤ docking condition, afloat;
 - ⑥ instantaneous conditions of loading and unloading, where applicable;
 - ⑦ for bulk carriers to which the harmonized class notation BC-A, BC-B or BC-C is assigned in accordance with the requirements of Section 12, Chapter 8 of this PART, conditions specified in 8.12.4 of Section 12, Chapter 8 of this PART are also to be calculated.
- (2) Oil tankers:
 - ① homogeneous loading conditions (excluding dry and clean ballast tanks) and ballast or part-loaded conditions;
 - ② any specified non-uniform distribution of loading;
 - ③ mid-voyage conditions relating to tank cleaning or other operations where these differ significantly from the ballast conditions;
 - ④ docking condition, afloat;
 - ⑤ instantaneous conditions of loading and unloading, where applicable.

(3) Chemical tankers:

- ① conditions as specified for oil tankers;
- ② conditions for high density or segregated cargo.

(4) Combination carriers:

- ① conditions as specified for oil tankers and cargo ships.

2.2.2.4 Where the typical condition during ballast water exchange at sea is to be taken into account, reference may be made to the Guidelines for the Preparation of Ship's Ballast Water Management Plan.

2.2.2.5 Partially filled ballast tanks in ballast loading conditions (relevant recommendations are given in Appendix 3 of this Chapter)

Ballast loading conditions involving partially filled peak and/or other ballast tanks at departure, arrival or during intermediate conditions are not permitted to be used as design conditions unless:

- design stress limits are satisfied for all filling levels between empty and full, and
- for bulk carriers, the requirements in Section 8, Chapter 8 of this PART, as applicable, are complied with for all filling levels between empty and full.

To demonstrate compliance with all filling levels between empty and full, it will be acceptable if, in each condition at departure, arrival and where required by 2.2.2.3 of this Section, any intermediate condition, the tanks intended to be partially filled are assumed to be:

- empty;
- full;
- partially filled at intended level.

Where multiple tanks are intended to be partially filled, all combinations of empty, full or partially filled at intended level for those tanks are to be investigated.

However, for conventional ore carriers with large wing water ballast tanks in cargo area, where empty or full ballast water filling levels of one or maximum two pairs of these tanks lead to the ship's trim exceeding one of the following conditions, it is sufficient to demonstrate compliance with maximum, minimum and intended partial filling levels of these one or maximum two pairs of ballast tanks such that the ship's condition does not exceed any of these trim limits. Filling levels of all other wing ballast tanks are to be considered between empty and full. The trim conditions mentioned above are:

- trim by stern of 3% of the ship's length, or
- trim by bow of 1.5% of ship's length, or
- any trim that cannot maintain propeller immersion (I/D) not less than 25%, where:

I — the distance from propeller centerline to the waterline;

D — propeller diameter (see Figure 2.2.2.5).

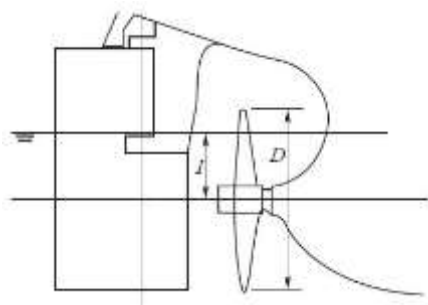


Figure 2.2.2.5

The maximum and minimum filling levels of the above-mentioned pairs of side ballast tanks are to be indicated in the loading manual.

2.2.2.6 Partially filled ballast tanks in cargo loading conditions

In cargo loading conditions, the requirements in 2.2.2.5 of this Section apply to the peak tanks only.

2.2.2.7 Sequential ballast water exchange

Requirements of 2.2.2.5 and 2.2.2.6 of this Section are not applicable to ballast water exchange using the sequential method. However, bending moment and shear force calculations for each de-ballasting or ballasting stage in the ballast water exchange sequence are to be included in the loading manual or ballast water management plan of any ship that intends to employ the sequential ballast water exchange method.

2.2.3 Wave bending moment and wave shear force

2.2.3.1 The hogging and sagging wave bending moments $M_W(+)$ and $M_W(-)$ at each transverse section along the ship's length are to be obtained from the following formulae:

$$M_W(+) = +190 M C L^2 B C_b \times 10^{-3} \quad \text{kN}\cdot\text{m}$$

$$M_W(-) = -110 M C L^2 B (C_b + 0.7) \times 10^{-3} \quad \text{kN}\cdot\text{m}$$

where: M — distribution factor of bending moment, see Figure 2.2.3.1;

L — length of ship, in m;

B — breadth of ship, in m;

C_b — block coefficient, taken not less than 0.60;

C — coefficient to be obtained from the following formulae:

$$C = 0.0412L + 4 \quad \text{for } L < 90 \text{ m};$$

$$C = 10.75 - \left(\frac{300 - L}{100} \right)^{3/2} \quad \text{for } 90 \leq L \leq 300 \text{ m};$$

$$C = 10.75 \quad \text{for } 300 < L < 350 \text{ m};$$

$$C = 10.75 - \left(\frac{L - 350}{150} \right)^{3/2} \quad \text{for } 350 \leq L \leq 500 \text{ m}.$$

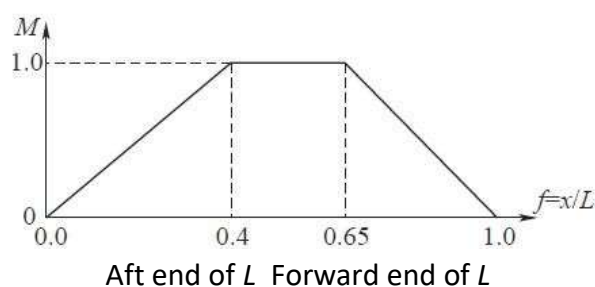


Figure 2.2.3.1

2.2.3.2 The hogging and sagging wave shear forces $F_w(+)$ and $F_w(-)$ at each transverse section along the ship's length are to be obtained from the following formulae:

$$F_w(+) = +30F_1CLB(C_b + 0.7) \times 10^{-2} \text{ kN}$$

$$F_w(-) = -30F_2CLB(C_b + 0.7) \times 10^{-2} \text{ kN}$$

where: F_1, F_2 — shear force distribution factor given in Figure 2.2.3.2(1) and Figure 2.2.3.2(2);

C — coefficient to be obtained from 2.2.3.1 of this Section;

C_b — see 2.2.3.1 of this Section;

L — length of ship, in m;

B — breadth of ship, in m.

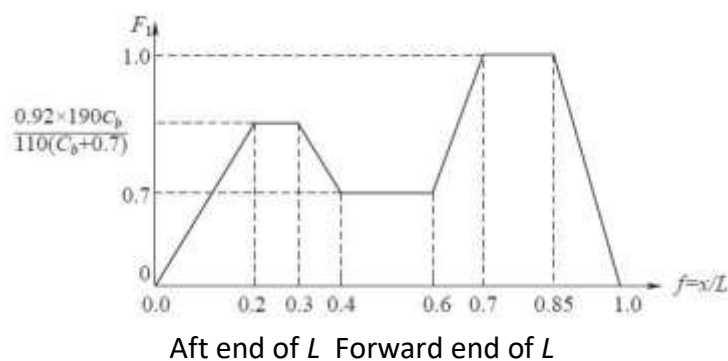


Figure 2.2.3.2(1)

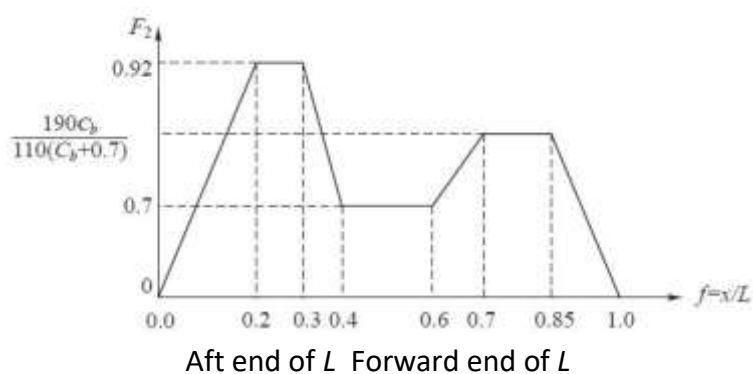


Figure 2.2.3.2(2)

2.2.4 Calculation of hull girder section properties

2.2.4.1 The moment of inertia of the hull girder section about its horizontal neutral axis divided by the vertical distance from the neutral axis to the top of strength deck at side gives the hull girder section modulus W_d at the strength deck; and that divided by the vertical distance from the neutral axis to the top of keel gives the hull girder section modulus W_b at bottom.

2.2.4.2 The strength deck and all continuous longitudinal members below the strength deck within $0.4L$ amidships may be included in the calculation of hull girder section modulus. The extension of the sheer strake above the strength deck and the continuous stringer angles may be included in the calculation. Where trunk decks or continuous hatch coamings (except inboard coamings of multi-hatch arrangements) above the strength deck are effectively supported by longitudinal bulkheads or deep girders, their sectional area may also be included in the calculation of the hull girder section modulus.

2.2.4.3 For multi-hatch arrangements, the effective sectional area for the inboard continuous hatch coaming and supporting members below is to be determined by direct calculation in accordance with support conditions. The following provision is applicable to cases without detailed calculation:

- (1) Where a continuous longitudinal underdeck girder, or girders, are arranged to support the inboard hatch coamings, 50% of their sectional area are to be included in the calculation of the hull girder section modulus. If the girder is fitted in conjunction with a longitudinal bulkhead,
- (2) The percentage of the sectional area to be included for inboard continuous hatch coamings is to be the same percentage as that of the longitudinal girder under.

2.2.4.4 For the cases in 2.2.4.2 and 2.2.4.3 of this Section, when calculating the hull girder section modulus, the lever Z_t , vertical distance from the point considered to the neutral axis, is to be taken as follows, with Z_t being greater than the vertical distance from the neutral axis to the moulded deck line at side:

$$Z_t = Z_c \left(0.9 + 0.2 \frac{y}{B_1} \right) \quad \text{m}$$

where: Z_c — vertical distance from the neutral axis to the top of the continuous strength member, in m;

y — horizontal distance from the top of the continuous strength member to the centerline of the ship, in m;

B_1 — breadth of ship at section considered, in m.

In calculation, Z_c and y are to be measured to the point giving the maximum value of Z_t .

2.2.4.5 Where deck longitudinals or deck girders are arranged above the strength deck, the sectional area may be included in the calculation of the hull girder section modulus. The lever Z_t is to be taken as the vertical distance from the neutral axis to the moulded deck line at side amidships plus the depth of the longitudinal member.

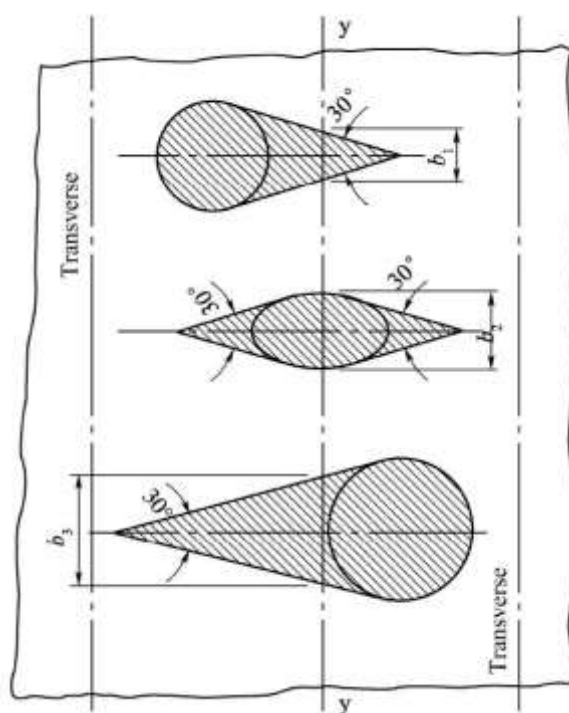
2.2.4.6 Deck openings having a length in the fore-and-aft direction exceeding 2.5 m or a breadth exceeding 1.2 m or $0.04B$ (whichever is the lesser) or scallops where scallop-welding is applied are to be deducted from the sectional areas used in the calculation of the hull girder section modulus.

2.2.4.7 Smaller openings (including manholes, lightening holes, single scallops in way of seams, etc.) smaller than those stated in 2.2.4.6 above need not be deducted from the sectional areas used in the calculation of the hull girder section modulus, provided that the sum bc of their breadths or shadow area breadths (The shadow area will be obtained by drawing two tangent lines with an opening angle of 30° , as shown in Figure 2.2.4.7) in one transverse section complies with the following or that the section modulus at deck or bottom is not reduced by more than 3%:

$$b_c \leq 0.06(B_1 - \sum b)$$

where: B_1 — breadth of ship at section considered, in m;

$\sum b$ — sum of breadths of deductible openings at section considered in accordance with 2.2.4.6 of this Section, in m.



Sum of breadths of small openings at y-y section is to be $b_c = b_1 + b_2 + b_3$

Figure 2.2.4.7

2.2.4.8 Openings in longitudinals or longitudinal girders (such as lightening holes, freeing ports, single scallops in way of welds) need not be deducted from the sectional areas used in the calculation of the hull girder section modulus, if their depth does not exceed 25% of the web depth (with a maximum depth of 75 mm for scallops).

2.2.5 Hull girder bending strength

2.2.5.1 The minimum midship section modulus W_0 at deck and keel is not to be less than that obtained from the following formula:

$$W_0 = CL^2 B (C_b + 0.7) K \quad \text{cm}^3$$

where: C — coefficient, to be taken in accordance with 2.2.3.1 of this Section;

C_b — the same as that in 2.2.3.1 of this Section;

L — length of ship, in m;

B — breadth of ship, in m;

K — material factor.

Scantlings of all continuous longitudinal members of the hull girder based on the minimum midship section modulus W_0 are to be maintained within 0.4L amidships. However, in special cases, based on consideration of type of ship, hull form and loading conditions, the scantlings may be gradually reduced towards the ends of the 0.4L amidships, bearing in mind the desire not to inhibit the vessel's loading flexibility. In ships where part of the longitudinal strength material in the deck or bottom area are forming boundaries of tanks for oil cargoes or ballast water and such tanks are provided with an effective corrosion protection system, certain reductions in the scantlings of these boundaries are allowed. These reductions, however, are in no case to reduce the minimum hull girder section modulus for a new ship by more than 5%.

2.2.5.2 The moment of inertia of midship section about the horizontal neutral axis I is not to be less than that obtained from the following formula:

$$I = 3W_0 L / K \quad \text{cm}^4$$

where: W_0 — the minimum midship section modulus, in cm^3 , calculated in accordance with 2.2.5.1 of this Section;

L — length of ship, in m;

K — material factor.

2.2.5.3 The hull girder bending strength outside 0.4L amidships is to comply with the requirements of 2.2.5.4 of this Section and also the following requirements:

- (1) As a minimum, hull girder bending strength checks are to be carried out at the following locations:
 - in way of the forward end of the engine room;
 - in way of the forward end of the foremost cargo hold;
 - at any locations where there are significant changes in hull cross-section;
 - at any locations where there are changes in the framing system.
- (2) Buckling strength of members contributing to the longitudinal strength and subjected to compressive and shear stresses is to be checked, in particular in regions where changes in the framing system or significant changes in the hull cross-section occur.
- (3) Continuity of structure is to be maintained throughout the length of the ship. Where significant changes in structural arrangement occur, adequate transitional structure is to be provided.

(4) For ships with large deck openings such as container ships, sections at or near to the aft and

2.2.5.4 The designer is to provide permissible hogging and sagging still water bending moments $\overline{M}_s$ (+) and $\overline{M}_s$ (-) of hull girders at each transverse section along the ship's length, provided that the following conditions are satisfied:

- (1) The permissible hogging and sagging still water bending moments $\overline{M}_s$ of hull girders are to cover the most severe hogging and sagging design still water bending moments calculated for any navigation condition given in the loading manual, see 2.2.2 of this Section.
- (2) The permissible hogging and sagging still water bending moments $\overline{M}_s$ of hull girders are not to be greater than the values obtained from the following formulae:

$$\overline{M}_s (+)_{\max} = \overline{M} - M_w (+) \quad \text{kN}\cdot\text{m}$$

$$\overline{M}_s (-)_{\min} = \overline{M} - M_w (-) \quad \text{kN}\cdot\text{m}$$

where: M_w — wave bending moment, see 2.2.3.1 of this Section;

$\overline{M}$ — combined permissible bending moment, in $\text{kN} \cdot \text{m}$, to be taken as one of the values obtained from the following formulae, whichever is the lesser:

$$\overline{M} = F_d W_d [\sigma] \times 10^{-3} \quad \text{kN}\cdot\text{m}$$

$$\overline{M} = F_b W_b [\sigma] \times 10^{-3} \quad \text{kN}\cdot\text{m}$$

where: F_d, F_b — determined in accordance with 2.2.5.6(1);

W_d — section modulus at deck, in cm^3 ;

W_b — section modulus at keel, in cm^3 ;

Permissible bending stress of hull girder $[\sigma]$ is determined in accordance with the following requirements:

$[\sigma] = 175/K$, in N/mm^2 , for $0.4 L$ amidships;

$[\sigma] = 125/K$, in N/mm^2 , for $0.1 L$ from the ship's ends;

for other areas, to be obtained by linear interpolation, where K is material factor.

2.2.5.5 Longitudinal bending stress is to be calculated in accordance with the following formula:

$$\sigma = \frac{|\overline{M}_s + M_w|}{W_c} \times 10^3 \quad \text{N/mm}^2$$

where: $\overline{M}_s$ — permissible still water bending moment, in $\text{kN}\cdot\text{m}$, see 2.2.5.4 of this Section;

M_w — wave bending moment, in $\text{kN}\cdot\text{m}$, calculated in accordance with 2.2.3.1 of this Section;

W_c — hull girder section modulus at the point considered, in cm^3 .

2.2.5.6 The reduction factor of scantlings of local members is to comply with the following:

- (1) Where the maximum longitudinal bending stresses at deck and keel are less than the permissible bending stress $[\sigma]$, appropriate reduction factors F_d and F_b may be taken to reduce

the scantlings of local member provided the following conditions are met:

$$F_d \geq \frac{\sigma_d}{[\sigma]}$$

$$F_b \geq \frac{\sigma_b}{[\sigma]}$$

where: σ_d — longitudinal bending stress at deck, in N/mm²

σ_b — longitudinal bending stress at keel, in N/mm²

$[\sigma]$ — permissible bending stress, see 2.2.5.4(2) of this Section.

In calculation of the thickness of shell plating t_1 and deck t_1 , reduction factor F_d may be calculated based on sagging bending moment and F_b may be calculated based on the hogging bending moment.

For shell plating and deck, reduction factors F_d and F_b are not to be less than 0.67; for framing, reduction factors F_d and F_b are not to be less than 0.75.

- (2) For ships less than 65 m in length, 1 is to be taken for both F_d and F_b .
- (3) (For container ships of 90 m in length and over, see Section 2 of Chapter 7 for the longitudinal bending stress and permissible bending stress in calculation of F_d and F_b).

2.2.5.7 Where higher tensile steel is used in some portions of hull, the vertical extent of application of the higher tensile steel is not to be less than:

Where higher tensile steel is applied to the strength deck, the region y_1 ($1 - K/F_d$) below the deck line is to be made of higher tensile steel; where applied to the bottom, the region y_2 ($1 - K/F_b$) above the keel is to be made of higher tensile steel. y_1 and y_2 are the vertical distances from the neutral axis to the deck line at side and to the plate keel respectively, in m, as shown in Figure 2.2.5.7. K is material factor, F_d and F_b are as defined in 2.2.5.6 above.

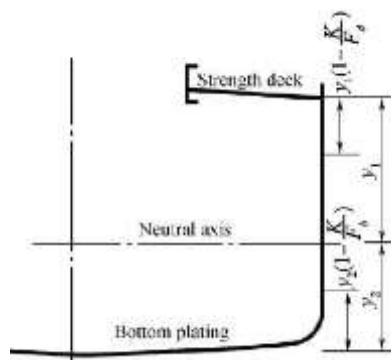


Figure 2.2.5.7

2.2.5.8 Where higher tensile steel is used amidships and low carbon steel at the ends of the ship, the region in which higher tensile steel is used is to be extended to the points where the thickness required for low carbon steel is equal to that of the higher tensile steel (see Figure 2.2.5.8).

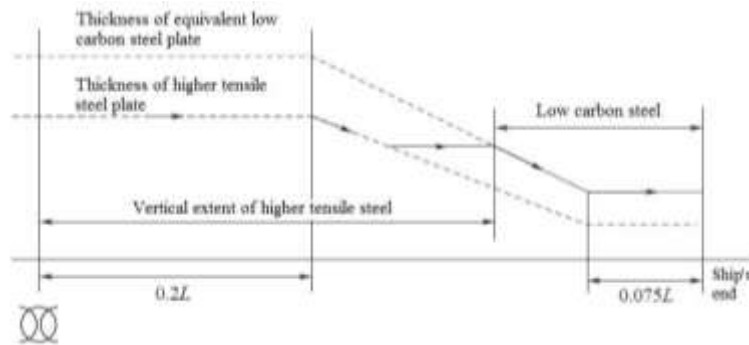


Figure 2.2.5.8

2.2.5.9 Where higher tensile steel is applied to strength deck structure, corresponding higher tensile steel is usually to be applied to the continuous members (e.g. stiffening members of hatch coamings and deck openings) welded to strength deck.

2.2.6 Hull girder shearing strength

2.2.6.1 Design still water shear force

- (1) Under different loading conditions, the design still water shear force at each transverse section along the ship's length is to meet the following conditions:

$$\begin{aligned} F_s(+) &\leq \overline{F}_s(+) \\ |F_s(-)| &\leq |\overline{F}_s(-)| \end{aligned}$$

where: F_s — design still water shear force under the conditions considered, in kN;

$\overline{F}_s$ — permissible still water shear force, in kN, calculated in accordance with 2.2.6.2.

- (2) For type 1 and type 2 hull sections as shown in Table 2.2.6.2, the still water shear force F_s at transverse bulkhead is to be corrected in respect to alternate or significantly non-homogeneous hold loading conditions. The correction of shear force is as shown in Figure 2.2.6.1. The values N_k and N_m of shear force correction are to be calculated in accordance with the following formulae respectively:

$$\begin{aligned} N_k &= F |F_{sA} - F_{sB}| \quad \text{kN} \\ N_m &= F |F_{sA} - F_{sC}| \quad \text{kN} \end{aligned}$$

where: F_{sA} , F_{sB} , F_{sC} — shear force in kN, obtained by calculation based on hull girder at transverse bulkheads A, B and C respectively;

F — correction factor of still water shear force, calculated in accordance with the following formula:

$$F = \frac{B_0}{2.2(B + l_H)}$$

where: B_0 — average breadth of the flat part of inner bottom of the hold considered, in m;

B — breadth of ship, in m;

l_H — length of hold, in m.

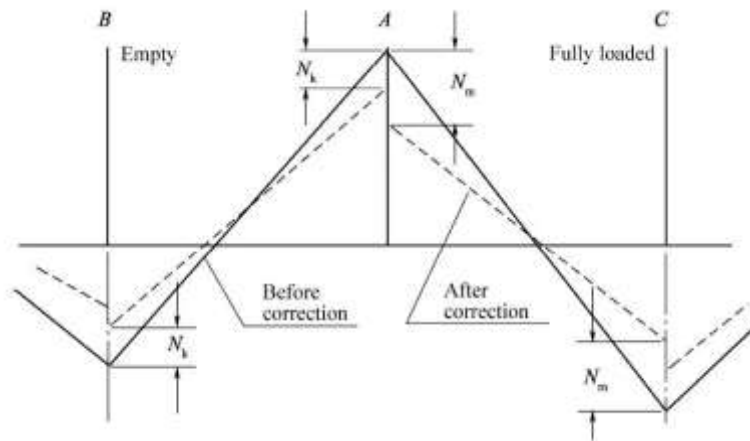


Figure 2.2.6.1

2.2.6.2 The designer is to provide permissible still water shear forces $\overline{F}_s (+)$ and $\overline{F}_s (-)$ of hull girders at each transverse section along the ship's length, provided that the following conditions are satisfied:

- (1) The positive and negative permissible still water shear forces $\overline{F}_s$ of hull girders are to cover the most severe positive and negative design still water shear forces calculated for any navigation condition given in the loading manual, see 2.2.2 of this Section.
- (2) The positive and negative permissible still water shear forces $\overline{F}_s$ of hull girders are not to be greater than the values obtained from the following formulae:

$$\overline{F}_s (+)_{\max} = [\tau] \frac{I\delta}{S} \times 10^{-2} - F_w (+) \text{ kN}$$

$$\overline{F}_s (-)_{\min} = -[\tau] \frac{I\delta}{S} \times 10^{-2} - F_w (-) \text{ kN}$$

where: F_w — wave shear force, in kN, calculated in accordance with 2.2.3.2;

I — moment of inertia about the horizontal neutral axis at the transverse section under consideration, in cm^4 ;

S — static moment, in cm^3 , about the horizontal neutral axis, of the area of the effective longitudinal members above the horizontal neutral axis, taken at the transverse section under consideration;

Permissible shearing stress $[\tau] = 110/K$, in N/mm^2 , where K is material factor;

δ — the lesser of δ_1 and δ_2 , calculated in accordance with the following formulae:

$$\delta_1 = \frac{t_1}{f_1 + m_1}$$

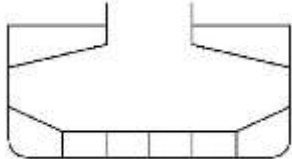
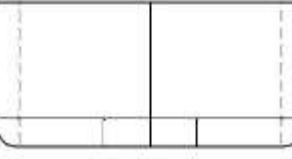
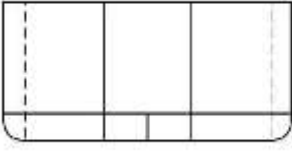
$$\delta_2 = \frac{t_2}{f_2 + m_2}$$

t_1 — thickness (the total thickness of inner and outer plating for double hull-skin ship) of side shell at the horizontal neutral axis of the section under consideration, in mm;

t_2 — thickness of longitudinal bulkhead plating at the horizontal neutral axis of the section under consideration, in mm;

f_1, f_2, m_1 , and m_2 — factors, see Table 2.2.6.2.

Table 2.2.6.2 - Factors f_1 , f_2 , m_1 and m_2

No.	Hull configuration	Factor f_i	Factor m_i
1		$f_1 = 0.5$	$m_1 = 0$
2		$f_1 = 0.5$	$m_1 = 0$
3		$f_1 = 0.261 + 0.058 A_1 / A_2$ $f_2 = 0.478 - 0.116 A_1 / A_2$	$m_1 = 0.5 m_2$ $m_2 = 0.5(0.1 + \gamma)$
4		$f_1 = 0.154 + 0.08 A_1 / A_2$ $f_2 = 0.346 - 0.08 A_1 / A_2$	$m_1 = m_2$ $m_2 = (0.1 + \gamma) \frac{b}{B}$

Notes: A_1 , A_2 — shear areas of side shell and longitudinal bulkhead plating respectively, in cm^2 , at one side of the section under consideration. The area for the centreline bulkhead is actual area and not to be reduced for symmetry around the centreline;

b — horizontal distance from longitudinal bulkhead to side shell plating, in m;

B — breadth of ship, in m;

γ — for transversely non-homogeneous loading condition, $\gamma = 0.15$; for transversely homogeneous loading condition, $\gamma = 0$.

2.2.6.3 For hull configurations not included in Table 2.2.6.2, e.g. ships with three or four longitudinal bulkheads, the shearing stresses at side shell and longitudinal bulkhead plating may be determined by direct calculation.

2.2.6.4 Shearing stress①

(1) The shearing stress τ at side shell is to be calculated in accordance with the following formula:

$$\tau = \frac{[F_s + F_w] S}{I \delta_1} \times 10^2 \quad \text{N/mm}^2$$

where: F — permissible still water shear force, in kN, see 2.2.6.2 of this Section;

S — static moment, in cm^3 . Where the point considered is above the horizontal neutral axis, S is to be taken as the static moment, about the horizontal neutral axis, of the area of all longitudinal members passing through the point above the neutral axis. Where the point considered is below the horizontal neutral axis, S is to be taken as the static moment, about the horizontal neutral axis, of the area of all longitudinal members passing through the point below the neutral axis;

F_w , I and δ_1 — see 2.2.6.2 of this Section.

① Direct shearing stress calculation may be used, subject to approval by ISC.

(2) Shearing force τ at longitudinal bulkhead plating is to be calculated in accordance with the following formula:

$$\tau = \frac{|\overline{F}_z + F_w| S}{I \delta_2} \times 10^3 \quad \text{N/mm}^2$$

where: $\overline{F}_z, S$ — see 2.2.6.4 (1) of this Section;
 F_w, I and δ_2 — see 2.2.6.2 of this Section.

2.2.7 Buckling strength

2.2.7.1 For ships of 90 m and over in length, where the plate panels and longitudinals are subject to hull girder bending and shear stresses, the buckling strength is to be checked according to the following requirements.

2.2.7.2 The working stress σ in compression of the plate panels and longitudinals as calculated in 2.2.5.5 of this Section (taken not less than $30/K$, in N/mm^2 , where K is material factor) is to comply with the following formula:

$$\sigma \leq \frac{1}{\beta} \sigma_c$$

where: $\beta = 1$, for plating and for web plating of stiffeners (local buckling);
 $\beta = 1.1$, for stiffeners;
 σ_c — critical buckling stress in compression, calculated according to 2.2.7.6 of this Section.

2.2.7.3 The working shear stress τ of plate panels as calculated in 2.2.6.4 of this Section is to comply with the following formula:

$$\tau \leq \tau_c$$

where: τ_c — critical buckling stress in shear, calculated according to 2.2.7.7 of this Section.

2.2.7.4 The ideal elastic buckling stresses of the plates are to be obtained from the following formulae:

(1) The ideal elastic buckling stress σ_E of the compression plate panel is to be obtained from the following formula:

$$\sigma_E = 0.9 K_c E \left(\frac{t_b}{1000s} \right)^2 \quad \text{N/mm}^2$$

where: E — modulus of elasticity of material, in N/mm^2 ;
 s — shorter side of plate panel, in m;
 t_b — net thickness, in mm, of plating, considering standard deductions equal to the values given in Table 2.2.7.4;

Table 2.2.7.4-Standard Deduction of Thickness

Structure	Standard deduction (mm)	Limit values min-max (mm)
Compartments carrying dry bulk cargoes: One side exposure to ballast or liquid cargo, vertical surfaces and surfaces sloped at an angle greater than 25° to the horizontal line.	0.05 t	0.5 ~ 1
One side exposure to ballast or liquid cargo, horizontal surfaces and surfaces sloped at an angle less than 25° to the horizontal line;	0.10 t	2 ~ 3
Two side exposure to ballast or liquid cargo, vertical surfaces and surfaces sloped at an angle greater than 25° to the horizontal line.		
Two side exposure to ballast or liquid cargo, horizontal surfaces and surfaces sloped at an angle less than 25° to the horizontal line.	0.15 t	2 ~ 4

Note: t is the designed thickness of plating, in mm.

K_c – coefficient, calculated according to the following:

K_c – coefficient, calculated according to the following:

$K_c = \frac{8.4}{\psi + 1.1}$ for plating with longitudinal stiffeners (parallel to compressive stress);

$K_c = C \left[1 + \left(\frac{S}{l} \right)^2 \right]^2 \frac{2.1}{\psi + 1.1}$ for plating with transverse stiffeners (perpendicular to compressive stress);

where:

l – longer side of plate panel, in m;

$C = 1.3$ when plating stiffened by floors or deep girders;

$C = 1.21$ when stiffeners are angles or T-sections;

$C = 1.10$ when stiffeners are bulb flats;

$C = 1.05$ when stiffeners are flat bars;

ψ – ratio between smallest and largest compressive stress, $0 \leq \psi \leq 1$ (see Figure 2.2.7.4).

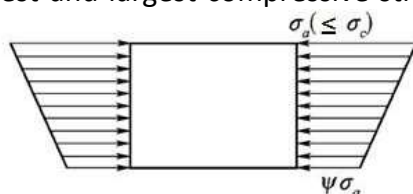


Figure 2.2.7.4

- (2) The ideal elastic buckling stress τ_E in shear of plate panels subjected to shearing forces is to be obtained from the following formula:

$$\tau_E = 0.9 K_s E \left(\frac{t_b}{1000s} \right)^2 \quad \text{N/mm}^2$$

where: $K_s = 5.34 + 4 \left(\frac{S}{l} \right)^2$;

for E , t_b , s and l , see (1) above.

2.2.7.5 The ideal elastic buckling stresses of longitudinals are to be obtained from the following formulae:

- (1) For the column buckling mode (perpendicular to plane of plating) without rotation of the cross section, the ideal elastic buckling stress σ_E of longitudinals is to be obtained from the following formula:

$$\sigma_E = 0.001 E \frac{I_a}{A l^2} \quad \text{N/mm}^2$$

where: I_a – moment of inertia, in cm^4 , of longitudinal, including plate flange and calculated with thickness as specified in Table 2.2.7.4 of this Section;

A – cross-sectional area, in cm^2 , of longitudinal, including plate flange and calculated with thickness as specified in Table 2.2.7.4 of this Section;

l – span, in m, of longitudinal.

- (2) The ideal elastic buckling stress σ_E of longitudinals for the torsional buckling mode is to be obtained from the following formula:

$$\sigma_E = \frac{\pi^2 EI_w}{I_p l^2 \times 10^4} \left(n^2 + \frac{K_B}{n^2} \right) + 0.385 E \frac{I_t}{I_p} \quad \text{N/mm}^2$$

where: $K_B = \frac{Cl^4}{\pi^4 EI_w} \times 10^6$;

n — number of half waves, given by Table 2.2.7.5:

Table 2.2.7.5 - Number of Half Waves

	$0 < K_B \leq 4$	$4 < K_B \leq 36$	$36 < K_B \leq 144$	$(n-1)^2 n^2 < K_B \leq n^2 (n+1)^2$
n	1	2	3	n

I_t — St Venant's moment of inertia, in cm^4 , of profile (without plate flange), to be obtained by the following formula:

$$I_t = \frac{h_w t_w^3}{3} \times 10^{-4}, \text{ for flat bars;}$$

$$I_t = \frac{1}{3} \left[h_w t_w^3 + b_f t_f^3 \left(1 - 0.63 \frac{t_f}{b_f} \right) \right] \times 10^{-4} \text{ for flanged profiles;}$$

I_p — polar moment of inertia, in cm^4 , of profile about connection of stiffener to plate:

$$I_p = \frac{h_w^3 t_w}{3} \times 10^{-4} \text{ for flat bars;}$$

$$I_p = \left(\frac{h_w^3 t_w}{3} + h_w^2 b_f t_f \right) \times 10^{-4} \text{ for flanged profiles;}$$

I_w — sectional moment of inertia, in cm^6 , of profile about connection of stiffener to plate:

$$I_w = \frac{h_w^3 t_w^3}{36} \times 10^{-6} \text{ for flat bars;}$$

$$I_w = \frac{t_f b_f^3 h_w^2}{12} \times 10^{-6} \text{ for Tee profiles;}$$

$$I_w = \frac{b_f^3 h_w^2}{12(b_f + h_w)^2} \left[t_f (b_f^2 + 2b_f h_w + 4h_w^2) + 3t_w b_f h_w \right] \times 10^{-6} \text{ for angles and bulb profiles;}$$

l — span of longitudinal, in m;

E — modulus of elasticity of material, in N/mm^2 ;

where: h_w — web height, in mm;

t_w — web thickness, in mm, considering standard deductions as specified in Table 2.2.7.4 of this Section;

b_f — flange width, in mm;

t_f — flange thickness, in mm, considering standard deductions as specified in Table 2.2.7.4 of this Section. For bulb profiles the mean thickness of the bulb may be used;

C — spring stiffness exerted by supporting plate panel, obtained by the following formula:

$$C = \frac{K_p E t_p^3}{3s \left(1 + \frac{1.33 K_p h_w t_p^3}{1000 s t_w^3} \right)} \times 10^{-3}$$

S — spacing of profiles, in m;

t_p — panel thickness, in mm, considering standard deductions as specified in Table 2.2.7.4 of this Section;

$K_p = 1 - \eta P$, not to be taken less than zero. For flanged profiles, K_p need not be taken less than 0.1;

$$\eta_P = \frac{\sigma}{\sigma_{EP}};$$

σ — working pressure in compression, calculated in accordance with 2.2.5.5 of this Section, but not to be taken as less than $30/K$, in N/mm^2 , where K is material factor;

σ_{EP} — elastic buckling stress of supporting plate as calculated in 2.2.7.4 of this Section.

(3) Web and flange buckling of longitudinals

- ① For web plate of longitudinals, the ideal elastic buckling stress σ_E is to be obtained from the following formula:

$$\sigma_E = 3.8E \left(\frac{t_w}{h_w} \right)^2 \text{ N/mm}^2$$

where: t_w , h_w , E — see (2).

- ② For flanges on angles and T-sections of longitudinals, buckling is taken care of by the following requirement:

$$\frac{b_f}{t_f} \leq 15$$

where:

b_f — flange width, in mm, for angles, half the flange width for T-sections;

t_f — flange thickness, in mm.

2.2.7.6 The critical buckling stress in compression σ_c is determined as follows:

$$\sigma_c = \sigma_E \quad \text{for } \sigma_E \leq \frac{R_{eH}}{2}$$

$$\sigma_c = R_{eH} \left(1 - \frac{R_{eH}}{4\sigma_E} \right) \quad \text{for } \sigma_E > \frac{R_{eH}}{2}$$

where: R_{eH} — yield stress of material, in N/mm^2 ;

σ_E — ideal elastic buckling stress, in N/mm^2 , calculated according to 2.2.7.4(1) and 2.2.7.5 of this Section.

2.2.7.7 The critical buckling stress in shear τ_c is determined as follows:

$$\tau_c = \tau_E \quad \text{for } \tau_E \leq \frac{\tau_s}{2}$$

$$\tau_c = \tau_s \left(1 - \frac{\tau_s}{4\tau_E} \right) \quad \text{for } \tau_E > \frac{\tau_s}{2}$$

$$\tau_s = \frac{R_{eH}}{\sqrt{3}};$$

where:

R_{eH} — yield stress of material, in N/mm²;

τ_E — ideal elastic buckling stress in shear, in N/mm², calculated according to 2.2.7.4(2) of this Section.

2.2.8 Loading manual and loading instrument

2.2.8.1 On completion of construction of the ship, a Loading Manual is to be formulated in time and submitted by the designer to ISC for approval. ISC Guidelines for Preparation of Loading Manuals may be referred to for formulating the Loading Manual.

2.2.8.2 The ship is to be loaded in accordance with the requirements specified in the Loading Manual to avoid the creation of unacceptable stresses in the hull structures.

2.2.8.3 The Loading Manual is to contain the following:

- (1) The loading conditions on which the design of the ship has been based, including curves of permissible still water bending moment and shear force along the length of the ship.
- (2) The results of the calculations of still water bending moments and shear forces under various loading conditions and where necessary, limitations due to torsional and lateral loads.
- (3) The allowable local loading for local structures (such as hatch covers, decks and double bottom, etc.).

2.2.8.4 Loading instruments are to comply with the following specifications:

- (1) A loading instrument is either an analog or a digital instrument, by means of which it can be easily and quickly ascertained that the still water bending moment, shear forces and where applicable, the still water torsional moments and lateral loads at specified read-out points will not exceed the specified permissible values in any loading or ballasting condition.
- (2) The loading instrument is generally to be provided with an operation manual.
- (3) Single-point loading instruments are not acceptable.
- (4) The detailed requirements for loading instruments are referred to Appendix 1 of this Chapter.

2.2.8.5 Those ships complying with one of the following provisions are Category I ships:

- (1) Ships with large deck openings where combined stresses due to vertical and horizontal hull girder bending as well as torsional and lateral loads are to be considered.
- (2) Ships possibly with non-homogeneous loadings, where the cargo and/or ballast may be unevenly distributed. Ships less than 120 m in length, when uneven distribution of cargo and/or ballast is considered in design, belong to Category II.
- (3) Chemical tankers and gas carriers.

2.2.8.6 Those ships complying with one of the following provisions are Category II ships:

- (1) ships with such arrangements that would allow only a small possibility for variation in the distribution of cargo and ballast, and ships operating on a regular and fixed trading pattern

where the loading manual gives sufficient guidance;

- (2) ships for which an exception is given under Category I.

2.2.8.7 A loading manual approved by ISC is to be supplied to all ships except those of Category II with length less than 90 m of which the deadweight does not exceed 30% of the displacement at the summer load line draft.

2.2.8.8 An approved loading manual is to be supplied to all ships of Category I with 100 m or over in length.

2.2.8.9 Bulk carriers, ore carriers and combination carriers of 150 m or over in length are to be provided with a loading manual and a loading instrument in accordance with the requirements of Section 7, Chapter 8 of this PART.

2.2.8.10 Conditions for approval of loading manuals:

- (1) The approval of the loading manual is to be based on the final data of the ship. The manual is to include the design loading and ballasting conditions upon which the approved scantlings of hull structures are approved.
- (2) In case of modifications resulting in changes to the main data of the ship, a new approved loading manual is to be issued.
- (3) The loading manual must be prepared in a language understood by the users. If this language is not English, a translation into English is to be included.

2.2.8.11 Conditions for approval of loading instruments:

- (1) The following are to be included in loading instruments and approved:
 - ① Confirmation of type approval, if any;
 - ② Confirming that the final data of the ship have been used;
 - ③ Confirmation of the number and positions of read-out points;
 - ④ Confirmation of relevant limits for all read-out points;
 - ⑤ Checking of proper installation and operation of the instrument on board, in accordance with the approved test report of loading calculation, and that a copy of the operation manual is available.
- (2) In case of modifications implying changes in the main data of the ship, the loading instrument is to be modified accordingly and reapproved.
- (3) The operation manual and the instrument output must be prepared in a language understood by the users. If this language is not English, a translation into English is to be included.
- (4) The operation of the loading instruments is to be verified upon installation. It is to be checked that the operation manual and the approved test loading conditions are available on board.

2.2.9 Direct calculation of wave loads

2.2.9.1 The direct calculation of wave loads is to be based on the following assumptions:

- (1) The calculation software is to be based on the three-dimensional linear or non-linear wave theory and approved by the classification society.
- (2) Wave statistics based on the marine environment of the North Atlantic, as given in IACS REC34,

are used in the prediction of wave loads.

- (3) The requirements for wave frequencies, wave heading angles and the considered ship speed are given in Section 5, Chapter 1 of this PART.
- (4) The wave spectrum and energy spread function under consideration are given in Section 5, Chapter 1 of this PART.
- (5) The long-term prediction results at the probability level of 10^{-8} are taken as calculation results.

2.2.9.2 The hydrodynamic models used in calculation are to comply with the following requirements:

- (1) The mass model is to correctly reflect the mass and its distribution of the real ship, ensuring that the error between mass of the model and that of the real ship is not greater than 0.1% and that the error between position of center of gravity of the model and that of the real ship is not greater than 0.1%L.
- (2) The model of wetted surface is to be sufficiently refined for an accurate simulation of the shape of the real ship from the hydrodynamic perspective. The error between displacement of the model and that of the real ship is not to be greater than 0.1%, the error between position of center of buoyancy of the model and that of the real ship is not to be greater than 0.1% L, and the number of elements is generally not to be less than 2,000.

2.2.9.3 The wave bending moments and shear forces obtained by the linear wave theory are to be subject to non-linear correction as follows:

- (1) The hogging wave bending moment $M_W (+)$ and the sagging wave bending moment $M_W (-)$ are to be calculated by the following formulas:

$$M_W (+) = M_{f_{nl-h}} M_{W,cal} \text{ kN}\cdot\text{m}$$

$$M_W (-) = -M_{f_{nl-s}} M_{W,cal} \text{ kN}\cdot\text{m}$$

where: $M_{W,cal}$ — maximum vertical wave bending moment between $0.4L$ and $0.6L$, obtained by direct calculation based on linear wave theory;

M — distribution factor of bending moment along ship's length, see Figure 2.2.3.1 of this Chapter;

f_{nl-h} , f_{nl-s} — non-linear correction factor, determined by the following formulas:

$$f_{nl-h} = \frac{190C_b}{95C_b + 55(C_b + 0.7)}$$

$$f_{nl-s} = \frac{110(C_b + 0.7)}{95C_b + 55(C_b + 0.7)}$$

where: C_b — block coefficient, taken not less than 0.6.

- (2) The hogging wave shear force $F_W (+)$ and the sagging wave shear force $F_W (-)$ are to be calculated by the following formulas:

$$F_W (+) = F_{nl,1} F_{WV}, \text{ maxkN}$$

$$F_W (-) = -F_{nl,2} F_{WV}, \text{ maxkN}$$

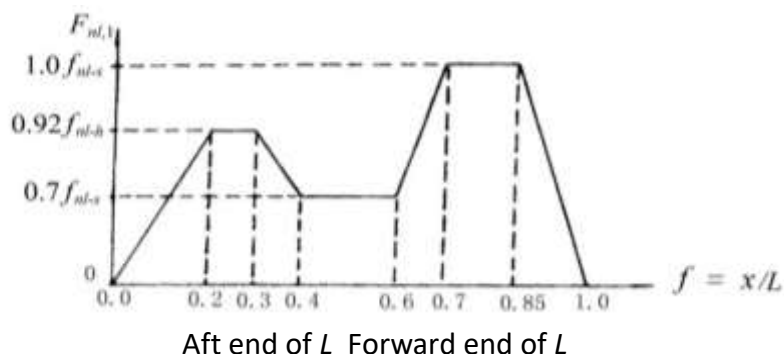
where: $F_{nl,1}$, $F_{nl,2}$ — distribution factors taking non-linear correction into account, see Figures 2.2.9.3(1) and 2.2.9.3(2) respectively. For f_{nl-h} , f_{nl-s} in the Figures, see (1) above.

$F_{WV, \max}$ is to be calculated by the following formula:

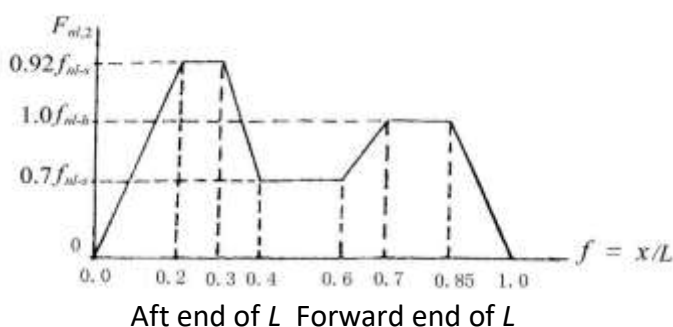
$$F_{WV, \max} = \max \left(\frac{\max |F_{WV, CAL, A}|}{0.92}, \frac{\max |F_{WV, CAL, F}|}{1.0} \right) \text{ kN}$$

where: $F_{WV, CAL, A}$ — wave shear force, in kN, directly calculated for sections with $x/L < 0.5$;

$F_{WV, CAL, F}$ — wave shear force, in kN, directly calculated for sections with $x/L \geq 0.5$.



Figures 2.2.9.3(1) Distribution of Factor $F_{nl,1}$ along Ship's Length



Figures 2.2.9.3(2) Distribution of Factor $F_{nl,2}$ along Ship's Length

2.2.9.4 For specific ships, e.g. engineering ships which need to carry out short-term operation, short-term prediction of wave loads is to be used to determine wave loads in the operating condition based on the most severe short-term sea state provided by the designer. The period of short-term prediction is generally taken as 3 hours or the operating hours provided by the designer, whichever is greater.

SECTION 3 - SHELL PLATING

2.3.1 Bottom shell

2.3.1.1 Bottom shell means the shell plating between the plate keel and the bilge strake.

2.3.1.2 In a ship with transverse bottom framing, the thickness t of bottom shell plating within $0.4L$ amidships is not to be less than the following:

$$t_1 = 0.072sE^{-1}(L+170) \sqrt{\frac{F_b}{K}} \quad \text{mm}$$

$$t_2 = 7.0s \sqrt{(d+h_1)F_bK} \quad \text{mm}$$

where: s — spacing of frames, in m, to be taken as not less than the standard spacing of frames;

d — draught, in m;

L — length of ship, in m, to be taken as not greater than 200 m;

F_b — reduction factor, see 2.2.5.6 of this Chapter;

$E = 1 + \frac{s^2}{S^2}$, where S is spacing of girders or keelsons, in m;

$h_1 = 0.26 C$, to be taken as not greater than 0.2 d ;

C — coefficient, see 2.2.3.1 of this Chapter;

K — material factor.

2.3.1.3 In a ship with longitudinal bottom framing, the thickness t of bottom shell plating within 0.4L amidships is not to be less than the values obtained from the following:

$$t_1 = 0.043s(L+230) \sqrt{\frac{F_b}{K}} \quad \text{mm}$$

$$t_2 = 5.6s \sqrt{(d+h_1)F_b K} \quad \text{mm}$$

where: s — spacing of longitudinals, in m, to be taken as not less than the standard spacing of longitudinals;

d — draught, in m;

L — length of ship, in m, to be taken as not greater than 190 m;

F_b, h_1 — see 2.3.1.2 of this Section;

K — material factor.

2.3.1.4 The thickness t of bottom shell plating within the regions of 0.075L from the ship's ends is not to be less than that obtained from the following formula:

$$t = (0.035L + 6) \sqrt{\frac{sK}{0.7}} \quad \text{mm}$$

where: L — length of ship, in m, L need not be taken as greater than 300 m;

s — spacing of frames or longitudinals, in m, to be taken as not less than 0.7;

K — material factor.

2.3.1.5 The thickness of bottom shell plating is not to be less than that obtained by the following formula:

$$t = (0.035L + 6) \sqrt{K} \quad \text{mm}$$

where: L — length of ship, in m;

K — material factor.

The thickness of bottom shell plating beyond 0.4L amidships is to be tapered gradually to the end thickness of bottom shell plating.

2.3.1.6 The thickness of bottom shell plating at fore end is, in addition, to comply with the relevant requirements of Section 15 of this Chapter.

2.3.2 Plate keel

2.3.2.1 The width b of the plate keel is not to be less than that obtained from the following formula:

$$b = 900 + 3.5L \quad \text{mm}$$

where: L — length of ship, in m.

The width of the plate keel need not be greater than 1,800 mm, and is to be maintained over the whole length of the ship.

2.3.2.2 The thickness of the plate keel is not to be less than that of the bottom shell plating calculated according to 2.3.1 of this Section in accordance with its structural configuration plus 2.0 mm nor less than that of the adjacent bottom shell plating.

2.3.3 Bilge strake

2.3.3.1 Where the bilge is framed transversely, the thickness of the bilge plating is not to be less than the value obtained from 2.3.1.2 of this Section, and where the bilge is framed longitudinally, the thickness of the bilge plating is not to be less than the value obtained from 2.3.1.3 of this Section.

2.3.3.2 Where both the bottom and side shells are framed longitudinally and the bilge longitudinals are omitted, and where transverse strength members or corresponding bilge brackets are fitted in accordance with the requirements of 2.6.15.5 of this Chapter, the thickness of the bilge strake is

neither to be less than $\frac{rF_b}{165K}$ (r being the radius of bilge, in mm, K being material factor and F_b being reduction factor of bottom), nor to be less than that of the adjacent bottom plating.

2.3.4 Side shell plating

2.3.4.1 Side shell plating means the shell plating between the bilge strake and the sheer strake.

2.3.4.2 Where the side shell is framed transversely, the thickness *t* of side shell plating within 0.4*L* amidships is to be as follows:

(1) The thickness *t* of side shell plating above $\frac{3}{4}D$ from base is not to be less than the following:

$$t_1 = 0.073sE^{-1}(L+110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 4.2s\sqrt{(d+h_2)K} \quad \text{mm}$$

(2) The thickness *t* of side shell plating within $\frac{1}{2}D$, the centre point of which is 0.5*D* from base, is not to be less than the following:

$$t_1 = 0.06s(L+110)\sqrt{\frac{F_m}{K}} \quad \text{mm}$$

$$t_2 = 5.1s\sqrt{(d+h_2)K} \quad \text{mm}$$

(3) The thickness *t* of side shell plating below $\frac{1}{4}D$ from base is not to be less than the following:

$$t_1 = 0.072sE^{-1}(L+110)\sqrt{\frac{F_b}{K}} \quad \text{mm}$$

$$t_2 = 6.3s\sqrt{(d+h_1)F_bK} \quad \text{mm}$$

where: *s* — spacing of frames, in m; to be taken as not less than the standard spacing of frames;

L — length of ship, in m, *L* need not be taken as greater than 190 m;

D — draught, in m;

F_d, *F_b* — reduction factors, see 2.2.5.6 of this Chapter;

F_m — reduction factors, to be taken as F_d or F_b , whichever is the greater;

$$E = 1 + \frac{s^2}{S^2}, \text{ where } S \text{ is the spacing of side stringers, in m;}$$

$h_2 = 0.5C$, to be taken as not greater than $0.36d$;

h_1, C — see 2.3.1.2 of this Section;

K — material factor.

- (4) In calculation of t_1 , except the minimum range of high tensile steel stipulated in Section 2 of this Chapter, the material factor K may be taken as 1.

2.3.4.3 Where the side shell is framed longitudinally, the thickness t of side shell plating within $0.4L$ amidships is to be as follows:

- (1) The thickness t of side shell plating above $\frac{1}{2} D$ from base is not to be less than the following:

$$t_1 = 0.06s(L + 110)\sqrt{F_d / K} \quad \text{mm}$$

$$t_2 = 4.2s\sqrt{(d + h_2)K} \quad \text{mm}$$

- (2) The thickness t of side shell plating below $\frac{1}{4} D$ from base is not to be less than the following:

$$t_1 = 0.06s(L + 110)\sqrt{F_b / K} \quad \text{mm}$$

$$t_2 = 5.4s\sqrt{(d + h_1)F_b K} \quad \text{mm}$$

where: s — spacing of longitudinals, in m, to be taken as not less than the standard spacing of longitudinals;

L — length of ship, in m, L need not be taken as greater than 190 m;

d — draught, in m;

F_d, F_b — reduction factors, see 2.2.5.6 of this Chapter;

h_1 — see 2.3.1.2 of this Section; h_2 — see 2.3.4.2 of this Section; K — material factor.

- (3) The thickness t of side shell plating between $\frac{1}{4} D$ and $\frac{1}{2} D$ from base is to be obtained by interpolation between the values of t_2 in (1), (2) above, but not less than t_1 in (2) above.

- (4) For the calculation of t_1 , except the minimum range of high tensile steel stipulated in Section 2 of this Chapter, the material factor K may be taken as 1.

2.3.4.4 The thickness of side shell plating within $0.075L$ from the ship's ends is to comply with the requirements of 2.3.1.4 of this Section.

2.3.4.5 The thickness of side shell plating is not to be less than that obtained by the following formula:

$$t = (0.035L + 6)\sqrt{K} \quad \text{mm}$$

where: L — length of ship, in m;

K — material factor.

The thickness of side shell plating beyond 0.4L amidships is to be tapered gradually to the end thickness of side shell plating.

2.3.5 Sheer strake

2.3.5.1 The width of the sheer strake is not to be less than:

$b = 800 + 5L$ mm, but need not be greater than 1,800 mm where:

L — length of ship, in m.

2.3.5.2 Where the side shell is framed transversely, the thickness t of the sheer strake within 0.4L amidships is not to be less than the following:

$$t_1 = 0.085sE^{-1}(L_1 + 110) \sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 1.05s \sqrt{(L + 75)K} \quad \text{mm}$$

where: s — spacing of frames, in m, to be taken as not less than the standard spacing of frames;

L — length of ship, in m;

$L_1 = L$, in m, need not be taken as greater than 200 m;

F_d, E — see 2.3.4.2 of this Section;

K — material factor.

2.3.5.3 Where the side shell is framed longitudinally, the thickness t of the sheer strake within 0.4L amidships is not to be less than the following:

$$t_1 = 0.06s(L_1 + 110) \sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 0.9s \sqrt{(L + 75)K} \quad \text{mm}$$

where: s — spacing of longitudinals, in m, to be taken as not less than the standard spacing of longitudinals;

L — length of ship, in m;

$L_1 = L$, in m, need not be taken as greater than 200 m in calculation;

F_d — reduction factors, see 2.2.5.6 of this Chapter;

K — material factor.

2.3.5.4 The thickness of sheer strake within 0.4L amidships is in any case not to be less than 0.8 times that of the stringer plate of the strength deck, nor less than that of adjacent side shell plating, and may be gradually tapered to the end thickness of the side shell plating.

2.3.5.5 Where the sheer strake is connected to the stringer plate by welding, the upper edge of the sheer strake is to be dressed smooth, and any fittings welded to the top of the sheer strake within 0.5L amidships are to be avoided. Scupper openings are not to be cut in the sheer strake which is protruded above the deck within 0.5L amidships or in way of breaks of superstructures. Where a rounded sheer strake is adopted, the radius is not to be less than 15 times the thickness of the plate.

The thickness of rounded sheer strake is to be at least equal to that of deck plating. Effective measures are to be taken to maintain the required properties of material after shaping. Deck fittings welded directly to the rounded sheer strake within 0.5L amidships are to be avoided, wherever possible.

2.3.6 Local strengthening

2.3.6.1 The thickness of shell plates connected to the stern frame or fitted in way of the shaft bossing in single screw ships and in way of the palms of propeller struts in multi-screw ships, is neither to be less than 1.5 times the thickness of shell plating at ends, nor to be less than the thickness of the shell plating amidships.

2.3.6.2 The shell plating in way of hawse pipe and one plate below are to be increased in thickness or to be fitted with doubler plates. The outlet of hawse pipe is to have adequate corner radius. It is recommended that the corner radius of chafing lips made of steel plate or cast steel be not less than 12 times the diameter of anchor chain.

2.3.7 Openings in shell plating

2.3.7.1 Openings cut in the turn of the bilge strake within 0.5L amidships are to be avoided as far as possible, but if necessary, the openings are to be elliptical with the major axis arranged in the fore and aft direction.

2.3.7.2 In general, compensation will not be required for circular openings in the sheer strake which are clear of the gunwale and the deck openings outside the line of hatchways and whose depth does not exceed 20% of that of the sheer strake or 380 mm, whichever is the lesser. Circular openings in sheer strake are to be kept well clear of the ends of superstructures. Openings cut in a rounded gunwale are not allowed.

2.3.7.3 Sea inlets and other openings are to have well rounded corners. The thickness of sea inlet box plating and its steel grade are not to be lower than the adjacent shell. For ships of 90 m or over in length, this thickness is not to be less than 12 mm, but need not exceed 25 mm.

2.3.7.4 Cargo door openings are to have well rounded corners, and are to be kept clear of the ends of superstructures and the deck openings outside the line of hatchways. Such openings within 0.5L amidships are to be fully compensated by insert plates or doubler plates with a sufficient length in the fore and aft direction.

2.3.8 Bilge keels

2.3.8.1 Where bilge keels are fitted, they are to be attached to a continuous flat bar which may be welded to the shell. All butts of bilge keels, flat bars and shell plating are to be properly shifted from one another. Bilge keels and flat bars are not to be interrupted abruptly, but to be gradually tapered at their ends and terminated on a suitably stiffened panel.

SECTION 4 – DECKS

2.4.1 General requirements

2.4.1.1 This Section applies to all decks with longitudinal or transverse framing.

2.4.1.2 Where the platform decks terminate within $0.4L$ amidships, horizontal brackets are to be provided at their ends and are to extend over a suitable length.

2.4.2 Strength deck

2.4.2.1 The thickness t of strength deck plating outside the line of openings within $0.4L$ amidships is, in addition to complying with the requirements for midship section modulus, not to be less than the following:

(1) For transverse framing:

$$t_1 = 0.085sE^{-1}(L_1 + 110) \sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 1.05s \sqrt{(L + 75)K} \quad \text{mm}$$

where: s — spacing of frames, in m, to be taken as not less than the standard spacing of frames;

L — length of ship, in m;

$L_1 = L$, in m, need not be taken as greater than 200 m in calculation;

F_d — reduction factor, see 2.2.5.6 of this Chapter;

$E = 1 + \frac{s^2}{S^2}$, where S is spacing of deck longitudinals;

K — material factor.

(2) For longitudinal framing:

$$t_1 = 0.06s(L_1 + 110) \sqrt{\frac{F_d}{K}}$$

$$t_2 = 0.9s \sqrt{(L + 75)K}$$

where: s — spacing of longitudinals, in m, to be taken as not less than the standard spacing of longitudinals;

L — length of ship, in m;

$L_1 = L$ in m, need not be taken as greater than 200 m;

F_d — reduction factor, see 2.2.5.6 of this Chapter;

K — material factor.

2.4.2.2 The thickness t of strength deck plating inside the line of openings and within $0.075L$ from the ship's ends, irrespective of longitudinal or transverse framing, is not to be less than that obtained from the following formula:

$$t = 0.9s \sqrt{(L + 75)K} \quad \text{mm}$$

where: s — spacing of frames, in m, to be taken as not less than the standard spacing of frames;

L — length of ship, in m;

K — material factor.

2.4.2.3 The minimum thickness t of the strength deck plating (including deck plating at ends) is not to be less than 6 mm.

2.4.2.4 Where the long bridge deck within $0.5L$ amidships is regarded as the strength deck, the midship section modulus and the minimum thickness are to comply with the requirements of 2.2.5 and 2.4.2.1 of this Chapter.

2.4.2.5 The thickness of strength deck plating is to be maintained for $0.4L$ amidships and is to be gradually tapered to the end thickness.

2.4.2.6 Where the strength deck at the ship's fore end is not protected by a forecastle, the plate thickness of strength deck forward of $0.15L$ from the fore perpendicular is to meet the requirements for forecastle deck.

2.4.3 Stringer plates

2.4.3.1 The thickness of strength deck stringer plates is not to be less than the thickness of strength deck plating. The breadth of strength deck stringer plates within $0.4L$ amidships is to comply with the relevant requirements of Section 3, Chapter 1 of this PART. The breadth of strength deck stringer plates at ends of the ship is not to be less than 65% of that amidships.

2.4.4 Deck openings

2.4.4.1 Where the corners of engine/boiler room or hatch openings in the strength deck are parabolic or elliptical, insert plates are not required, but the requirements as shown by Figure 2.4.4.1 are to be complied with.

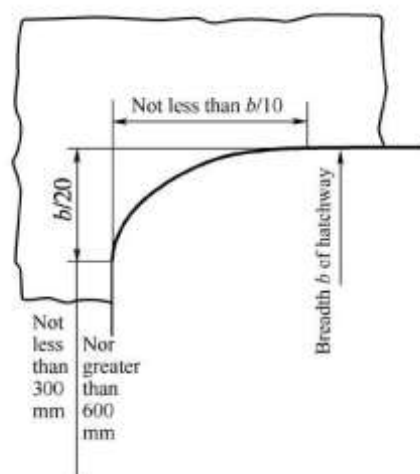


Figure 2.4.4.1

2.4.4.2 Where the corners of engine/boiler room or hatch openings in the strength deck are rounded, insert plates are required, and the radius of the rounded corner is not to be less than $1/20$ of the breadth of the opening, but not less than $1/10$ provided that deck girders are not fitted in

way of the hatch coamings. Rounded corners are to have a minimum radius of 300 mm if the deck plating extends inside the coaming, or 150 mm if the coamings are welded to the inner edge of the deck plating in the form of a spigot.

The extension of the insert plates is to be as shown in Figure 2.4.4.2 (R is the radius of hatch corners, e is not to be less than 760 mm and for longitudinal framing, not to be less than one longitudinal spacing). The butt of the insert plate is to be kept well clear of the butt in coaming and the fillet welds of deck framing. The thickness of the insert plate is to be 4 mm greater than the thickness of strength deck framing. If the thickness or extension of the insert plate can not meet above requirements, direct calculation covering yield, buckling and fatigue is to be adopted for verification.

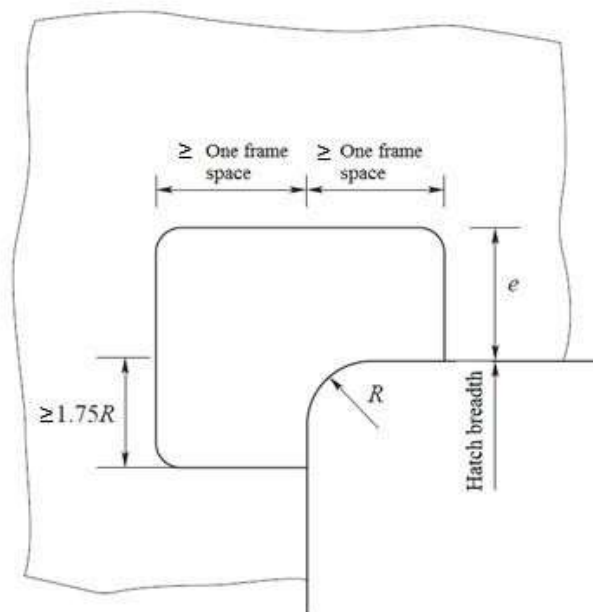


Figure 2.4.4.2

2.4.4.3 Openings in the strength deck outside the line of hatchways are to be kept to a minimum and are to be arranged clear of hatch corners. The corners of all openings are to be well rounded and with the edges smoothed. Openings in the strength deck between midship bridge or deckhouse end bulkheads and hatches are to be avoided so far as possible.

2.4.4.4 Compensation is not required for openings in the strength deck outside the line of hatchways and situated within $0.5L$ amidships provided that they comply with the provisions of 2.2.4.7 of this Chapter. Edge reinforcement will not be required for:

- (1) elliptical openings having their major axis in the fore and aft direction and an aspect ratio not less than 2;
- (2) openings of other shapes provided that it has been shown by suitable tests that the stress concentration factor does not exceed 2 for low carbon steel and 1.5 for higher tensile steel.

2.4.4.5 Where the openings in the strength deck within $0.5L$ amidships and outside the line of hatchways do not comply with the provisions of 2.2.4.7 of this Chapter, compensation is required.

Compensation is normally arranged by increasing the deck plate thickness. Where the openings do not comply with the provisions of 2.4.4.4(1) or (2) of this Section, the edge reinforcement in the form of a spigot as shown in Figure 2.4.4.5 is to be adopted, or alternative arrangements will be considered. Where a spigot is adopted, the sectional area A of the ring plate is not to be less than that obtained from the following formula: $A = 0.5rt \text{ mm}^2$ where: r — radius of opening, in mm, and to be taken as the half breadth of the openings for elliptical openings; t — thickness of deck plating, in mm.

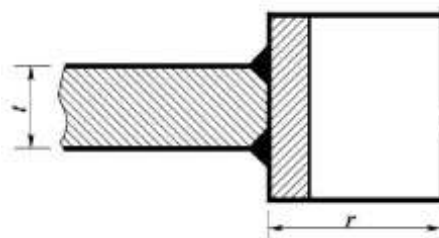


Figure 2.4.4.5

2.4.4.6 Lower deck openings are to comply with the following requirements:

- (1) Inserts are required for machinery spaces and cargo hatch opening corners on second tier decks, and the thickness of inserts is to be 2.5 mm greater than the deck thickness. Insert plates will not generally be required for hatch corners on third tier decks and decks below (including platform decks).
- (2) Openings outside the line of hatchways are to be as far as practicable kept clear of hatch corners and other areas of high stress. The provisions of 2.4.4.4 and 2.4.4.5 of this Section are generally also applicable to openings in lower decks, but compensation will not be required unless the total breadth of openings (see shadow areas as shown in Figure 2.2.4.7 of this Chapter) in such decks exceeds 15% of the breadth of deck plating used in midship section modulus calculation.

2.4.4.7 The above requirements for deck openings are, in general, also applicable to regions outside 0.5L amidships.

2.4.5 Lower decks and platform decks with loading not exceeding 40 kPa

2.4.5.1 The thickness t of second tier deck plating outside the line of hatchways and within 0.4L amidships is not to be less than that obtained from the following formula:

$$t = 12s K \text{ mm, and not less than 6 mm}$$

The thickness t of second tier deck plating inside the line of hatchways and within 0.075L from the ship's ends is not to be less than that obtained from the following formula:

$$t = 10s K \text{ mm, and not less than 6 mm}$$

where: s — spacing of frames, in m, to be taken as not less than the standard spacing of frames.

2.4.5.2 The thickness t of third tier deck or platform deck plating is not to be less than that obtained from the following formula:

$$t = 10s K \text{ mm, and not less than 6 mm}$$

where: s — spacing of frames, in m, to be taken as not less than the standard spacing of frames;
 K — material factor.

2.4.6 Raised quarter decks

2.4.6.1 For the requirements for raised quarterdecks, see 2.17.8 of this Chapter.

2.4.7 Superstructure ends

2.4.7.1 The deck strengthening at ends of superstructures is to comply with the requirements of 2.17.6 of this Chapter.

2.4.8 Deck coverings

2.4.8.1 The deck coverings are to be of materials which are not corrosive to steel, or they are to be effectively insulated from the steel by a noncorrosive protective coating.

2.4.8.2 Wood sheathing on exposed steel deck is to have a thickness not less than 50 mm for pine and 45 mm for teak wood in ships less than 120 m in length, and 60 mm and 50 mm respectively in ships of 120 m or over in length. For enclosed spaces, the thickness of pine sheathing on the steel deck is not to be less than 40 mm. The thickness of steel deck plating sheathed with wood planks may be reduced by 1 mm, but each plank is to be well secured to the deck plating at every beam by studs.

2.4.8.3 Where chemical covering is used as a substitute for wood sheathing, the thickness of the steel deck plating is not to be reduced.

SECTION 5 - SINGLE BOTTOMS

2.5.1 Application

2.5.1.1 This Section applies to transversely framed single bottom ships of not greater than 90 m in length.

2.5.2 Centre keelson

2.5.2.1 The centre keelsons are to be provided in way of the central longitudinal section of the ship. The depth of the centre keelson is to be the same as that of floors, and the web thickness t and the sectional area A of the face plate of the centre keelson are not to be less than the following:

Within $0.4L$ amidships $t = \sqrt{LK} + 2 \text{ mm}$, and not less than 6 mm
 $A = 0.67LK \text{ cm}^2$, and not less than 12.5 cm^2

Within $0.075L$ from the ship's ends: $t = \sqrt{LK} + 0.5 \text{ mm}$, and not less than 6 mm
 $A = 0.52LK \text{ cm}^2$, and not not less than 12.5 cm^2

where: L — length of ship, in m; K — material factor.

In the forepeak tank, the centreline keelson may have the same depth and thickness and the same sectional area of face plate as the floor.

2.5.2.2 The centre keelson is normally to extend as far forward and aft as practicable. Where the centre keelson is cut in way of a bulkhead, it is to be connected to the bulkhead by one of the following means:

- (1) The web plate of the centre keelson is to be gradually raised, within one frame spacing to 1.5 times the original web depth at the bulkhead, and the face plate of the centre keelson is to extend and to be welded to the bulkhead, as shown in Figure 2.5.2.2(1).

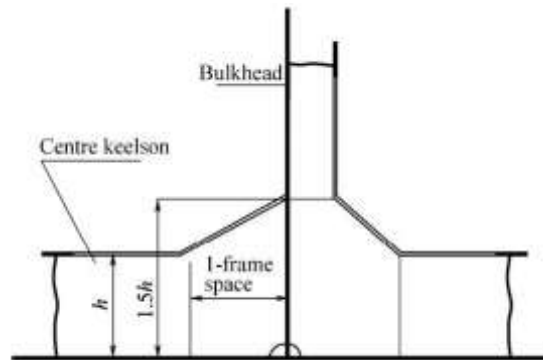


Figure 2.5.2.2(1)

- (2) The centre keelson is to be attached to the bulkhead by brackets having a face plate or flange, and the depth and length of the brackets are to be equal to the depth of the keelson. In this case, the face plate of the centre keelson may not be welded to the bulkhead. The thickness of the brackets is to be the same as that of the web of the centre keelson, as shown in Figure 2.5.2.2(2).

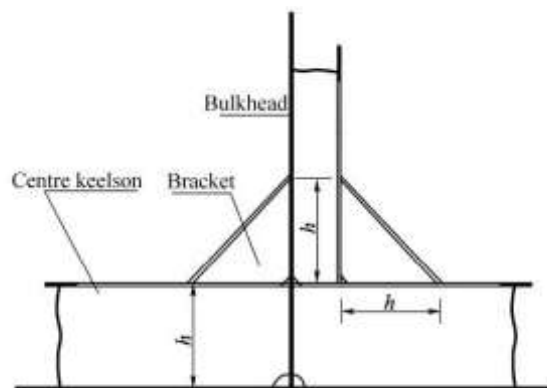


Figure 2.5.2.2(2)

- (3) The face plate of the centre keelson is, within one frame spacing, to be gradually widened to twice its original width at the bulkhead, and to be welded to the bulkhead, as shown in Figure 2.5.2.2(3).

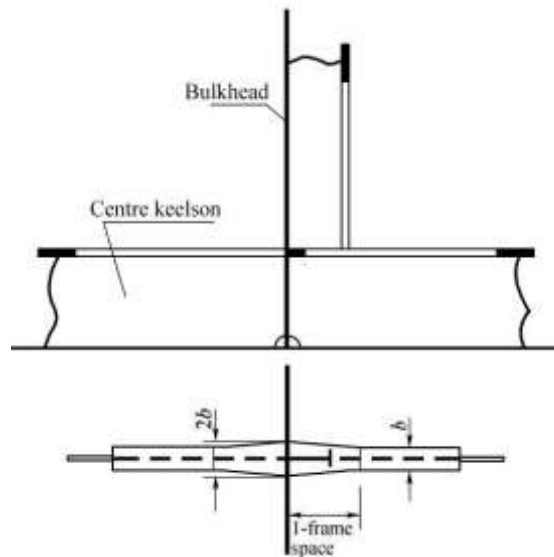


Figure 2.5.2.2(3)

2.5.2.3 In the machinery space the thickness of the centre keelson web is to be equal to the value obtained from 2.5.2.1 of this Section plus 1 mm. Where a single main engine is fitted, the centre keelson may be omitted in the machinery space provided that the longitudinal girders under the engine seating extend over the whole length of the engine room and brackets are fitted at the outside of both end bulkheads of the engine room for transition. Within the engine room where the centre keelson is cut, however, gradually tapered brackets having a length not less than two frame spaces are to be fitted for transition, as shown in Figure 2.5.2.3.

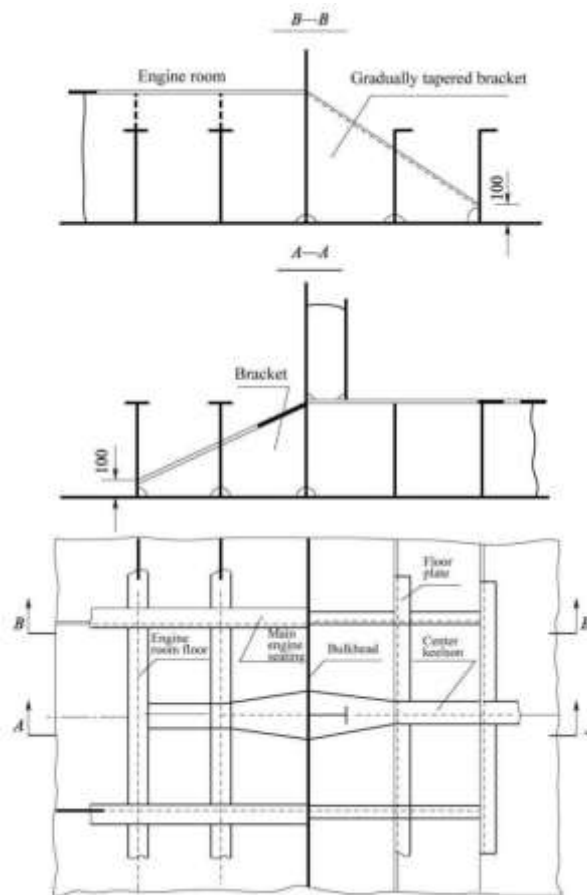


Figure 2.5.2.3

In machinery spaces situated at the aft end, such engine seating girders are to be carried as far aft as practicable and the ends effectively supported by web frames or transverses. Where it is impracticable to provide transition brackets abaft the aft peak bulkhead because the aft body of the ship is too fine, such brackets may be dispensed with.

2.5.3 Side keelsons

2.5.3.1 The depth of side keelsons is to be the same as that of floors, and the web thickness t and the face plate sectional area A of side keelsons are not to be less than the following:

$$t = \sqrt{LK} \quad \text{mm, and not less than 6 mm}$$

$$A = 0.25L + 5 \quad \text{cm}^2, \text{ and not less than 10 cm}^2$$

where: L — length of ship, in m; K — material factor.

In the machinery space, the web thickness of side keelsons is not to be less than that of the centre keelson as required in 2.5.2.1 of this Section.

2.5.3.2 One side keelson at least is to be fitted on each side of the centre keelson where the breadth of ship is equal to 9 m or less, and two at least where the breadth exceeds 9 m but does not exceed 16 m. In addition, continuous or intercostal longitudinal stiffeners are to be fitted where the panel aspect ratio exceeds 4. Side keelsons are to be uniformly fitted and are to extend as far forward and aft as practicable. Outboard of the main engine seating girders, side keelsons as required in 2.5.3.1 of this Section are to be fitted, and attention is to be given to structural continuity. In the case of

ships having duplicate main engines situated at the aft end, where it is impracticable to fit the side keelsons owing to the confined space in the engine room, such keelsons may be dispensed with.

2.5.3.3 The attachment of side keelsons to the bulkheads is to be the same as required for the centre keelson (see 2.5.2.2 of this Section).

2.5.4 Floors

2.5.4.1 Plate floors are to be fitted at every frame and are, at the centreline, to have a web depth h , a web thickness t and a sectional area A of face plate not less than:

$$h = 42(B + d) - 70 \text{ mm}$$

$$t = (0.01h + 3) \sqrt{K} \text{ mm, but not less than 6 mm and need not be greater than 14 mm}$$

$$A = (4.8d - 3) K \text{ cm}^2$$

where: B — breadth of ship, in m; d — moulded draught, in m; K — material factor.

2.5.4.2 The thickness of the face plate of the floor is not to be less than that of its web plate. The breadth of the face plate is not to be less than 10 times its thickness, but need not exceed 15 times.

2.5.4.3 In ships having considerable rise of floor (or towards fore and aft ends), the depth of floor plates is to be increased. The floor plates forming part of a watertight, deep tank or tank bulkhead are not to be less than 900 mm in depth measured at the centreline, and have a thickness not less than that required for the bottom strake of a bulkhead. For small ships, the depth of the floor plates at the centreline may be suitably reduced.

2.5.4.4 In machinery spaces the web thickness of floors is not to be less than that of the centre keelson as required in 2.5.2.1 of this Section. In way of machinery spaces situated amidships, the depth of the web plate and the face plate sectional area of floors are to be increased by 10% above those obtained from 2.5.4.1 of this Section. In way of machinery spaces situated astern, the face plate area of floors is to be increased by 10% above those obtained from 2.5.4.1 of this Section. The floors are not to be flanged instead of having face plates.

In way of machinery spaces situated aft or where there is considerable rise of floor, the depth of floors is to be appropriately increased in accordance with the ship's lines and strength.

2.5.5 Bilge brackets

2.5.5.1 Floors are to be connected to the frames by bilge brackets. The depth of the bilge brackets measured from the base line is to be twice that of the floors in way of the centreline, and the length of the brackets, measured from the inner edge of frames, is to be equal to the floor depth on the centreline. The thickness of the brackets is to be equal to that of floors. The brackets are to have a flange or face plate. When flanged, the width of the flange is neither to exceed 10 times the thickness of the bracket nor to be less than 50 mm.

2.5.5.2 Where it is impracticable to arrange the bilge brackets due to the ship's lines or other reasons, the floors are to extend to the ship's side and to be raised to the required depth for bilge Brackets.

2.5.5.3 Where bilge brackets or floors are connected to the frames by means of a welded lap joint, the length of overlap is to be as follows:

- (1) when the depth of frames is 100 mm or less, the length of overlap is not to be less than twice the depth of frames;
- (2) when the depth of frames exceeds 100 mm, the length of overlap is neither to be less than 1.5 times the depth of the frame nor less than 200 mm.

2.5.6 Drain holes

2.5.6.1 Drain holes are to be cut in the floors and side keelsons in way of the bottom. Provision is to be made for the free passage of water from all parts of the bottom to the suction, taking into account the pumping rates required.

SECTION 6 - DOUBLE BOTTOMS

2.6.1 General requirements

2.6.1.1 Double bottoms are to comply with the requirements of this Section and in addition, the relevant requirements of Section 12, Chapter 1 of this PART.

2.6.1.2 Where the double bottom is interrupted, the continuity of bottom longitudinal members is to be maintained. The centre and side keelsons within the single bottom in way of the break are to be the continuation of the centre and side girders of the double bottom. The inner bottom plating is to extend beyond the break of the double bottom and to be gradually tapered for a length of not less than three frame spaces to form the face plate of the keelsons, and the breadth of the face plate at the break of the double bottom is not to be less than half the spacing of side keelsons. The margin plate is also to extend not less than three frame spaces beyond the break of the double bottom. Where the margin plate is inclined, the extension portion is to have a face plate or flange, and the width of the margin plate may be reduced gradually. Within the single bottom, side keelsons, which are not the direct continuation of the girders in the double bottom, are to be extended into the double bottom and to be gradually tapered off over a length of not less than three frame spaces with their free edges flanged.

2.6.1.3 Sufficient girders are to be arranged in way of the main machinery and structural continuity is to be maintained. In midship machinery spaces, these girders are to extend for the full length of the space and are to be carried for at least three frame spaces beyond the fore and after bulkheads of the engine room. However, the extension beyond the after bulkhead is also to support the foremost shaft tunnel bearing; in machinery spaces situated at the aft end such girders are to be carried as far aft as practicable and the ends effectively supported by web frames or transverses. Outboard of the main engine seating girders, side girders are to be arranged and attention is to be given to the structural continuity.

2.6.1.4 Manholes are to be cut in the floors and side girders. Except for lightened floors, the depth of manholes is not to exceed 50% of that of the double bottom, unless edge reinforcement is provided. Manholes cut in floors are to be arranged along a straight line in the fore and aft direction for easy

access. Manholes or lightening holes are not permitted within the range of floor ends (generally taken as 1 spacing of longitudinals in way of the longitudinal bulkhead or 600 mm, whichever is greater) and in the side girders for one frame space from transverse bulkheads, unless the edges of holes are strengthened. The edges of all holes are to be smoothed.

2.6.1.5 Air and drain holes are to be cut in floors, side girders and bottom and inner bottom longitudinals to ensure the free passage of air and water from all parts of the tanks to the air pipes and suction, account being taken of the pumping rates required.

2.6.1.6 The minimum thickness of floors and girders of double bottoms is to be 6 mm.

2.6.1.7 The strake connecting the inner bottom plating to the shell plating is the margin plate.

2.6.2 Centre girders

2.6.2.1 Centre girders are to be provided in way of the central longitudinal section of the ship. The depth h_0 of centre girders is to comply with the requirements for the depth of double bottoms in Section 12, Chapter 1 of this PART and not to be less than that calculated by the following formula:

$$h_0 = 25B + 42d + 300 \text{ mm, nor less than 760 mm}$$

where: B — breadth of ship, in m; d — draught, in m.

For double hull ships (with double bottom and double side skin), the distance from midpoint between outer and inner shells at one side to that at the other side may be taken as equivalent breadth in lieu of the breadth B of ship (see Figure 2.6.2.1). B_e is generally not to be less than $0.9B$, and if the double bottom strength is in compliance with the ISC criteria for direct strength calculations, not to be less than $0.8B$.

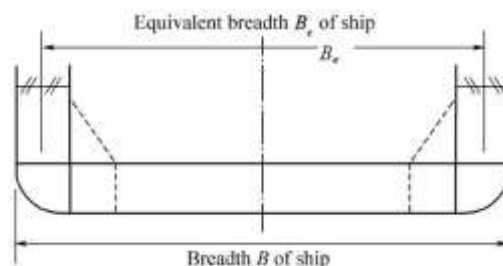


Figure 2.6.2.1

2.6.2.2 The thickness t of centre girders is not to be less than:

(1) For $0.4L$ amidships:

$$t = (0.0077h_0 + 4)\sqrt{K} \text{ mm}$$

where: h_0 — considered height of double bottom, in mm;

K — material factor.

(2) For $0.075L$ from the ship's ends, the thickness t of centre girders may be decreased by 2 mm from that required in (1) above.

(3) The thickness of centre girders in boiler spaces is to be increased by 2.5 mm above that required for centre girders within $0.4L$ amidships.

2.6.2.3 The centre girders within 0.75L amidships are to be continuous and to extend as far as practicable to the stem and stern frame.

2.6.2.4 Manholes or lightening holes are not to be cut in the centre girders within 0.75L amidships, but if such holes are essential in exceptional cases, suitable compensation is to be provided. Outside 0.75L amidships, holes may be cut in centre girders (excluding one frame space forward and aft of a transverse bulkhead) with a depth not exceeding 40% of that of the centre girders at that place.

2.6.3 Duct keels

2.6.3.1 Duct keels (pipe tunnels) may be substituted for centre girders. The thickness of side plates of the duct keel is not to be less than that of the watertight floors. The side plates are in general not to be spaced more than 2 m apart; for ships of 150 m or above in length, the side plates may be spaced not more than 3 m apart upon verification by direct calculation.

The bottom shell and inner bottom within the region of duct keels are to be suitably increased in thickness.

2.6.3.2 The framing members of the duct keel are to be as follows:

- (1) Bottom and inner bottom stiffening members are to be fitted to the duct keel at every frame, and the section modulus W of these framing members is not to be less than that obtained from the following formula:

$$W = 22sdl^2K \text{ cm}^3$$

where: s — spacing of frames, in m;

d — draught, in m;

l — span, in m, to be taken as the distance between side plates;

K — material factor.

- (2) Bottom and inner bottom stiffening members are to be gradually increased in scantlings at both ends and are to be connected to the side plates of the duct keel. The enlarged portions are to have a length and depth not less than 1.5 times the depth of the members. In such a case, brackets having the same thickness as the plate floors are to be fitted outside the side plates at each frame where no floor is fitted, and are to be attached to the longitudinals.
- (3) Bottom longitudinals are to be fitted within the duct keel on the centreline of the ship, which may be intercostal in way of transverse framing members.

2.6.3.3 At the connection between the duct keel and the ordinary centre girder, they are to be overlapped over a length not less than 3 frame spaces for transition.

2.6.4 Transverse framing — side girders

2.6.4.1 The thickness of side girders is not to be less than that obtained from the following formula:

$$t = (0.0077h_0 + 1)\sqrt{K} \quad \text{mm}$$

where: h_0 — considered height of double bottom, in mm.

K — material factor.

The thickness of watertight side girders is to be increased by 1 mm above that obtained from the above formula. Where the double bottom tanks are interconnected with side tanks or cofferdams, the thickness of side girders is to be as required for deep tanks.

2.6.4.2 At least one side girder is to be fitted on each side of the centreline when the breadth of the ship exceeds 10 m, and at least two side girders spaced apart generally not more than 4 m are to be fitted on each side of the centreline when the breadth of the ship exceeds 18 m. But forward of 0.2L from the F.P., the spacing of side girders is not to be greater than 3 frame spaces. Side girders are to be equally spaced as far as practicable.

2.6.5 Transverse framing — plate floors

2.6.5.1 The thickness t of plate floors in cargo holds or machinery spaces is not to be less than that obtained from the following formula, but need not exceed 15 mm:

$$t = (0.0077h_0 + 1)\sqrt{K} \text{ mm}$$

where: h_0 — considered height of double bottom, in mm;

K — material factor.

The thickness of plate floors in boiler rooms and in way of the bilge wells is to be 2.5 mm greater than that given by the above formula.

2.6.5.2 Plate floors are to be fitted at least 4 frame spaces apart at a spacing not exceeding 3.2 m. Where the length of ships exceeds 90 m or the depth of floors exceeds 0.9 m, vertical stiffeners spaced not more than 1.5 m apart are to be fitted on the plate floors, generally having the same thickness as that of floors and the width of which is not to be less than 150 mm. For ships less than 90 m in length, the width of such stiffeners is not to be less than 1.65L, with a minimum of 50 mm.

2.6.5.3 Plate floors are to be fitted at every frame in the engine room and under the boiler bearers, thrust seatings, transverse bulkheads and heels of pillars. Plate floors are to be fitted at every frame forward of 0.2L from the F.P.

2.6.6 Transverse framing — watertight floors

2.6.6.1 The thickness of watertight floors is to be as follows:

- (1) The thickness of watertight floors is to be 2 mm greater than that of the plate floors in cargo holds, but generally need not exceed 15 mm. Watertight floors are to be fitted below transverse watertight bulkheads wherever practicable.
- (2) The thickness of oiltight floors in oil tanks is to be the same as required for the above watertight floors.

2.6.6.2 Where the depth of watertight floors is greater than 0.9 m but does not exceed 2 m, they are to be fitted with vertical stiffeners spaced not more than 0.9 m apart. Both ends of stiffeners are to be snipped, the thickness and depth are to comply with the requirements of 2.6.5.2 of this Section, and the section modulus W of which is not to be less than that obtained from the following formula:

$$W = 5.5shl^2K \text{ cm}^3$$

where: s — spacing of stiffeners, in m;
 h — vertical distance, in m, from the inner bottom to the top of overflow;
 l — span of stiffener, in m, i.e. the considered height of double bottom;
 K — material factor.

The section modulus of the stiffeners on the oiltight floors in oil tanks is to be the same as required in the above formula.

2.6.6.3 Where the double bottom tanks are interconnected with side tanks or cofferdams, or the depth of the plate floor is greater than 2 m, the scantlings of the watertight floors are not to be less than those required for deep tanks, furthermore, vertical stiffeners are to be bracketed at both ends.

2.6.7 Bracket floors

2.6.7.1 Where transverse framing is adopted in the double bottom, bracket floors are to be fitted at every frame where no plate floor is fitted. The breadth of the brackets attaching the frames and the reversed frames to the centre girder and margin plate is not to be less than 75% of the depth of the centre girder, and the thickness of the brackets is to be the same as that of plate floors in that region. Where the depth of the double bottom is equal to 800 mm or more, the brackets are to have a flange or face plate on the unsupported edge and the breadth of the flange or face plate is to be 10 times the thickness but need not exceed 90 mm. Stiffeners having the same scantlings as the reversed frames are to be fitted on one side of the side girders (see Figure 2.6.7.1). Where l as shown in the Figure is greater than 2.5 m, struts as required in 2.6.7.2 of this Section are to be fitted.

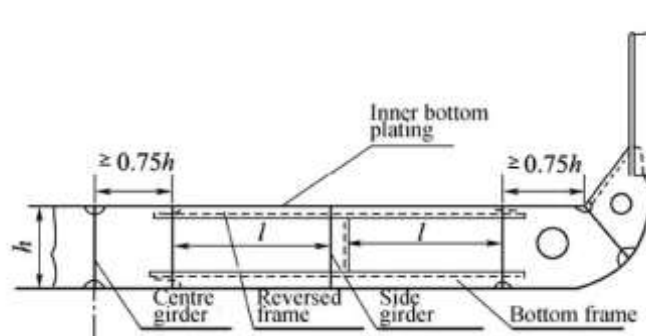


Figure 2.6.7.1

2.6.7.2 The bottom frames of bracket floors are to have a section modulus W not less than that obtained from the following formula:

$$W = (15 - 2.5/l)sd^2K \text{ cm}^3$$

where: s — spacing of frames, in m;
 d — draught, in m;
 l — span of bottom frames, in m, measured from the edge of the bracket to the side girder (see Figure 2.6.7.1);

l_1 — the same as l , but l_1 is to be taken as 2.5 m for $l > 2.5$ m;

K — material factor.

Where struts are fitted at the mid-point of the span l , the section modulus W of the bottom frames is not to be less than half of that given by the above formula. The cross sectional area A of the struts is not to be less than the following:

$$A = 23.8 + 0.04W \text{ cm}^2 \text{ for } W > 85 \text{ cm}^3$$

$$A = 0.32W \text{ cm}^2 \text{ for } W \leq 85 \text{ cm}^3$$

where: W — section modulus of bottom frames, in cm^3 .

The reversed frames are to have a section modulus not less than 85% of that given above for the bottom frames.

In boiler rooms, the thickness of the bottom frames, reversed frames and struts is to be increased by 2 mm.

2.6.7.3 The attachment of bottom frames and reversed frames to brackets is to be the same as required in 2.5.5.3 of this Chapter for the attachment of frames to bilge brackets.

2.6.8 Lightened floors

2.6.8.1 Where transverse framing is adopted in the double bottom, lightened floors may be fitted at every frame where no plate floor is fitted, as substitutes for bracket floors. The thickness of the web plate of lightened floors is not to be less than that of the plate floor in the same region. The distance from the edge of the lightening hole to bottom and inner bottom is not to be less than 0.2 times the depth of the centre girder; the distance from the edge of the lightening hole to the centre girder and margin plate is not to be less than 0.5 times the depth of the centre girder; the distance from the edge of the lightening hole to the side girder is not to be less than 0.25 times the depth of the centre girder; and the length of the the lightening hole is not to exceed 1.2 times the depth of the centre girder, as shown in Figure 2.6.8.1. The dimensions of the vertical stiffeners on the floors are to comply with the requirements of 2.6.5.2 of this Section, and the spacing of the stiffeners is not to be more than 2.2 m.

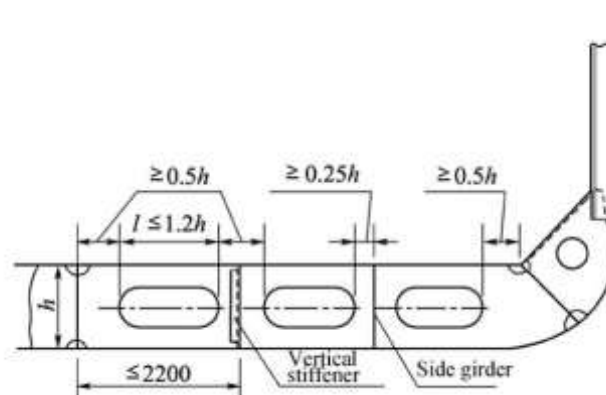


Figure 2.6.8.1

2.6.9 Transverse framing — inner bottom plating and margin plate

2.6.9.1 The thickness t of the inner bottom plating is not to be less than the following:

$$t = (0.04L + 5s + 2.1)\sqrt{K} \quad \text{mm for } 0.4L \text{ amidships}$$

$$t = (0.055L + 4.8)\sqrt{K} \quad \text{mm for engine spaces}$$

where: L — length of ship, in m, to be taken as not greater than 400 m;

s — spacing of frames, in m;

K — material factor.

For $0.075L$ from the ship's ends, the thickness is to be 0.9 times that required for $0.4L$ amidships. The thickness of the inner bottom plating in other regions is to be tapered gradually to the end thickness from the thickness within $0.4L$ amidships.

2.6.9.2 Local strengthening of inner bottom plating:

- (1) Where the double bottom tanks are used to carry oil fuel, the thickness of the inner bottom plating is not to be less than 8 mm.
- (2) The thickness of the inner bottom plating under hatchways is to be increased at least by 2 mm if no wood ceiling is fitted. If cargo is regularly discharged by grabs or other similar means and where no wood ceiling as required in 3.3.1.5 of this PART is fitted, the thickness of the inner bottom plating under hatchways is to be increased at least by 5 mm.

2.6.9.3 Where the margin plate is inclined downwards, the breadth of the margin plate is not to be less than 80% of the depth of the centre girder. Where the margin plate is horizontal, the breadth is not to be less than that of bilge brackets plus 50 mm.

Where the margin plate is inclined downwards, the thickness of the margin plate throughout the hold is to be 1.5 mm greater than that required for the inner bottom plating when the length of the ship is equal to 110 m or less, and 2 mm when the length of the ship is greater than 110 m. In engine rooms and boiler rooms, the thickness of the margin plate is not to be less than that required for the inner bottom plating within such spaces respectively.

2.6.10 Longitudinal framing — bottom girders

2.6.10.1 The depth and thickness of the centre girder are to be the same as required in 2.6.2.1 and 2.6.2.2 of this Section. Between plate floors, brackets having the same thickness as the plate floors are to be fitted on each side of the centre girder, extending to the adjacent longitudinals. Such brackets are in general to be spaced not more than 1.20 m apart. Where the centre girder is watertight, vertical stiffeners spaced not more than 0.9 m apart are to be fitted between the plate floors and brackets (when the distance between them is greater than one frame space). For these stiffeners, the section modulus is to comply with the requirements of 2.6.6.2, the thickness is to be the same as that of the center girder web and in general, the breadth is to comply with the requirements of 2.6.5.2.

2.6.10.2 At least one side girder is to be fitted on each side of the centreline when the breadth of the ship exceeds 12 m but not greater than 20 m, and at least two side girders spaced apart generally not more than 5 m are to be fitted on each side of the centreline when the breadth of the ships exceeds 20 m. Forward of $0.2L$ from the F.P. the spacing of side girders is not to be greater

than four longitudinal spaces. The side girders are to be equally spaced as far as practicable. The thickness of side girders and watertight side girders are to comply with the requirements of 2.6.4.1 of this Section. Where the double bottom tanks are interconnected with side tanks or cofferdams, the thickness of side girders is to be as required for deep tanks.

Side girders and watertight side girders are in general to be fitted with vertical stiffeners. Vertical stiffeners of side girders are to be spaced not more than 1.5 m apart, having the same thickness as that of side girder webs and generally, a breadth is to comply with the requirements of 2.6.5.2. Vertical stiffeners of watertight side girders are to be spaced not more than 0.9 m apart, the thickness is to be the same as that of watertight side girder web and generally, the breadth is to comply with the requirements of 2.6.5.2 and the section modulus W is to comply with the requirements of 2.6.6.2.

Where side girders and watertight side girders are fitted with horizontal stiffeners, the thickness of stiffeners is generally the same as that of side girder webs and the breadth is to comply with the requirements of 2.6.5.2. The section modulus W of horizontal stiffeners on watertight side girders is to comply with the requirements of 2.6.6.2.

2.6.11 Longitudinal framing — plate floors

2.6.11.1 In machinery spaces, plate floors are to be fitted at least at alternate frames, and are to be fitted at every frame under the main engine seating, boiler bearers, thrust seatings, transverse bulkheads and heels of pillars. Plate floors are to be fitted at alternate frames within the region forward of $0.2L$ from the F.P. Elsewhere, the spacing of the plate floors is not to exceed 3.6 m.

2.6.11.2 The thickness of plate floors for longitudinally framing is to be 10% greater than that required in 2.6.5.1 of this Section, but need not exceed 15 mm, and the thickness of watertight and oiltight floors is to be the same as required in 2.6.6.1 of this Section.

Vertical stiffeners are to be fitted at each longitudinal. The thickness of vertical stiffeners for floors is to be the same as that of the floors and the width of which is to comply with the requirements of 2.6.5.2. In addition, the scantlings of vertical stiffeners for watertight floors are to comply with the requirements of 2.6.6.2 of this Section. Vertical stiffeners are to be attached to the inner bottom and shell longitudinals by welding.

The ratio of thickness to depth of the floors is not to be less than $1/130$. Where the double bottom tanks are interconnected with side tanks or cofferdams, the thickness of watertight floors and the stiffeners are to be as required for deep tanks.

2.6.12 Longitudinal framing — bottom longitudinals

2.6.12.1 The spacing of bottom longitudinals is not to be greater than 1 m.

2.6.12.2 The section modulus W of bottom longitudinals is not to be less than that obtained from the following formula:

$$W = \frac{8.5f}{1.73 - F_b} (d + h_1) s l^2 K \text{ cm}^3$$

where: s — spacing of longitudinals, in m;

l — span of longitudinal, in m, but not less than 1.5 m;

d — draught, in m;

f — factor, taken as 0.52 when intermediate vertical struts are fitted, or 1.0 when no intermediate vertical strut is fitted;

F_b — reduction factor, see 2.2.5.6 of this Chapter;

h_1 — see 2.3.1.2 of this Chapter;

K — material factor.

Where the spacing of plate floors is greater than 2.5 m, vertical struts connecting the bottom longitudinals and inner bottom longitudinals may be fitted at the midpoint of the spacing, and the cross sectional area A of the vertical struts is not to be less than the following:

$$A = 23.8 + 0.04W \text{ cm}^2 \text{ for } W > 85 \text{ cm}^3$$

$$A = 0.32W \text{ cm}^2 \text{ for } W \leq 85 \text{ cm}^3$$

where: W — section modulus of longitudinals, in cm^3 .

2.6.12.3 The section modulus of inner bottom longitudinals is to be equal to 85% of that of the bottom longitudinals. In boiler rooms, the thickness of the longitudinals, struts and brackets is to be increased by 2 mm.

2.6.12.4 Where longitudinals pass through non-watertight floors, they are to be welded to the floors and the vertical stiffeners on the floors in way. Where longitudinals are cut in way of watertight floors, they are to be bracketed to the watertight floors. The scantlings of the brackets are to comply with the requirements of 1.2.6 of this PART. Where the length of the ship exceeds 200 m or higher tensile steel is used, the bottom longitudinals are to be continuous in way of watertight floors, or alternative arrangements may be considered.

2.6.13 Longitudinal framing — inner bottom plating and margin plate

2.6.13.1 The thickness of the inner bottom plating is to comply with the requirements of 2.6.9 of this Section. But for the calculation of the thickness of the inner bottom plating within $0.4L$ amidships, the s in the formula is to be taken as the spacing of longitudinals, and the value considered may be reduced by 1 mm.

2.6.13.2 The thickness of the margin plate is to comply with the requirements in 2.6.13.1 of this Section and in addition, is to be increased in accordance with the requirements of 2.6.9.3 of this Section.

2.6.13.3 The margin plate is to be provided with brackets at every frame, extending to the adjacent

longitudinal, as shown in Figure 2.6.13.3. The edges of the brackets are to be strengthened, and the thickness of the brackets is to be the same as that of floors.

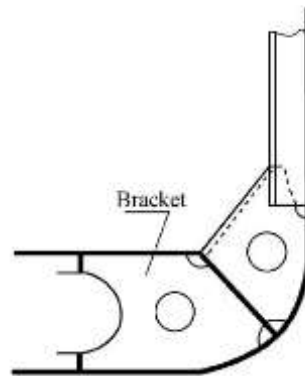


Figure 2.6.13.3

2.6.14 Reinforcement for using fork lift trucks in cargo holds

2.6.14.1 Where fork lift trucks are used for handling cargo in holds, the inner bottom plating and framing are to comply with the relevant requirements of Section 21 of this Chapter for vehicle decks.

2.6.15 Tank side brackets

2.6.15.1 Tank side brackets are to be fitted at every frame and their thickness is to be the same as that of plate floors. Circular lightening holes may be cut in the tank side brackets and the distance from any point of hole edges to the side of brackets is not to be less than $\frac{1}{3}$ breadth of the bracket.

2.6.15.2 Tank side brackets are to be flanged or provided with a face plate on the free edge, and the breadth of the flange or face plate is generally to be 10 times the thickness of the bracket.

2.6.15.3 The standard depth and breadth of tank side brackets are to be as follows:

The depth of tank side brackets connecting secondary members is to be equal to 10% of the distance between the inner bottom and nearest deck or 2.2 times the depth of the web of frames, whichever is the greater. The depth of tank side brackets connecting primary members is to be equal to 1.65 times the depth of the web of web frames. The breadth of tank side brackets is to be equal to their depth. The breadth and depth of tank side brackets are to be measured in accordance with Figure 2.6.15.3. Where the inner bottom margin plate of the double bottom is horizontal, vertical stiffeners are to be fitted to the floors under the toes of the brackets (as shown in Figure 2.6.15.3). The requirements for the stiffeners are to be the same as required in 2.6.5.2 of this Section.

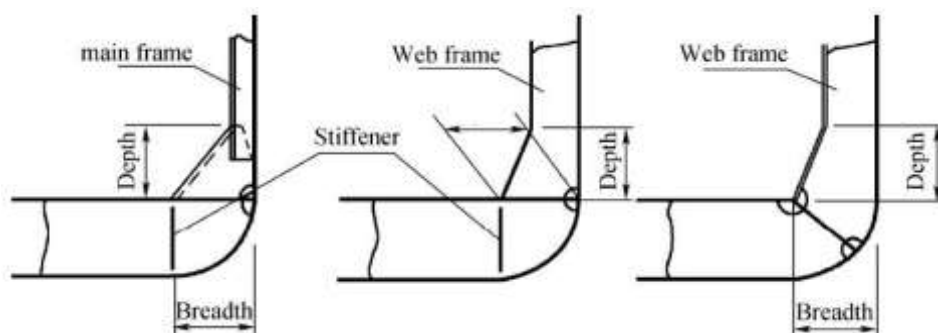


Figure 2.6.15.3

2.6.15.4 Where lap joint is adopted for the connection of tank side brackets to frames, the length of overlap is to comply with the requirements of 2.5.5.3 of this Chapter.

2.6.15.5 Where bottom and sides of the ship are framed longitudinally and no bilge longitudinals are fitted, the transverse strength members or corresponding bilge brackets in way are to have a

2.6.15.6 spacing S not exceeding:

$$S = 8 \times 10^6 \frac{t^2}{Dr} \sqrt{\frac{t}{r}} \quad \text{mm}$$

where: t — thickness of bilge plating, in mm;

D — moulded depth, in m;

r — radius of the bilge, in mm.

Furthermore, a suitable number of intermediate bilge brackets connected to the longitudinals situated at the upper and lower turns of the bilge are to be fitted between the plate floors.

SECTION 7-SIDE FRAMING

2.7.1 General requirements

2.7.1.1 The maximum spacing of frames or side longitudinals is not to be greater than 1.0 m.

2.7.2 Frames

2.7.2.1 The section modulus W of main frames (except those in fore and after peaks) is not to be less than that obtained from the following formula:

$$W = c c_1 s d l^2 K \quad \text{cm}^3$$

where: s — spacing of frames, in m;

d — draught, in m;

K cm³

l — span of frames, but in no case is it to be taken as less than D (D being moulded depth), in m. For frames between collision bulkhead and 0.2 L from F.P., it is to be the greatest frame span of the similar structural arrangement in that region:

$$c = \frac{2 + \frac{0.65d}{D}}{1.45 - \frac{\sqrt{D}}{l}}$$

c_1 — coefficient: $c_1 = 1.05$ for $L < 90$ m; $c_1 = 1.00$ for $L \geq 90$ m; K — material factor.

2.7.2.2 Corrections to the section modulus of main frames:

- (1) Where the depth of tank side brackets is less than that required in 2.5.5.1 or 2.6.15.3 of this Chapter, the section modulus of main frames is to be increased by 2.7% of the value required in 2.7.2.1 of this Section for each reduced 100 mm.
- (2) Where the arm length of the brackets connecting main frames to beams or deck longitudinals at side is greater than that required in 1.2.6.7 of this PART, the section modulus of main frames may be decreased by 1.3% of the value required in 2.7.2.1 of this Section for each increased 100 mm of difference.

2.7.2.3 Where side stringers are uniformly fitted in compliance with the requirements of 2.7.3.1 of this Section, the section modulus of main frames may be reduced in accordance with the following:

- (1) Where one stringer is fitted, the section modulus of main frames may be 1/2 of the value required in 2.7.2.1 or 2.7.2.2 of this Section.
- (2) Where two stringers are fitted, the section modulus of main frames may be 2/7 of the value required in 2.7.2.1 or 2.7.2.2 of this Section.
- (3) Where three stringers are fitted, the section modulus of main frames may be 1/5 of the value required in 2.7.2.1 or 2.7.2.2 of this Section.

2.7.2.4 The section modulus of the main frames under hatch end beams is not to be less than 1.67 times that of normal main frames as required in this Section.

2.7.2.5 In midship machinery spaces where web frames are not fitted in accordance with 2.7.4.2 of this Section, the section modulus of main frames in the machinery spaces is to be 50% greater than that normally required.

2.7.2.6 The scantlings of main frames are in no case to be less than those of 'tween decks above, and the main frame section modulus is not to be less than 20 cm³.

2.7.2.7 The moment of inertia I of main frames is not to be less than that obtained from the following formula:

$$I = 3.2Wl/K \text{ cm}^4$$

where: W — section modulus of main frames as required in this Section, in cm³;

l — span of frames, in m, as required in 2.7.2.1 of this Section where fitted with no side stringer, or being the vertical distance measured from the upper edge of floor or top of inner bottom to the side stringer or between side stringers or from the side stringer to the lowest deck at side where fitted with side stringers;

K — material factor.

2.7.2.8 The frames in fore and after peaks are to comply with the following requirements:

- (1) The section modulus W and the moment of inertia I of frames below the lowest deck in fore and after peaks are to be respectively not less than the values obtained from the following formulae:

$$W = 4.6sdDK \text{ cm}^3$$

$$I = 3.5Wl/K \text{ cm}^4$$

where: s — spacing of frames, in m;

d — draught, in m;

D — moulded depth, in m;

L — span of frames, in m, being the vertical distance measured from the upper edge of floor to the side stringer (perforated flat), or distance between side stringers (perforated flats) or from the side stringer (perforated flat) to the lowest deck;

K — material factor.

- (2) Where the lowest deck in the fore peak is below 1.0 m above the full-load waterline, the 'tween deck frames fitted from the lowest deck up to 1.0 m above the full-load waterline are also to comply with the requirements of (1) above.
- (3) Other 'tween deck frames in the fore peak are also to comply with the requirements of 2.7.2.9 of this Section.

2.7.2.9 The section modulus W of the frames in 'tween decks and superstructures is not to be less than that obtained from the following formula:

$$W = CC_1 s d l \sqrt{D} K \text{ cm}^3$$

where:

s — spacing of frames, in m;

d — draught, in m;

l — span of frame, in m.

For frames in 'tween deck space where the actual span is less than 2.6 m,

$l = 2.6$ m is to be taken and for those in superstructures where the actual span is less than 2.3 m,

$l = 2.3$ m is to be taken;

D — moulded depth, in m;

$$C = 0.7 + 4 \frac{d}{D};$$

C — coefficient, to be taken as

C_1 — coefficient, to be determined by the position of frame:

$C_1 = 1.0$ for those in the first 'tween deck below the upper deck;

$C_1 = 1.1$ for those in the second 'tween deck;

$C_1 = 1.45$ for those in the third and lower 'tween decks;

$C_1 = 0.90$ for those in forecastle; $C_1 = 0.80$ for those in bridge and poop;

K — material factor.

2.7.2.10 The section modulus of the frames under hatch end beams in 'tween deck spaces is not to be less than 1.67 times that of normal 'tween deck frames, as required in this Section.

2.7.2.11 In midship machinery spaces where web frames are not fitted in accordance with 2.7.4.2 of this Section, the section modulus of the 'tween deck frames under the lowest deck above the load waterline is to be 50% greater than that normally required.

2.7.2.12 Where the length of the forecastle or poop exceeds 0.25L, the scantlings of the two frames fitted at the after end of the forecastle or at the fore end of the poop are to be calculated by the formula used for 'tween deck frames located below the upper deck in way of the forecastle or poop.

2.7.2.13 The scantlings of four frames fitted at each end of the bridge are to be calculated by the formula used for 'tween deck frames located below the upper deck in way of the bridge.

2.7.2.14 The end connections of frames are to comply with the following:

- (1) The scantlings of brackets connecting beams to upper ends of frames are to comply with 1.2.6 of this PART. Where decks are framed longitudinally, the brackets at the upper end of frames are to be extended to the nearest deck longitudinal and welded to it.
- (2) The tank side brackets at the lower ends of main frames are to comply with the relevant requirements in Sections 5 and 6 of this Chapter.
- (3) Where 'tween deck frames terminate at lower decks, their lower ends are to be bracketed. The scantlings of the brackets are to be the same as those at the upper end of 'tween deck frames. Where the 'tween deck frames and the frames thereunder are directly attached to the lower deck by welding, the lower end of the 'tween deck frames may not be bracketed.

2.7.3 Side stringers

2.7.3.1 Where side stringers are fitted to support the main frames and 'tween deck frames, the section modulus W and the moment of inertia I of the side stringers are not to be less than those obtained from the following formulae respectively:

$$W = 7.8hbI^2K \text{ cm}^3$$

$$I = 2.5WI/K \text{ cm}^4$$

where: b — width of areas supported by the side stringers, in m;

h — vertical distance, in m, measured from the mid-span of side stringer to upper deck at side;

I — span of side stringers, in m;

K — material factor.

2.7.3.2 Brackets are to be fitted at the connection between side stringers and transverse bulkheads, and the requirements of 1.2.7 of this PART are to be complied with. Side stringers and web frames are to be so connected that an adequate continuity of the face plate or flange of side stringers is kept.

2.7.3.3 In transversely framed machinery spaces, side stringers are to be fitted to support main frames where the main frame span exceeds 6 m and their section modulus and moment of inertia are to comply with 2.7.3.1 of this Section and their web depth is not to be less than 2.5 times that of main frames.

2.7.3.4 In transversely framed machinery spaces, an arrangement of intercostal side stringers spaced generally 2.5 m apart may be accepted as an alternative to the side stringers specified in

2.7.3.3 of this Section and their web depth is to be the same as that of main frames, their web thickness t and sectional area A are to be respectively not less than those obtained from the following formulae:

$$t = 0.023L + 6 \text{ mm}$$

$$A = (0.14L + 1)K \text{ cm}^2$$

where: L — length of ship, in m, to be taken as not greater than 215 m in calculation;
 K — material factor.

2.7.4 Transverse framing - web frames

2.7.4.1 The scantlings of web frames supporting side stringers are to be determined by direct calculation based on the assumptions that their both ends are rigidly fixed and that they are subject to concentrated loadings transmitted by side stringers (the considered pressure head being the distance from the mid-span of side stringers to upper deck at side, in m), with the permissible bending stress being taken as $93.2/K$, in N/mm^2 and the allowable shear stress as $83.4/K$, in N/mm^2 .

2.7.4.2 Where machinery spaces are situated aft and the ship's sides are transversely framed, web frames are to be fitted and spaced not more than five frame spaces apart in the machinery spaces, extending from the inner bottom to the upper deck.

2.7.4.3 In the areas of transversely framed machinery spaces, the scantlings of web frames supporting side stringers are to be determined in accordance with 2.7.4.1 of this Section.

2.7.4.4 In the areas of transversely framed machinery spaces, the section modulus W of web frames not supporting side stringers is not to be less than that obtained from the following formulas:

$$W = 5Shl^2K \quad \text{cm}^3 \quad \text{for spaces below the lowest deck}$$

$$W = 3.5Sdl\sqrt{D}K \quad \text{cm}^3 \quad \text{for 'tween decks}$$

where: S — spacing of web frames, in m;

h — vertical distance, in m, measured from the mid-span of web frame to upper deck at side;

l — span of web frame, in m;

d — draught, in m;

D — moulded depth, in m;

K — material factor.

2.7.4.5 In the areas of transversely framed machinery spaces, the web depth of web frames is not to be less than 2.5 times the depth of adjacent frames.

2.7.4.6 The end connections of web frames for transverse framing are to comply with the relevant provisions in 2.6.15 and 2.8.7.9 of this Chapter.

2.7.5 Side longitudinals

2.7.5.1 The section modulus W of side longitudinals below the upper deck (including bilge longitudinals) is not to be less than that obtained from the following formula:

$$W = \frac{8.5}{f} h s l^2 K \quad \text{cm}^3$$

where: s — spacing of longitudinals, in m;

l — span of longitudinals, in m;

f — factor, to be taken in accordance with following two formulae, and to be taken as not greater than 1.077:

$$f = 1.73 - F_d \frac{Z - Z_n}{D - Z_n} \quad \text{for } Z \geq Z_n$$

$$f = 1.73 - F_b \frac{Z_n - Z}{Z_n} \quad \text{for } < Z_n$$

h — design pressure head, to be taken from the following formula:

$$h = 0.26C + d - \frac{Z}{D}(0.06C + d)$$

Z_n — the height of horizontal neutral axis, from base line, of hull cross section, in m;

D — moulded depth, in m;

d — draft, in m;

C — coefficient, see 2.2.3.1 of this Chapter;

F_b, F_d — reduction factors, see 2.2.5.6 of this Chapter; Z — height of longitudinals from base line, in m; K — material factor.

2.7.5.2 Within the region between 0.2L from the F.P. and the forepeak bulkhead, the section modulus of side longitudinals below the upper deck is to be in accordance with 2.7.5.1 of this Section and also in accordance with 2.7.5.4 of this Section.

2.7.5.3 For machinery spaces situated aft, the section modulus of side longitudinals in the areas of the machinery spaces is to be in accordance with 2.7.5.1 of this Section and in addition, not less than 0.8 times that obtained from the formula in 2.7.5.5.

2.7.5.4 In the forepeak, the section modulus W of side longitudinals is to be taken as not less than that obtained from the following formula:

$$W = 7.5 s h l^2 K \text{ cm}^3$$

where: s — spacing of longitudinals, in m;

h — vertical distance, in m, measured from the longitudinal to 3 m above the minimum bow height required by the load line, not less than the vertical distance from the longitudinal to upper deck at side;

l — span of longitudinals, in m, but taken as not less than 1.5 m;

K — material factor.

2.7.5.5 In the aft peak, the section modulus W of side longitudinals is to be taken as not less than that

obtained from the following formula:

$$W = 8.5s^2(h + 0.167D)K \text{ cm}^3$$

where: s — spacing of longitudinals, in m;

l — span of longitudinals, in m, but taken as not less than 1.5 m;

h — vertical distance from the longitudinal to upper deck at side, in m, but not to be less than 3 m;

D — moulded depth, in m, but taken as not greater than 20 m;

K — material factor.

2.7.5.6 The section modulus of side longitudinals (including bilge longitudinals) need not be greater than that of bottom longitudinals with the same spacing.

2.7.5.7 The side longitudinals are to penetrate web frames and the intersections of longitudinal webs and frame webs are to be welded. Where a side longitudinal is cut in way of a transverse bulkhead, brackets are to be fitted at the connection between the longitudinal and the bulkhead, and the brackets are to comply with the relevant provisions in 1.2.6 of this PART.

2.7.6 Longitudinal framing — web frames

2.7.6.1 Where the side is framed longitudinally, web frames supporting side stringers are to be fitted in line with plate floors. In general, the spacing of web frames is not to be greater than 3.6 m for ships of 100 m in length or less, and not greater than $0.006L + 3.0$ m (L being length of ship) for ships more than 100 m in length. In the forepeak and aft peak, the spacing of web frames is not to be greater than 2.5 m for ships of 100 m in length or less, and not greater than 3.5 m for ships of 300 m or over in length. The intermediate values are to be obtained by interpolation.

2.7.6.2 Other than in machinery spaces and forepeak and aft peak, the section modulus W of web frames is not to be less than that obtained from the following formula:

$$W = 10Shl^2K \text{ cm}^3$$

where: S — spacing of web frames, in m;

h — vertical distance, in m, measured from the mid-span of the web frame to upper deck at side;

l — span of web frame, in m;

K — material factor.

2.7.6.3 In longitudinally framed machinery spaces, the section modulus W of web frames is not to be less than that obtained from the following formula:

$$W = 10Shl^2K \text{ cm}^3 \quad \text{below the lowest deck}$$

$$W = 4.4Sdl\sqrt{D}K \text{ cm}^3 \quad \text{in 'tween decks}$$

where: S — spacing of web frames, in m;

h — vertical distance, in m, measured from the mid-span of the web frame to upper deck at side;

l — span of web frame, in m;

- d — draught, in m;
 D — moulded depth, in m;
 K — material factor.

The web depth of web frames is not to be less than 2.5 times that of the side longitudinal supported by it.

2.7.6.4 In the longitudinally framed forepeak, the section modulus W and the moment of inertia I of web frames are respectively not to be less than those obtained from the following formulae:

$$W = 14Shl^2K \text{ cm}^3$$

$$I = 2.5WI/K \text{ cm}^4$$

where: S — spacing of web frames, in m;

h — vertical distance, in m, measured from the mid-span of the web frame to tank top or half of the vertical distance from the mid-span of the web frame to the top of overflow, whichever is the greater;

l — span of web frame, in m;

K — material factor.

Where struts are fitted, the web frames and struts are to comply with the relevant provisions of Section 5 of Chapter 6 of this PART.

2.7.6.5 In the longitudinally framed aft peak, the section modulus W is not to be less than that obtained from the following formula:

$$W = 10Shl^2K \text{ cm}^3$$

where: S — spacing of web frames, in m;

h — vertical distance, in m, measured from the mid-span of the web frame to upper deck at side;

l — span of web frame, in m;

K — material factor.

2.7.6.6 The end connections of web frames for longitudinal framing are to comply with the relevant provisions in Sections 6 and 8 of this Chapter and Chapter 5 of this PART.

SECTION 8 - DECK FRAMING

2.8.1 General requirements

2.8.1.1 The design head h of decks is to be determined according to Table 2.8.1.1, and the corresponding design load p is to be calculated by the following formula:

$$p = \frac{9.81h}{\gamma} \quad \text{kPa}$$

where: h — design head, in m, see Table 2.8.1.1 of this Section;

γ — stowage rate, in m³/t, taken as the standard rate of 1.39 m³/t.

For decks in deep tanks, the relevant requirements in Section 13 of this Chapter are also to be complied with, and the corresponding design load P is to be calculated by the following formula:

$$p = 9.81\rho h \text{ kPa}$$

where: h — design head, in m, see Section 13 of this Chapter;

ρ — density of liquid, in t/m^3 , to be taken not less than 1.025 t/m^3 .

Table 2.8.1.1-Design Heads of Decks

Name and Location of Deck	Design Head, h (m)	Permissible Cargo Load (kPa)
Weather Decks (minimum sizes of structural members):		
Forward of 0.075L from F.P.	Primary members: $h_0 + 3$; Secondary members: $1.5h_0$	8.5
Between 0.075L and 0.15L from F.P.	Primary members: $h_0 + 2$; Secondary members: $1.25h_0$	8.5
Aft of 0.15L from F.P.	h_0	8.5
Weather Decks (specified cargo load):		
Forward of 0.075L from F.P.	$0.49p + h_0 - 1.2$	$p (> 8.5)$
Between 0.075L and 0.15L from F.P.	$0.37p + h_0 - 1.2$	$p (> 8.6)$
Aft of 0.15L from F.P.	$0.14p + h_0 - 1.2$	$p (> 8.7)$
Cargo Decks (not exposed to weather)	$0.14p$, but not to be less than mean height H (in m) of 'tween decks	Max (p , $7.06H$)
Accommodation Decks	1.2	—
Decks for Stores	2	—
Decks for Engine Room Platform, Workshop and Stores	2.6	—
Superstructure Decks:		
1st tier	0.90, increased for exposed portion ($h_0 - 1.2$)	
2nd tier	0.60, increased for exposed portion ($h_0 - 1.2$)	—
3rd tier and above	0.45, increased for exposed portion ($h_0 - 1.2$)	—
Forecastle deck (forward of 0.2L from F.P.)	Same as weather decks in corresponding locations	—

Notes:

- ① h_0 in the Table is not to be less than that obtained from the following formula, but it is neither to be less than 1.2 m, nor greater than 1.5 m:

$$h_0 = 1.20 + \frac{2}{1000} \left(\frac{100 + 3L}{D - d} - 150 \right) \text{ m}$$

where: L — length of ship, in m; D — moulded depth, in m; d — draught, in m.

- ② For ships less than 90 m in length, the design head of primary members within the areas of fore and aft ends of ships may be appropriately reduced, but not less than that of secondary members at the same location.
- ③ The superstructure deck is defined in 2.17.1.6 of this Chapter.

2.8.2 Deck beams

2.8.2.1 The section modulus W of deck beams is not to be less than that obtained from the following formula:

$$W = (C_1 C_2 D d + C_3 s h^2) K \text{ cm}^3$$

where: C_1 — coefficient, dependent on the number of decks (including bridge, poop decks and engine room platform) at the position of the beam under consideration: $C_1 = 2.0$ for 1st tier, $C_1 = 1.33$ for 2nd tier, $C_1 = 1.05$ for 3rd tier, $C_1 = 0.93$ for 4th tier and above, $C_1 = 1.33$ for forecastle deck;

C_2, C_3 — coefficients, see Table 2.8.2.1;

D — moulded depth, in m;

- d — draught, in m;
 s — spacing of beams, in m;
 h — design head, in m, see 2.8.1.1 of this Section;
 l — span of beam, in m, to be taken not less than 2 m;
 K — material factor.

Table 2.8.2.1-Coefficients C_2 and C_3

Location of deck	C2	C3
Weather/strength deck or exposed forecastle deck forward of 0.075L from F.P.	0.8	0.54B
Weather/strength deck or exposed forecastle deck between 0.075L and 0.15L from F.P.	0.8	Beams connected to ship side: 0.36B Beams elsewhere: 0.33B
Weather/strength deck or exposed forecastle deck aft of 0.15L from F.P.	0.54	
Short bridge and poop deck where exposed to the weather	0.14	
Cargo decks and other decks (engine room, forepeak tank and aftpeak tank platforms)	0.4	4
Accommodation strength decks or lower decks	0.52	4

Note: B in the Table is the breadth of ship, in m.

2.8.2.2 The section modulus W of weather deck beams need not be greater than that obtained from the following formula:

$$W = Bshl^2K \text{ cm}^3$$

where: B — breadth of ship, in m, to be taken as not greater than 21.5 m;

s, h, l — see 2.8.2.1 of this Section;

K — material factor.

2.8.2.3 The web depth of deck beams is not to be less than 60 mm.

2.8.2.4 The connections between beams and frames are to comply with the requirements in 1.2.6 of this PART.

2.8.2.5 Beams are to pass through deck girders, and they are to be connected to the girder web by welding. Where beams are to be cut in way of the web of hatch side girders or deck girders, the beams are to be bracketed to the girders and the scantlings of brackets are to comply with the provisions in 1.2.6 of this PART. The brackets are to be extended to the face plate of deck girders.

2.8.3 Transverse framing — deck girders

2.8.3.1 For weather strength deck forward of 0.075L from F.P., the spacing of deck girders supporting beams is not to be greater than 3.6 m. For the upper and lower decks after the aft peak bulkhead, the spacing of deck girders supporting beams is not to be greater than 3 m.

2.8.3.2 The section modulus W of deck girders supporting beams is not to be less than that obtained from the following formula:

$$W = 4.75bh^2K \text{ cm}^3$$

where: b — mean width, in m, of deck area supported by deck girders;

h — design head of deck, in m, see 2.8.1.1 of this Section;

l — span of deck girder, in m;

K — material factor.

2.8.3.3 Where deck girders arranged to support beams are subject to a concentrated load, their section modulus W is to be not less than that obtained from the following formula:

$$W = 0.102cPlK \text{ cm}^3$$

where: P — concentrated load, in kN;

l — span of deck girder, in m;

c — coefficient, to be obtained from Table 2.8.3.3 where a is the distance, in m, between the application point of concentrated load P and the farther one of two supports of the girder;

K — material factor.

Table 2.8.3.3-Coefficient c

a/l	0.94	0.9	0.85	0.8	0.75	0.7	0.6	0.5
c	1.44	3.36	5.68	7.36	8.64	9.2	9.6	10

2.8.3.4 Where deck girders arranged to support beams are subject to two or three point loads, their section modulus W is to be determined by direct calculations assuming fixed ends and using an allowable bending stress of $124/K$, in N/mm^2 .

2.8.3.5 The section moment of inertia I of deck girders is not to be less than that obtained from the following formula:

$$I = 2Wl/K \text{ cm}^4$$

where: W — section modulus of deck girders required in this Section, in cm^3 ;

l — span of deck girder, in m;

K — material factor.

2.8.3.6 The web depth of deck girders is not to be less than 1.6 times the depth of cut-outs for the passage of beams. The cut-outs in deck girders are to be designed to minimize the creation of stress concentration on the web. The web thickness of deck girders is not to be less than 1% of the web depth plus 4 mm.

2.8.3.7 Holes cut for the passage of pipes or cables in the web of deck girders are to have a depth not greater than 25% of that of the web and a width not exceeding 60% of the spacing of beams or the web depth, whichever is the greater, otherwise compensation is required. Normally the compensation is achieved by fitting doublers, spigots or insert plates for strengthening, and the cross-sectional area of such strengthening pieces is to be not less than that lost from the web due to openings. The strength level of the material of strengthening pieces is not to be lower than that of the web material. The edges of holes are not to be less than 40% of the web depth from the face plate of girders. The edges of the holes are to be smooth and well rounded. The holes are not to be concentrated in the adjacent frame spaces. No holes are to be cut on the girder web within 200 mm from the toe of girder brackets.

2.8.3.8 The ends of deck girders are to be connected to transverse bulkheads in accordance with the relevant provisions in 1.2.7 of this PART. For deck girders contributing to the longitudinal strength, special attention is to be paid to the longitudinal structural continuity at transverse bulkheads.

2.8.4 Transverse framing — deck transverses

2.8.4.1 For deck transverses supporting deck girders, the scantlings are to be determined by direct calculations assuming fixed ends and the function for sustaining concentrated loads transmitted by deck girders and using an allowable bending stress of $124/K$, in N/mm^2 .

2.8.4.2 The section moment of inertia I of deck transverses supporting deck girders is not to be less than that obtained from the following formula:

$$I = 2Wl^3/K \text{ cm}^4$$

where: W — section modulus of deck transverses, in cm^3 , obtained according to 2.8.4.1 of this Section;

l — span of deck transverse, in m;

K — material factor.

2.8.4.3 The thickness and cutouts of the web of deck transverses supporting deck girders are to comply with the provisions in 2.8.7.7 and 2.8.7.8 of this Section.

2.8.4.4 The connections between deck transverses supporting deck girders and frames or web frames or longitudinal bulkheads are to comply with the provisions of 2.8.7.9 of this Section.

2.8.5 Deck longitudinals

2.8.5.1 The section modulus W of weather/strength deck longitudinals is not to be less than the greater obtained from the following formulae:

$$W = c_1 s h l^2 K \text{ cm}^3$$

$$W = (c_2 s h + c_3 s l^2 L^2 \times 10^{-4}) K \text{ cm}^3$$

where:

s — spacing of longitudinals, in m;

h — design head of deck, in m, to be determined according to 2.8.1.1 of this Section, but outside the line of deck openings within $0.4L$ amidships:

$$h \geq \frac{22.6L}{1780 - L};$$

l — span of longitudinal, in m, to be taken as not less than 2 m;

c_1, c_2, c_3 — coefficients, to be determined according to Table 2.8.5.1;

L — length of ship, in m, L need not be taken as greater than 200 m;

K — material factor.

Table 2.8.5.1-Coefficients C_1, C_2, C_3

Item	Location of Deck Longitudinal	Region	C_1	C_2	C_3
1	Forward of $0.075L$ from F.P.		12.5	63.5	7.8

2	Between 0.075L ~ 0.15L from F.P.		12.5	57	7.2
3	At 0.15L from F.P.	Outside the line of openings	9	48.5	6.2
		Inside the line of openings	7.5	40	5.5
4	Between 0.15L ~ 0.3L from F.P.	Outside the line of openings	See note		
		Inside the line of openings	7.5	40	5.5
5	0.4L amidships	Outside the line of openings	10.5	—	—
		Inside the line of openings	7.5	40	5.5
6	Between 0.075L ~ 0.3L from A.P.	Outside the line of openings	See note		
		Inside the line of openings	7.5	40	5.5
7	Aft of 0.07L from A.P.		7.5	40	5.5

Note: The section modulus W of deck longitudinals in way of the region may be determined after tapering the section moduli of amidships and end deck longitudinals.

2.8.5.2 The section modulus W of cargo deck longitudinals (including longitudinals of decks/platforms within the engine room, fore and aft peaks) is not to be less than the following:

$$W = (2.5shl^2 + 0.6sL)K \text{ cm}^3 \text{ for } L \geq 90 \text{ m}$$

$$W = 5shl^2K \text{ cm}^3 \text{ for } L < 90 \text{ m}$$

where: s, h, l, L, K — see those in 2.8.5.1 of this Section.

2.8.5.3 The section modulus W of accommodation and superstructure deck longitudinals is not to be less than the following:

$$W = (2.5shl^2 + 0.52sL)K \text{ cm}^3 \text{ for } L \geq 90 \text{ m}$$

$$W = 4.4shl^2K \text{ cm}^3 \text{ for } L < 90 \text{ m}$$

where: s, h, l, L, K — see those in 2.8.5.1 of this Section.

2.8.5.4 The web depth of deck longitudinals is in no case to be less than 60 mm.

2.8.5.5 The deck longitudinals outside the line of deck openings are to pass through deck transverses and to be connected to the deck transverse webs by welding. Where the deck longitudinals are cut in way of the web plates of hatch end beams or deck transverses (only for those inside the line of deck openings or at the ship's ends), brackets are to be fitted at the connection between deck longitudinals and hatch end beams or deck transverses and the scantlings of the brackets are to comply with the relevant provisions in 1.2.6 of this PART. The brackets are to be extended to the face plate of hatch end beams or deck transverses along the web plates of hatch end beams or deck transverses.

2.8.5.6 Where deck longitudinals are cut in way of transverse bulkheads, brackets are to be fitted at the connection between deck longitudinals and transverse bulkheads and the scantlings of the brackets are to comply with the relevant provisions in 1.2.6 of this PART. Where the ship's length exceeds 200 m or higher tensile steel is adopted, the deck longitudinals outside the line of deck openings are to be continuous through the transverse bulkheads, but alternative arrangements maybe considered.

2.8.5.7 The deck longitudinals outside the line of deck openings are not to be terminated at the same transverse section and their ends are to be suitably shifted from one another. These ends are

to extend to the adjacent transverse members.

2.8.6 Longitudinal framing — deck girders

2.8.6.1 For deck girders supporting deck transverses, the scantlings are to be determined by direct calculations assuming fixed ends and the function for sustaining concentrated loads transmitted by deck transverses and using an allowable bending stress of $124/K$, in N/mm^2 .

2.8.6.2 The section moment of inertia I of deck girders supporting deck transverses is not to be less than that obtained from the following formula:

$$I = 2WL^3/K \text{ cm}^4$$

where: W — section modulus of deck girders, in cm^3 , obtained according to 2.8.6.1 of this Section;

l — span of deck girder, in m;

K — material factor.

2.8.6.3 The thickness and cutouts of the web of deck girders supporting deck transverses are to comply with the relevant provisions in 2.8.3.6 and 2.8.3.7 of this Section respectively.

2.8.6.4 The connections between deck girders supporting deck transverses and transverse bulkheads are to comply with the relevant provisions of 2.8.3.8 of this Section.

2.8.7 Longitudinal framing — deck transverses

2.8.7.1 Where the deck is framed longitudinally, deck transverses supporting the deck longitudinals are to be fitted in line with plate floors. In general, the spacing of deck transverses is not to be greater than 3.6 m for ships of 100 m in length or less and not greater than $0.006L + 3.0$ m (L being length of ship) for ships more than 100 m in length. In the forepeak and aft peak, the spacing of deck transverses is not to be greater than 2.5 m for ships of 100 m in length or less and not greater than 3.5 m for ships of 300 m or over in length. The intermediate values are to be obtained by interpolation.

2.8.7.2 In the machinery spaces and aft peak tank, deck transverses supporting deck longitudinals are to be fitted in frames spaces of web frames.

2.8.7.3 The section modulus W of deck transverses supporting deck longitudinals is not to be less than that obtained from the following formula:

$$W = 5Sh^2/K \text{ cm}^3$$

where: S — spacing of deck transverses, in m;

h — design head of deck, in m, to be determined according to 2.8.1.1 of this Section;

l — span of deck transverses, in m;

K — material factor.

2.8.7.4 The section modulus of deck transverses in single deck ships is to be 15% greater than that obtained from the formula in 2.8.7.3 of this Section.

2.8.7.5 Where the deck transverses supporting deck longitudinals are subject to concentrated loads, their increased section modulus may be determined by calculations in accordance with the requirements for deck girders in 2.8.3.3 or 2.8.3.4 of this Section.

2.8.7.6 The section moment of inertia I of deck transverses supporting deck longitudinals is not to be less than that obtained from the following formula:

$$I = 2Wl^3/K \text{ cm}^4$$

where: W — section modulus of deck transverses, in m^3 , as required in this Section;

l — span of deck transverses, in m;

K — material factor.

2.8.7.7 The web depth of deck transverses is not to be less than 1.6 times the depth of cut-outs for the passage of deck longitudinals. The cutouts in deck transverses are to be designed to minimize the creation of stress concentration on the web. The web thickness of deck transverses is not to be less than 1% of the web depth plus 4 mm.

2.8.7.8 Holes cut for the passage of pipes or cables in the web of deck transverses are to have a depth not greater than 25% of that of the web and a width not exceeding 60% of the spacing of deck longitudinals or the web depth, whichever is the greater, otherwise compensation is required. Normally the compensation is achieved by fitting doublers, spigots or insert plates for strengthening, and the cross-sectional area of such strengthening pieces is to be not less than that lost from the web due to openings. The strength level of the material of strengthening pieces is not to be lower than that of the web material. The edges of holes are not to be less than 40% of the web depth from the face plate of deck transverses. The edges of the holes are to be smooth and well rounded. The holes are not to be concentrated in the spacings of adjacent longitudinals. No holes are to be cut on the web of deck transverses within 200 mm from the bracket toe of deck transverses.

2.8.7.9 The ends of deck transverses are to be bracketed to frames or web frames or longitudinal bulkheads, and the scantlings of brackets are to comply with the relevant provisions in 1.2.7 of this PART. Where the connection between deck transverses and web frames or longitudinal bulkhead vertical webs is designed as an integral structure, a ring system is generally to be formed and connecting brackets are to have the form of an circular arc with a radius generally not less than the web depth of deck transverses or web frames or longitudinal bulkhead vertical webs, whichever is the smallest. The brackets are to be provided with a face plate to connect the face plate of deck transverses and that of web frames or longitudinal bulkhead vertical webs, and the scantlings of the face plate are to be the same as those of the face plate of deck transverses.

2.8.8 Deck hatch side girders

2.8.8.1 Where weather deck hatch side girders (including weather deck hatch side coamings) act as deck girders and are supported at both ends of the hatchway, their section modulus W and section moment of inertia I are not to be less than those obtained from the following formulae respectively:

$$W = 7hb l^2 K \text{ cm}^3$$

$$I = 2.6Wl/K \text{ cm}^4$$

where: h — design head of deck, in m, see 2.8.1.1 of this Section;

b — mean width, in m, of deck area supported by deck hatch side girders;

l — span of deck hatch side girder, in m;

K — material factor.

2.8.8.2 The section modulus W and section moment of inertia I of 'tween deck hatch side girders are not to be less than those obtained from the following formulae respectively:

$$W = 5.2hb l^2 K \text{ cm}^3$$

$$I = 2Wl/K \text{ cm}^4$$

where: h — design head of deck, in m, see 2.8.1.1 of this Section;

b — mean width, in m, of deck area supported by 'tween deck hatch side girders;

l — span of 'tween deck hatch side girder, in m;

K — material factor.

2.8.8.3 Where 'tween deck hatch side girders are subject to concentrated loads, the section modulus is to be increased to 1.1 times that obtained according to 2.8.3.3 or 2.8.3.4 of this Section.

2.8.8.4 The depth of the web of deck hatch side girders below deck is not to be less than that of the beam web to which it is connected.

2.8.8.5 The thickness of the web of deck hatch side girders is not to be less than 1% of its depth plus 4 mm. The thickness and structure of hatch coamings are to comply with the requirements of 2.20.3.2 of this Chapter.

2.8.8.6 In the calculation of the section modulus and section moment of inertia of deck hatch side girders (including hatch coamings), the upper edge of the horizontal face plate (excluding holes in the face plate) of hatch coamings may be included; or only the upper edge of the horizontal stiffener is to be included if no horizontal face plate is fitted.

2.8.8.7 A gradual transition in depth is to be made for the extension of deck hatch side girders.

2.8.8.8 Where the deck is framed longitudinally, deck hatch side girders are to be bracketed to deck transverses. Where the web depth of deck hatch side girders below deck is the same as that of deck transverses, the girders and transverses are to be directly connected. Where the spacing of deck transverses is greater than two frame spaces, an additional tripping bracket is to be fitted between the transverses. This tripping bracket is to extend to the face plate of the deck hatch side girder and to the adjacent deck longitudinals. The thickness of the bracket is to be the same as that of the web

plate of adjacent deck transverses, and the flange or face plate of the bracket is to comply with the provisions in 1.2.6.6 of this PART.

2.8.8.9 Where the deck is framed transversely, a bracket is to be fitted at the connection between each beam and deck hatch side girders. These brackets are to extend to the face plate of deck hatch side girders, and the scantlings of the brackets are to comply with the provisions in 1.2.6 of this PART.

2.8.9 Hatch end beams

2.8.9.1 Hatch end beams are to be fitted in accordance with the following requirements:

- (1) Where a pillar complying with the requirements of Section 10 of this Chapter is fitted at each corner of the hatchway (i.e. hatch end beams do not support hatch side girders), the section modulus of hatch end beams is to meet the requirements of 2.8.2.1 of this Section, but in this case, s in the formula is to be the actual width of deck area supported by hatch end beams.
- (2) Where hatch end beams support the full load of hatch side girders, pillars are fitted below the beams at the longitudinal centerline of deck and deck longitudinal girders or longitudinal bulkheads are also fitted at the longitudinal centerline, hatch end beams are to be continuous within the breadth of ship and their section modulus W and section moment of inertia I are not to be less than those obtained from the following formulae respectively:

$$W = 4.6chAK \text{ cm}^3$$

$$I = 3WI/K \text{ cm}^4$$

where: l — span of hatch end beams, in m;

K — material factor;

A — load area, in m^2 , to be determined according to the following conditions:

- ① Where the deck is framed longitudinally and the extension of hatch side girders supports one or more deck transverses, see Figure 2.8.9.1(1): $A = F1 + 2F3 + F4 + F5$
- ② Where the deck is framed longitudinally and the extension of hatch side girders does not support any deck transverse, see Figure 2.8.9.1(2): $A = F1 + F2 + F3$
- ③ Where the deck is framed transversely without additional girders, see Figure 2.8.9.1(3):

$$A = F1 + F4$$

- ④ Where the deck is framed transversely and with fitted with additional girders, see Figure 2.8.9.1(4): $A = F1 + F4$;

h — design head of deck, in m, see 2.8.1.1 of this Section;

c — coefficient, to be taken according to the distance a between the hatch side

girder and the longitudinal centreline: $c = 1.6$ for $a \geq l/2$ (l being span of hatch end beams), $c = 1.5$ for $a \leq l/3$, and c is to be obtained by interpolation for $l/3 < a < l/2$.

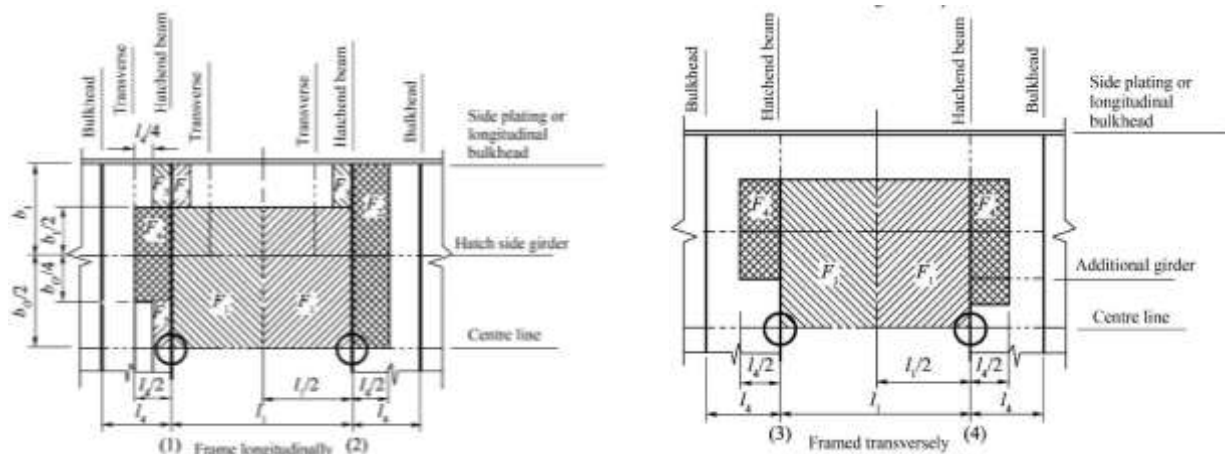


Figure 2.8.9.1

2.8.9.2 The connections between hatch end beams and frames or web frames or longitudinal bulkheads are to comply with the requirements of 2.8.7.9 of this Section.

SECTION 9 – CANTILEVERS

2.9.1 General requirements

2.9.1.1 Cantilevers covered by this Section are the deck transverse extending from ship side to the deck hatch side girders supported by them. The structural configuration of cantilevers and their supporting frames is as shown in Figure 2.9.1.1.

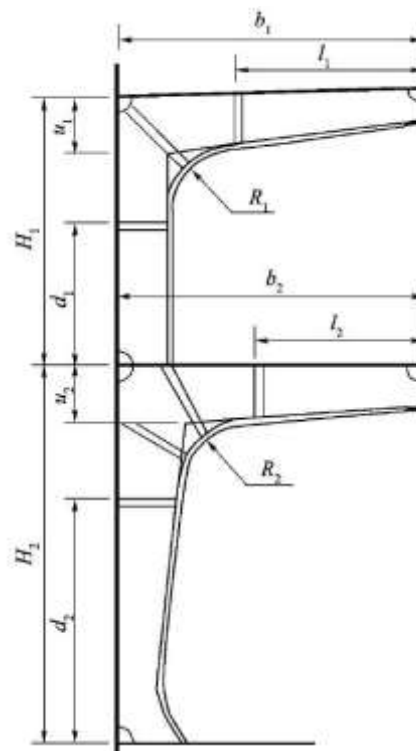


Figure 2.9.1.1

2.9.1.2 The considered sections of the cantilever and its supporting frame are to be the corresponding sections at the toe of the connecting bracket (i.e. at the tangential point of the arc of the bracket).

2.9.1.3 The requirements of this Section are applicable to ships having cantilevers approximately equally arranged, hatch side girders supported by cantilevers and uniform loading on decks and hatch covers.

2.9.2 Cantilevers

2.9.2.1 The section modulus W_i of the considered section of cantilevers is not to be less than the respective values given below:

(1) Where cantilevers are not supported by hatch side girders:

$$W_i = 30.6 S l_i (l_i h_1 + b_0 h_2) K \text{ cm}^3$$

where: S — load width of cantilever, in m;

l_i — span of cantilever, in m;

b_0 — width of hatch, in m;

h_1 — design head of deck outside the line of hatch openings, in m, see 2.8.1.1 of this Chapter;

h_2 — design head of deck or hatch cover inside the line of hatch openings, in m, see 2.8.1.1 or 2.20.2 of this Chapter;

K — material factor.

(2) Where both ends of hatch side girders are fitted with the hatch end beams complying with the requirements of 2.8.9 of this Chapter and cantilevers are partially supported by hatch side girders:

$$W_i = W_0 - G \text{ cm}^3$$

where: $W_0 = 30.6 S l_i (l_i h_1 + b_0 h_2) K \text{ cm}^3$

where: S, l_i, b_0, h_1, h_2 — see (1) above;

$$G = \frac{8 l_i}{(n+1) l_h} (W_h + W_p) \text{ cm}^3$$

where: W_h — section modulus of the hatch side girder derived from 2.8.8.1 or 2.8.8.2 of this Chapter, in cm^3 , and the span of cantilevers taken as the spacing of cantilevers;

W_p — section modulus of deck girders on the extension line of hatch side girders, in cm^3 , derived from 2.8.3 of this Chapter, and W_p is to be taken not greater than W_h ;

n — number of cantilevers between hatch end beams;

l_h — length of hatch, in m;

l_i — span of cantilevers, in m.

(3) Where both ends of hatch side girders are supported by transverse bulkheads and cantilevers are partially supported by hatch side girders:

$$W_i = \frac{n+1}{n} \left[0.5 \left(1 + \frac{1}{Q} \right) W_0 - QG - (1-Q)E \right] \text{ cm}^3$$

where: W_0, G, n — see (2) above;

$$Q = \frac{l_h}{l_b};$$

where:

l_h, l_b — See Figure 2.9.2.1(1) of this Section;

$$E = \frac{4}{n+1} (W_1 + W_2) \text{ in cm}^3:$$

in cm^3 for hatch end beams the midpoint of which is not supported by pillars, etc., or

$$E = \frac{4}{n+1} \left[(W_1 + W_2) + \frac{2 l_i}{b_0} (W_2 + W_3) \right]$$

in cm^3 , for hatch end beams the midpoint of which is supported by pillars or bulkheads;

where:

W_1 , W_2 and W_3 are section moduli of hatch end beams, in cm^3 , as shown in Figure 2.9.2.1(2), W_2 is to be taken as the lesser of the section moduli of hatch end beams at both sides of the line of hatch openings; l_i , b_0 — see Figure 2.9.2.1(1) of this Section.

And in addition, the section modulus W_i of the cantilever is not to be less than that obtained from (2) above.

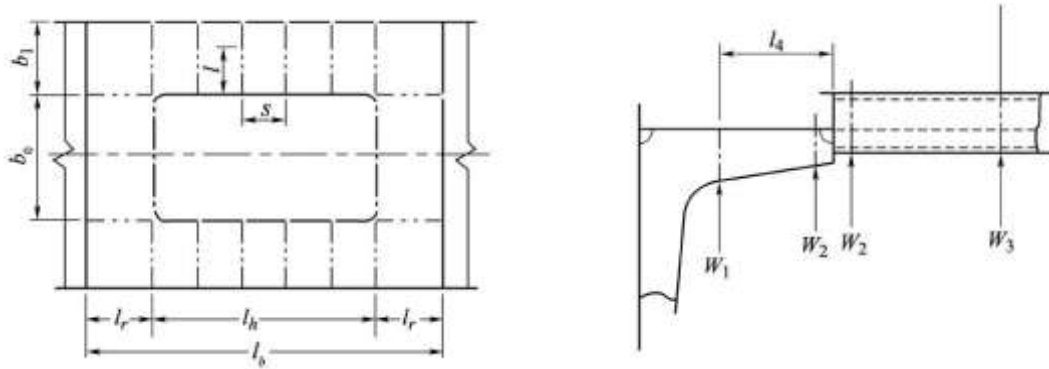


Figure 2.9.2.1(1) Figure 2.9.2.1(2)

- (4) Where loading is concentrated at hatch side girders and cantilevers are partially supported by hatch side girders:

$$W_i = W'_0 - \frac{3.5l_i}{S} W_h \quad \text{cm}^3$$

where: W'_0 — section modulus, in cm^3 , of the cantilever when subjected to concentrated loading and uniform loading, with no support from hatch side girders. In the calculation, the cantilever is to be assumed fixed at one end, and the allowable bending stress is to be taken as 115.2 N/mm^2 ;

l_i , S , W_h — see (1) and (2) above.

And in addition, the section modulus W_i of the cantilever is not to be less than those obtained from (2) and (3) above.

2.9.2.2 The moment of inertia I of the cantilever at the section under consideration is not to be less than that obtained from the following formula:

$$I = 9 W_i l_i / K_i \quad \text{cm}^4$$

where: W_i — section modulus of cantilevers, in cm^3 , derived from the formula in 2.9.2.1 of this Section;

l_i — span of cantilevers, in m;

K_i — material factor.

2.9.2.3 The net sectional area A_x of the cantilever web is not to be less than that obtained from the following formula:

$$A_x = 0.43 S \left(2h_i X + b_o h_2 + \frac{0.283}{S} P_c \right) \frac{W_i}{W_o} \quad \text{cm}^2$$

where: S , b_o , h_1 , h_2 — see 2.9.2.1(1) of this Section;

X — distance, in m, between the section of cantilever under consideration and the hatch side girder;

W_o — see 2.9.2.1(2) of this Section, in cm³;

W_i — section modulus of cantilevers, in cm³, as required in 2.9.2.1 of this Section;

P_c — concentrated loading, in kN, applied on the hatch side girder for calculation in accordance with 2.9.2.1(4) of this Section. $P_c = 0$, if no concentrated loading is applied.

2.9.3 Supporting frames

2.9.3.1 The section modulus W_{fi} at the considered section of supporting frames is not to be less than that obtained from the following formula:

$$W_{fi} = \frac{d_i}{H_i} \left[\frac{b_i}{l_i} W_i - W_{f(i-1)} \right] \quad \text{cm}^3$$

where: d_i , H_i , b_i , l_i — see Figure 2.9.1.1 of this Section;

$W_{f(i-1)}$ — section modulus of supporting frames of the cantilevers on the $i - 1$ tier deck, in cm³,
and $W_{f(i-1)} = 0$ for the upper deck;

W_i — section modulus of cantilevers, in cm³, as required in 2.9.2.1 of this Section;

i — tier sign of decks, $i = 1$ for upper deck, $i = 2$ for 2nd tier deck and so on.

2.9.3.2 The scantlings of the supporting frames of the lower deck are, in general, not to be less than those of the supporting frames of the 'tween deck above.

2.9.4 Structural requirements

2.9.4.1 Cantilevers and supporting frames are to be connected by brackets. The radius of the arc of the bracket is not to be less than u_i . The sectional area of the face plate and the web thickness of the bracket are not to be less than those of the larger one of connected members. Tripping brackets are to be fitted at the toes of the brackets (i.e. in way of the considered section of the cantilever and supporting frame), and an adequate number of stiffeners is to be fitted to the web connecting the bracket. See Figure 2.9.1.1.

2.9.4.2 Where the deck is framed longitudinally, cantilevers are to be provided with tripping brackets in accordance with the requirements of 1.2.5.4 of this PART; where the deck is framed transversely, the tripping brackets of cantilevers are to be generally spaced 3 m apart.

2.9.4.3 The minimum thickness of the web plate of cantilevers and supporting frames is not to be less than 1% of the web depth plus 4.5 mm. Where the web depth is greater than 700 mm, vertical stiffeners are to be fitted and spaced not greater than 1.5 times the web depth apart.

2.9.4.4 The web depth and the sectional area of face plates of cantilevers and supporting frames may be gradually tapered from the considered section to the ends, but the minimum web depth at ends is not to be less than 50% of the web depth at the considered section, and the sectional area of face plates at ends is not to be less than 60% of that at the considered section. Longitudinals passing through cantilevers and supporting frames are, in addition, to comply with the relevant requirements of 2.8.7.7 of this Chapter.

2.9.4.5 The effective area of the attached plating of cantilevers and supporting frames is to be calculated according to the requirements of 1.2.2.1 of this PART.

2.9.4.6 Where cantilevers and supporting frames consist of two or three combined members having a T-shaped cross section, they are to be regarded as a single cantilever, and the section modulus of such combined cantilevers is to be determined according to 2.9.2.1 of this Section, and the individual modulus of each cantilever is then determined by dividing this modulus by the actual number of cantilevers.

2.9.4.7 The supporting frames in holds are to be securely connected to the inner bottom by brackets. Plate floors or other stiffening arrangements are to be provided in the double bottom in line with cantilevers and supporting frames.

2.9.4.8 The web depth of hatch side girders below the deck is in general not to be less than that of the web plate at the end of cantilevers. Cantilevers and hatch side girders are to be securely connected with each other.

SECTION 10-PILLARS

2.10.1 Load supported by pillars

2.10.1.1 The load P supported by the pillar is to be calculated according to the following formula:

$$P = 7.06abh + P_0 \text{ kN}$$

where: a — length of deck area supported by the pillar, in m, as shown in Figure 2.10.1.1;

b — mean width of deck area supported by the pillar, in m, as shown in Figure 2.10.1.1;

h — design head of the deck supported by the pillar, in m, see 2.8.1.1 of this Chapter;

P_0 — load transmitted from the pillar above, in kN.

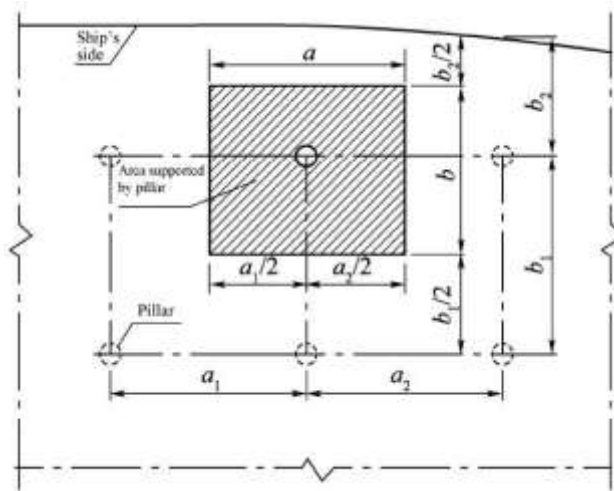


Figure 2.10.1.1

2.10.2 Cross-sectional area of pillars

2.10.2.1 The cross-section area A of pillars is not to be less than that obtained from the following formula:

$$A = \frac{KP}{12.26 - 5.10 \frac{l}{r\sqrt{K}}} \text{ cm}^2$$

where: P — see 2.10.1.1 of this Section;

l — the effective length of pillars, in m, to be taken as 0.8 times the whole length of pillars;

r — minimum radius of gyration of the cross section of pillars, in cm;

K — material factor, but it is not to be taken less than 0.72.

2.10.3 Minimum wall thickness of pillars

2.10.3.1 The wall thickness t of tubular pillars is not to be less than the following:

$$t = \frac{P}{0.392d_p - 4.9l} \text{ mm}$$

$$t = \frac{d_p}{40} \text{ mm}$$

where: P — see 2.10.1.1 of this Section;

l — see 2.10.2.1 of this Section;

d_p — mean diameter of tubular pillars, in mm.

The minimum wall thickness of tubular pillars is to be 5 mm for ship's length $L < 60$ m; 6 mm for $60 \text{ m} \leq L < 90$ m and 7 mm for $L \geq 90$ m.

2.10.3.2 The built or rolled-section pillars are to comply with the following requirements:

- (1) The wall thickness t of hollow rectangular pillars or the web thickness t of I-shaped or channel-section pillars is not to be less than the lesser of the following:

$$t = \frac{br}{60l} \quad \text{mm}$$

$$t = \frac{b}{55} \quad \text{mm}$$

where: b — length of hollow rectangular pillars or web depth of I-shaped or channel-section pillars, in mm;

l, r — see 2.10.2.1 of this Section.

The minimum wall thickness of hollow rectangular pillars or the minimum web thickness of I-shaped or channel-section pillars is not to be less than 5 mm for ship's length $L < 60$ m, 6 mm for $60 \text{ m} \leq L < 90$ m and 7 mm for $L \geq 90$ m.

- (2) The side thickness t of angular pillars and the face plate thickness t of channel-section pillars are not to be less than the lesser of the following:

$$t = \frac{br}{20l} \quad \text{mm}$$

$$t = \frac{b}{18} \quad \text{mm}$$

where: b — side length of angular pillars or face plate breadth of channel-section pillars, in mm;

l, r — same as defined in 2.10.2.1 of this Section.

- (3) The thickness t of face plate of I-shaped pillars is not to be less than the lesser of the following:

$$t = \frac{br}{40l} \quad \text{mm}$$

$$t = \frac{b}{36} \quad \text{mm}$$

where: b — breadth of face plate of I-shaped pillars, in mm;

l, r — same as defined in 2.10.2.1 of this Section.

2.10.4 Strengthening of structures at heads and heels of pillars

2.10.4.1 The structures at the heads and heels of pillars are to be so arranged that loads are reasonably supported and transmitted. Tubular and hollow rectangular pillars are to be attached at their heads to plates supported by efficient brackets. Longitudinal and transverse brackets are to be fitted at the heads and heels of the built or rolled-section pillars. Doubler or insert plates are to be fitted below pillars.

2.10.4.2 Pillars are to be fitted on plate floors or girders, and these plate floors or girders are to be fitted with vertical stiffeners. Widely spaced pillars are to be fitted at the intersection of plate floors and girders and if they are not fitted at the intersection, partial floors or girders are to be fitted below such pillars. Manholes are not to be cut in the floors and girders below pillars.

2.10.4.3 Where pillars are fitted on a shaft tunnel or any weak framing, structural strengthening is required in way of the pillars.

2.10.4.4 For pillars fitted inside ballast tanks or other tanks, attention is to be given to the effects of possible tensions.

2.10.4.5 Tubular or hollow rectangular pillars are not to be used inside oil tanks.

SECTION 11 - NON-WATERTIGHT PILLAR BULKHEADS

2.11.1 General requirements

2.11.1.1 The minimum thickness of bulkhead plating is to be 7 mm in lower holds and 6 mm in tween decks and where the ship's length is less than 90 m, the minimum thickness is to be 5 mm.

2.11.1.2 The maximum spacing of bulkhead stiffeners is to be 1,500 mm.

2.11.1.3 The sectional area A of bulkhead stiffeners (including attached plating not exceeding 600 mm in width), which support beams, longitudinals, girders, transverses, etc., is not to be less than the following:

$$A = \frac{KP}{12.26 - 5.1 \frac{l}{r\sqrt{K}}} \quad \text{cm}^2 \quad \text{for } \frac{s}{t} \leq 80$$

$$A = \frac{KP}{4.86 - 1.475 \frac{l}{r\sqrt{K}}} \quad \text{cm}^2 \quad \text{for } \frac{s}{t} \geq 120$$

A is to be obtained by interpolation for $80 < \frac{s}{t} < 120$

where: P, r — see 2.10.2.1 of this Chapter;

l — span of stiffeners, in m;

s — spacing of stiffeners, in mm;

t — thickness of bulkhead plating, in mm;

K — material factor, to be taken not less than 0.72.

2.11.1.4 The minimum web depth of stiffeners is to be 150 mm in lower holds and 100 mm in 'tween decks and where the ship's length is less than 90 m, the minimum depth is to be 100 mm and 75 mm respectively.

SECTION 12 - WATERTIGHT BULKHEADS

2.11.2 General requirements

2.11.2.1 Watertight bulkheads are to comply with the requirements of this Section and in addition, the relevant requirements of Section 12, Chapter 1 of this PART.

2.11.2.2 The total number of transverse watertight bulkheads is, in general, not to be less than that given in Table 2.12.1.2. For ships over 190 m in length, this number is to be determined by direct calculation.

Table 2.12.1.2-Total Number of Transverse Watertight Bulkheads

Ship's Length (L)	≤ 60	60 < L ≤ 85	85 < L ≤ 105	105 < L ≤ 125	125 < L ≤ 145	145 < L ≤ 165	165 < L ≤ 190
Machinery amidships	4	4	5	6	7	8	9
Machinery aft	3	4	5	6	6	7	8

2.11.2.3 Transverse watertight bulkheads are to be fitted in accordance with the following requirements:

- (1) All transverse watertight bulkheads are to extend to the bulkhead deck, except collision bulkheads and after peak bulkheads.
- (2) The bulkheads in the holds are to be spaced at uniform intervals. Where the length of a hold is greater than $0.15L$ or 30 m, whichever is the greater, transverse structures are to be strengthened and relevant supporting documents are to be submitted.
- (3) Where it is impracticable for the arrangement of transverse watertight bulkheads to comply with Table 2.12.1.2 due to the requirements of a special trade, one or more of these bulkheads may be dispensed with, subject to suitable structural compensation and demonstration by direct calculation that the transverse strength is adequate.

2.11.2.4 Where the bulkheads form the boundaries of deep tanks, the bulkhead structures are also to satisfy the requirements of Section 13 of this Chapter for the deep tank bulkheads.

2.11.2.5 The bulkheads may be of the plane, symmetrically corrugated or double-plated type.

2.12.2 Collision bulkhead

2.12.2.1 For the calculation of structural members of collision bulkheads, the value h is to be 1.25 times the height required accordingly.

2.12.3 Plane bulkhead plating

2.12.3.1 The thickness t of the plane watertight bulkhead plating is not to be less than that obtained from the following formula, nor less than 5.5 mm:

$$t = 4s \sqrt{hK} \quad \text{mm}$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, measured from the lower edge of the plate in a strake to the bulkhead deck at side, to be taken as not less than 2.5 m;

K — material factor.

2.12.3.2 The thickness of bulkhead plating in way of bilges or bilge wells is to be increased by 2.5 mm, and the thickness of bulkhead plating in way of the passage of the stern tube is to be doubled.

2.12.3.3 The lowest strake of bulkheads is not to be less than 900 mm in height measured from the inner bottom, or from the bottom in the case of single bottom. Where a double bottom is provided on one side and a single bottom on the other side of the bulkhead, the lowest strake is to extend at least 300 mm above the flat portion of the double bottom.

2.12.3.4 Where the difference in thickness between the bulkhead and the web of longitudinal girders attached to the bulkhead is too great, the thickness of bulkhead plating in way is to be increased.

2.12.4 Plane bulkhead stiffeners

2.12.4.1 The section modulus W of bulkhead stiffeners is not to be less than that obtained from the following formula:

$$W = Cshl^2K \text{ cm}^3$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, measured from the mid-span of stiffeners to the bulkhead deck at side, but not to be taken as less than 2 m;

l — span of stiffener, in m;

C — coefficients, to be taken as follows:

$C = 6$, for stiffeners unattached at both ends, or directly attached to unstiffened plating;

$C = 3$, for stiffeners bracketed at ends; stiffeners directly lapped to longitudinal members at ends; stiffeners directly connected to longitudinally framed deck plating (inner bottom) at ends, and the stiffeners are in line with the webs of longitudinals; stiffeners directly connected to deck plating or girder web at ends, provided that the other side of the deck plating or girder is connected to an adjacent member having at least the same cross section as and in line with the said stiffener;

K — material factor.

2.12.4.2 Where a transverse bulkhead supports deck girders, bulkhead stiffeners are to be fitted in way of the deck girders. The sectional area of these stiffeners together with attached plating is also to comply with the requirements of Section 11 of this Chapter for non-watertight pillar bulkheads.

2.12.4.3 The scantlings of end brackets of bulkhead stiffeners are to comply with the provisions in 1.2.6 of this PART. Stiffeners unattached at ends are applicable only in the upper 'tween deck spaces.

2.12.4.4 The brackets at the ends of stiffeners are to be extended and efficiently welded to the beams or floors adjacent to the bulkhead respectively. Where the deck or bottom is framed longitudinally and where the brackets at ends of stiffeners are not in line with longitudinals, stiffening bars are to be fitted between the ends of brackets and longitudinals.

2.12.4.5 The minimum web depth of stiffeners is to meet the requirements of 2.11.1.4 of this Chapter, and the thickness t of the web is to meet the following requirements:

For rolled or combined stiffeners with flange or face plate: $t \geq \frac{d_w}{60\sqrt{K}} \text{ mm}$

For flat bar stiffeners $t \geq \frac{d_w}{18\sqrt{K}} \text{ mm}$

where: d_w — depth of stiffener webs, in mm;

K — material factor.

2.12.5 Bulkheads with symmetrical corrugations

2.12.5.1 Symbols for the dimensions of corrugations are as shown in Figure 1.2.4.3, Chapter 1 of this PART.

2.12.5.2 Dimensions of corrugations are to comply with the following requirements:

- (1) The section modulus W of a corrugation over a spacing is not to be less than that obtained from the following formula:

$$W = Cshl^2K \text{ cm}^3$$

where: l — span of corrugation, in m;

h — vertical distance, in m, measured from the mid-span of the corrugation to the bulkhead deck at side, but not to be taken as less than 2 m;

s — spacing of corrugations, in m;

C — coefficient, to be taken according to the end fixity as specified in Table 2.12.5.2;

K — material factor.

- (2) The angle α between web and flange of corrugations is not to be less than 40° .

- (3) Where the span of corrugation exceeds 15 m, a diaphragm plate is to be arranged near the mid-span or equivalent measures for strengthening are to be taken.

Table 2.12.5.2-Value of Coefficient C

Upper end	Directly connected to deck	As shown in Figure 2.12.5.2(2) or (3)
Lower end		
As shown in Figure 2.12.5.2(1) or (2) or (3)	5.04	3.84

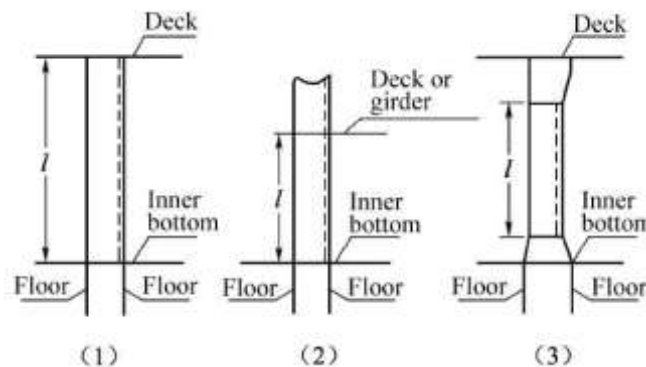


Figure 2.12.5.2

2.12.5.3 The plating thickness t of bulkheads with symmetrical corrugations is to comply with the requirements of 2.12.3.1 of this Section, and the following formula is to be complied with:

$$t \geq \frac{a}{85\sqrt{K}} \quad \text{mm} \quad \text{at top}$$

$$t \geq \frac{a}{70\sqrt{K}} \quad \text{mm} \quad \text{at bottom}$$

where: a — width of corrugation flange, in mm;

K — material factor. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check (see also 1.5.9, Chapter 1 of this PART) in direct calculation, the value of K for a lower

strength level may be taken.

2.12.5.4 The plating thickness at the mid-span of corrugated bulkheads is to be kept up to not less than 0.2l above the mid-span.

2.12.6 Double plate bulkheads

2.12.6.1 The section modulus W of webs of double plate bulkheads is not to be less than that obtained from the following formula:

$$W = Cshl^2K \text{ cm}^3$$

where: s — spacing of webs, in m, see Figure 1.2.4.4 of Chapter 1 of this PART;

h — vertical distance, in m, measured from the mid-span to the bulkhead deck at side, but to be taken as not less than 2 m;

l — span of webs, in m;

C — coefficient, to be taken according to the end fixity as specified in Table 2.12.6.1;

K — material factor.

Table 2.12.6.1-Value of coefficient C

Upper end	Directly connected to deck	As shown in Figure 2.12.5.2(2) or (3)
Lower end		
As shown in Figure 2.12.5.2(1) or (2) or (3)	3.96	3.00

2.12.6.2 The scantlings of double plate bulkheads are to comply with the requirements of 2.12.3.1 and 2.12.6.1 of this Section and in addition, the following requirements:

(1) The plating thickness t_p of double plate bulkheads is to comply with the following requirements:

$$t_p \geq \frac{s}{75\sqrt{K}} \quad \text{mm} \quad \text{at top}$$

$$t_p \geq \frac{s}{65\sqrt{K}} \quad \text{mm} \quad \text{at bottom}$$

where: s — spacing of webs, in mm;

K — material factor. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check (see also 1.5.9, Chapter 1 of this PART) in direct calculation, the value of K for a lower strength level may be taken.

(2) The plating thickness t_w and the shear area A_w of the web of double plate bulkheads are to comply with the following requirements:

$$t_w \geq \frac{b}{85\sqrt{K}} \quad \text{mm} \quad \text{at top}$$

$$A_w \geq 0.12 \frac{W}{l} \quad \text{cm}^2$$

$$t_w \geq \frac{b}{75\sqrt{K}} \quad \text{mm} \quad \text{at bottom}$$

$$A_w \geq 0.18 \frac{W}{l} \quad \text{cm}^2$$

where: b — spacing of plates of double plate bulkheads, in mm;

W — section modulus required in 2.12.6.1 of this Section, in cm^3 ;

l — span of webs, in m;

K — material factor. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check (see also 1.5.9, Chapter 1 of this PART) in direct calculation, the value of K for a lower strength level may be taken.

2.12.6.3 The plating thickness at the mid-span of double plate bulkheads is to be kept up to not less than 0.2l above the mid-span. Manholes or similar openings are not to be cut in the webs of double plate bulkheads within one-third of their length from either end.

2.12.7 Girders

2.12.7.1 The section modulus W of girders is not to be less than that obtained from the following formula:

$$W = 6.6bh^2l^2K \text{ cm}^3$$

where: b — breadth of the area supported by the girder, in m;

h — vertical distance, in m, measured from the mid-span of girders to the bulkhead deck at side, but to be taken not less than 2 m;

l — span of girder, in m;

K — material factor.

2.12.7.2 The web depth of girders is not to be less than 2.5 times that of the supported bulkhead stiffeners, and the breadth of the face plate of girders is not to be more than the web depth or 35 times the thickness of the face plate.

2.12.7.3 The girder ends are to be connected by brackets. The brackets are to extend to the adjacent frames or bulkhead stiffeners. The scantlings of brackets are to comply with the relevant provisions in 1.2.7 of this PART.

2.12.8 Watertight bulkhead steps

2.12.8.1 The section modulus W of beams of decks or flats forming the steps in bulkheads is not to be less than that obtained from the following formula:

$$W = 4.2sh^2l^2K \text{ cm}^3$$

where: s — spacing of beams, in m;

h — vertical distance, in m, measured from the deck or flat forming bulkhead steps to the bulkhead deck at side, but to be taken not less than 2 m;

l — span of beams, in m, but to be taken not less than 2 m;

K — material factor.

2.12.8.2 The thickness of plating of the deck or flat forming the steps in bulkheads is to be 1 mm thicker than that required in 2.12.3.1 of this Section, and in this case s in the formula is to be taken as the spacing of beams.

2.12.8.3 The thickness of plating of the deck or flat forming the steps in bulkheads and the

scantlings of beams are in no case to be less than those required, as appropriate, in Sections 4 and 8 of this Chapter for deck plating and beams.

SECTION 13 - DEEP TANKS

2.13.1 General requirements

2.13.1.1 The deep tanks referred to in this Section are those loaded with liquids, such as water, oil fuel, vegetable oil, spoil, etc., which form a part of hull within tank or 'tween deck.

2.13.1.2 For ballast tanks with ballast water exchange by overflow method, the design pressure head h is, in addition to complying with the requirements of this Section, not to be less than the vertical distance from the calculation point to the overflow point.

2.13.2 Plane bulkheads

2.13.2.1 The thickness t of plane bulkhead plating is not to be less than that obtained from the following formula:

$$t = 3.95s\sqrt{\rho h K} + 2.5 \text{ mm}$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, measured from the lower edge of the plate in a strake to the top of the deep tank, or half the distance to the top of overflow, whichever is the greater;

ρ — density of liquid, in t/m³, to be taken not less than 1.025;

K — material factor.

The thickness of bulkhead plating is not to be less than 8 mm for $L \geq 90$ m; not to be less than 7 mm for $60 \text{ m} \leq L < 90$ m; and not to be less than 6 mm for $L < 60$ m.

2.13.2.2 The thickness of bulkhead plating in way of bilges or bilge wells is to be increased by 2.5 mm.

2.13.2.3 The section modulus W of stiffeners of bulkheads is not to be less than that obtained from the following formula:

$$W = 8s\rho h l^2 K \text{ cm}^3$$

where: s — spacing of stiffeners, in m;

l — span of stiffener, in m;

h — vertical distance, in m, measured from the mid-span of the stiffener to the top of the deep tank, or half the distance to the top of overflow, whichever is the greater. The ends of stiffeners are to be connected by brackets, and the scantlings of these brackets are to be in accordance with the relevant requirements in 1.2.6 of this PART. The ends of the stiffeners may also be connected directly to the deck plating or girders provided that the other side of the deck plating or girder is connected to an adjacent member having at least the same cross section as and in line with the said stiffener;

ρ — density of liquid, in t/m³, to be taken not less than 1.025;

K — material factor.

The section moment of inertia I of stiffeners is not to be less than that obtained from the following formula:

$$I = 2.3Wl/K \text{ cm}^4$$

where: W, l — same as defined above.

2.13.3 Bulkheads with symmetrical corrugations

2.13.3.1 The scantlings of the bulkheads are to be in accordance with the following requirements:

- (1) The section modulus W of a corrugation over a spacing is not to be less than that obtained from the following formula:

$$W = Csphl^2K \text{ cm}^3$$

where: l — span of stiffener, in m;

h — vertical distance, in m, measured from the mid-span of the corrugation to the top of the deep tank or half the distance to the top of overflow, whichever is the greater;

ρ — density of liquid, in t/m³, to be taken not less than 1.025;

s — spacing of corrugation, in m;

C — coefficient, to be taken according to the end fixity as specified in Table 2.13.3.1;

K — material factor.

Table 2.13.3.1 - Value of coefficient C

Lower end \ Upper end	Directly connected to deck	As shown in Figure 2.12.5.2(2) or (3)
As shown in Figure 2.12.5.2(1) or (2) or (3)	13.30	10.30

- (2) The angle α between web and flange of corrugations is not to be less than 40°.

- (3) Where the span of corrugations exceeds 15 m, a horizontal girder is to be arranged near the mid-span.

2.13.3.2 The plating thickness t of corrugated bulkheads is to comply with the requirements of of this Section, and the following formula is to be complied with:

$$t \geq \frac{a}{70\sqrt{K}} \text{ mm}$$

where: a — width of corrugation flange, in mm;

K — material factor. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check (see also 1.5.9, Chapter 1 of this PART) in direct calculation, the value of K for a lower strength level may be taken.

2.13.3.3 The plating thickness at the mid-span of corrugated bulkheads is to be kept up to not less than 0.2l above the mid-span.

2.13.4 Double plate bulkheads

2.13.4.1 The section modulus W of webs and the spacing b of plates of double plate bulkheads are not to be less than those obtained from the following formulae:

$$W = Csphl^2K \text{ cm}^3$$

$$b = 40l \text{ mm}$$

where: s — spacing of webs, in m;

h — vertical distance, in m, measured from the mid-span to the top of the deep tank or half the distance to the top of overflow, whichever is the greater;

ρ — density of liquid, in t/m³, to be taken not less than 1.025;

l — span of web, in m;

C — coefficient, to be taken according to the end fixity as specified in Table 2.13.4.1;

K — material factor.

Table 2.13.4.1 - Value of coefficient C

Lower end \ Upper end	Directly connected to deck	As shown in Figure 2.12.5.2(2) or (3)
As shown in Figure 2.12.5.2(1) or (2) or (3)	10.20	8

2.13.4.2 The plating thickness t_p of double plate bulkheads is to comply with the requirements of 2.13.2.1 of this Section and in addition, the following formulae are to be complied with:

$$t_p \geq \frac{s}{75\sqrt{K}} \quad \text{mm} \quad \text{at top}$$

$$t_p \geq \frac{s}{65\sqrt{K}} \quad \text{mm} \quad \text{at bottom}$$

where: s — spacing of webs, in mm;

K — material factor. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check (see also 1.5.9, Chapter 1 of this PART) in direct calculation, the value of K for a lower strength level may be taken.

2.13.4.3 The plating thickness t_w and shear area A_w of webs of double plate bulkheads are to comply with the following requirements:

$$t_w \geq \frac{b}{85\sqrt{K}} \quad \text{mm} \quad \text{at top}$$

$$A_w \geq 0.07 \frac{W}{l} \quad \text{cm}^2$$

$$t_w \geq \frac{b}{75\sqrt{K}} \quad \text{mm} \quad \text{at bottom}$$

$$A_w \geq 0.10 \frac{W}{l} \quad \text{cm}^2$$

where: b — spacing of plates of double plate bulkheads, in mm;

W — section modulus required in 2.13.4.1 of this Section, in cm³;

l — span of webs, in m;

K — material factor. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check (see also 1.5.9, Chapter 1 of this PART) in direct calculation, the value of K for a lower strength level may be taken.

2.13.4.4 The plating thickness at the mid-span of double plate bulkheads is to be kept up to not less than 0.2l above the mid-span.

Manholes or similar openings are not to be cut in the webs of double plate bulkheads within one-third of their length from either end.

2.13.5 Girders

2.13.5.1 The section modulus W of girders is not to be less than that obtained from the following formula:

$$W = 11.7b\rho h^2 K \text{ cm}^3$$

where: b — breadth of the area supported by the girder, in m;

h — vertical distance, in m, measured from the mid-span of girder to the top of the deep tank, or half the distance to the top of overflow, whichever is the greater;

ρ — density of liquid, in t/m³, to be taken not less than 1.025;

l — span of girder, in m;

K — material factor.

2.13.5.2 The section moment of inertia I of girders is not to be less than that obtained from the following formula:

$$I = 2.5Wl/K \text{ cm}^4$$

where: W , l , K — same as defined in 2.13.5.1 of this Section.

2.13.5.3 The web depth of girders is not to be less than 2.5 times that of the supported bulkhead stiffeners, and the breadth of the face plate of girders is not to be more than the web depth or 35 times the thickness of the face plate.

2.13.5.4 The girder ends are to be connected by brackets. The brackets are to extend to the adjacent frames or bulkhead stiffeners. The scantlings of the brackets are to comply with the relevant provisions in 1.2.7 of this PART.

2.13.6 Transverse side framing

2.13.6.1 Frames are to comply with the following requirements:

- (1) The section modulus of frames other than those of forepeak and aft peak tanks is to be increased by 15% above that required in Section 7 of this Chapter.
- (2) The section modulus W and section moment of inertia I of frames are to be not less than those obtained from the following formulae in addition to the requirement mentioned above:

$$W = 6.8s\rho h^2 K \text{ cm}^3$$

$$I = 3.5Wl/K \text{ cm}^4$$

where: s — spacing of frames, in m;

l — span of frame, in m, the vertical distance measured from the upper edge of floor or inner bottom to the side stringer, or between side stringers or from the side stringer to the 'tween deck;

h — vertical distance, in m, measured from the mid-span of frame to the top of the deep tank or half the distance to the top of overflow, whichever is the greater;

ρ — density of liquid, in t/m³, to be taken not less than 1.025;

K — material factor.

- (3) The arm length of end brackets of frames is to be increased by 20% above that required in 1.2.6 of this PART.

2.13.6.2 Side stringers supporting the frames are to comply with the requirements of 2.13.5.3 to 2.13.5.4 of this Section and in addition, to have a section modulus W and a moment of inertia I not less than those obtained from the following formulae:

$$W = 11.7b\rho h^2 K \text{ cm}^3$$

$$I = 2.5Wl/K \text{ cm}^4$$

where: b — breadth of the area supported by the stringer, in m;

h — vertical distance, in m, from the mid-span of stringer to the top of the deep tank, or half the distance to the top of overflow, whichever is the greater, but not less than the distance measured from the mid-span of stringer to the upper deck, or to a point $1.4d$ (d being the draught, in m) above the plate keel, whichever is the lesser;

ρ — density of liquid, in t/m³, to be taken not less than 1.025;

l — span of stringer, in m;

K — material factor.

2.13.6.3 In deep tanks forward of 0.2L from F.P., side stringers are to be fitted and spaced not more than 5 m apart, or perforated flats having scantlings complying with the requirements of 2.15.1.11 of this Chapter are to be fitted. Where the length of the tank exceeds 14 m and perforated flats are fitted in lieu of the side stringers, web frames or transverse wash bulkheads are to be fitted.

2.13.6.4 The scantlings of web frames supporting the side stringers are to be calculated according to 2.7.4.1 of this Chapter. But the design head h is to be taken as the vertical distance measured from the side stringer to the top of the deep tank, or half the distance to the top of overflow, whichever is the greater, in m; but not to be less than the distance measured from stringers to the upper deck or to a point $1.4d$ (d being the draught, in m) above the plate keel, whichever is the lesser.

2.13.7 Longitudinal side framing

2.13.7.1 In addition to complying with the requirements of Section 7 of this Chapter, the section modulus W of side longitudinals is not to be less than that obtained from the following formula:

$$W = 8.8s\rho h^2 K \text{ cm}^3$$

where: s — spacing of longitudinals, in m;

h — vertical distance, in m, measured from the longitudinal to the top of the deep tank or half the distance to the top of overflow, whichever is the greater;

ρ — density of liquid, in t/m³, to be taken not less than 1.025;

l — span of longitudinal, in m;

K — material factor.

The end connections of side longitudinals are to comply with the relevant requirements of 2.7.5.7. The arm length of the end brackets is to be increased by 20% above that required in 1.2.6 of this PART.

2.13.7.2 The section modulus W of the web frames supporting the side longitudinals is not to be less

than that obtained from the following formula:

$$W = 11.7 s p h l^2 K \text{ cm}^3$$

where: s — spacing of web frames, in m;

h — vertical distance, in m, measured from the mid-span of web frame to the top of the deep tank, or half the distance to the top of overflow, whichever is the greater;

ρ — density of liquid, in t/m^3 , to be taken not less than 1.025;

l — span of web frame, in m;

K — material factor.

2.13.7.3 The section moment of inertia I of web frames is not to be less than that obtained from the following formula:

$$I = 2.5 W l / K \text{ cm}^4$$

where: W , l , K — same as defined in 2.13.7.2 of this Section.

2.13.7.4 In deep tanks forward of 0.2L from F.P., the section modulus of web frames supporting the side longitudinals is to be increased by 20% above that obtained from 2.13.7.2 of this Section.

In general, the spacing of web frames is not to be greater than 3.0 m for ships of 100 m in length or less and not greater than 4.2 m for ships of 300 m or over in length, and the intermediate values are to be obtained by interpolation. Where the depth of the tank exceeds 16 m, perforated flats are to be fitted, and transverses are to be fitted in way of the web frames.

2.13.8 Deck plating and framing

2.13.8.1 In addition to complying with the requirements of Section 4 of this Chapter, the plating thickness t of the deck (or flat) of deep tanks is not to be less than that obtained from the following formula:

$$t = 3.95 s \sqrt{\rho h K} + 3.5 \text{ mm}$$

where: s — spacing of frames, in m;

h — vertical distance, in m, measured from deck (or flat) to the top of the deep tank, or half the distance to the top of overflow, whichever is the greater;

ρ — density of liquid, in t/m^3 , to be taken not less than 1.025;

K — material factor.

The plating thickness t of the deck (or flat) is not to be less than 8 mm for ship's length $L \geq 90$ m;

7 mm for $60 \text{ m} \leq L < 90 \text{ m}$; 6 mm for $L < 60 \text{ m}$.

2.13.8.2 In addition to complying with the requirements of Section 8 of this Chapter, the section modulus W of longitudinals or beams of the decks (or flats) in deep tanks is not to be less than that obtained from the following formula:

$$W = 8.8 s p h l^2 K \text{ cm}^3$$

where: s — spacing of longitudinals or beams, in m;

h — vertical distance, in m, measured from deck (or flat) to the top of the deep tank, or half the distance to the top of overflow, whichever is the greater;

ρ — density of liquid, in t/m^3 , to be taken not less than 1.025;

l — span of longitudinal or beam, in m;

K — material factor.

The section moment of inertia I is not to be less than that obtained from the following formula:

$$I = 2.3Wl/K \text{ cm}^4$$

where: W, l, K — same as defined above.

2.13.8.3 In addition to complying with the requirements of Section 8 of this Chapter, the section modulus W of girders or transverses of decks (or flats) in deep tanks is not to be less than that obtained from the following formula:

$$W = 11.7S\rho h^2/K \text{ cm}^3$$

where: S — spacing of girders or transverses, in m;

h — vertical distance, in m, measured from deck (or flat) to the top of the deep tank, or half the distance to the top of the overflow, whichever is the greater;

ρ — density of liquid, in t/m^3 , to be taken not less than 1.025;

l — span of girder or transverse, in m;

K — material factor.

The section moment of inertia I is not to be less than that obtained from the following formula:

$$I = 2.5Wl/K \text{ cm}^4$$

where: W, l, K — same as defined above.

2.13.8.4 The web depth of deck girders or transverses is to comply with the relevant requirements of Section 8 of this Chapter.

2.13.8.5 In deep tanks forward of 0.2L from F.P., the spacing of deck transverses supporting the deck longitudinals is to be the same as that of web frames as provided in 2.13.7.4 of this Section.

2.13.9 Bottom framing

2.13.9.1 The transversely framed single bottom in deep tanks forward of 0.2L from F.P. is to comply with the following requirements:

- (1) Plate floors are to be fitted at every frame space, and the scantlings of floors are not to be less than those required in 2.15.1.1 of this Chapter. In way of web frames, the depth of floors and scantlings of face plates are not to be less than those of web frames.
- (2) The section modulus W of the centerline girder is not to be less than the greater of those obtained from the following formulae:

$$W = 9sh_1^2/K \text{ cm}^3$$

$$W = 9.8s\rho h_2^2/K \text{ cm}^3$$

where: s — mean spacing supported by centerline girder, in m;

l — span of centerline girder, in m;

h_1 — vertical distance, in m, measured from the mid-span to upper deck at side; for the region forward of 0.15L from F.P., to 3 m above the deck for measuring minimum

bow height (see Regulation 39 of the International Convention on Load Lines, 1966);
 h_2 — vertical distance, in m, measured from the mid-span to the top of the deep tank,
 or half the vertical distance to the top of overflow, whichever is the greater;
 ρ — density of liquid, in t/m³, to be taken not less than 1.025;
 K — material factor.

The section moment of inertia I is not to be less than that obtained by the following formula:

$$I = 2.5Wl/K \text{ cm}^4$$

where: W , l , K — same as defined above.

- (3) Intercoastal side girders are to be fitted and spaced not more than three frame spaces apart. The scantlings of intercoastal side girders are to be the same as those of floors.

2.13.9.2 For longitudinally framed single bottom in deep tanks forward of 0.2L from F.P., the spacing of plate floors supporting longitudinals is to be the same as that of the web frames as provided in 2.13.7.4 of this Section. The plate floors are to be supported by a continuous centreline girder or a longitudinal bulkhead. The scantlings of plate floors and centreline girders are to comply with the relevant requirements of Section 3, Chapter 6 of this PART.

2.13.10 Wash bulkheads

2.13.10.1 Where a deep tank extends from side to side of the ship, a wash bulkhead is to be fitted on the centreline. Where the widest breadth of the tank exceeds 0.5B within the region forward of 0.3L from F.P., a wash bulkhead is to be fitted on the centreline of the tank. Where the widest breadth of the tank exceeds 0.7B, it is recommended that a longitudinal bulkhead be fitted on the centreline of the tank.

2.13.10.2 The thickness of the wash bulkhead is to be the same as that required for the bulkheads mentioned in this Section. The section modulus of the stiffeners of the wash bulkhead is to be equal to 50% of that of those bulkheads, but h is to be measured to the top of the deep tank. The stiffeners are to be connected by brackets at both ends. The area of perforations is not to be less than 5% nor more than 10% of the total area of the bulkhead.

SECTION 14 - STEMS, STERN FRAMES, BULBOUS BOWS AND PROPELLER SHAFT BRACKETS

2.14.1 Stems

2.14.1.1 The cross-sectional area A of bar stems up to 0.5 m above the summer load waterline is not to be less than the following:

$$A = 1.2L \text{ cm}^2 \quad \text{for } L < 90 \text{ m}$$

$$A = 1.63L - 38 \text{ cm}^2 \quad \text{for } L \geq 90 \text{ m}$$

where: L — length of ship, in m.

From a position above 0.5 m from the summer load waterline, the cross-sectional area may be gradually tapered to the stem head where the area may be reduced by 25%.

2.14.1.2 The thickness t of plate stems up to 0.5 m above the summer load waterline is not to be

less than that obtained from the following formula:

$$t = (0.08L + 5.5)\sqrt{K} \text{ mm}$$

where: L — length of ship, in m, but not to be taken greater than 230 m;

K — material factor.

From a position above 0.5 m from the summer load waterline, the plate thickness may be gradually tapered to the stem head where the thickness may be the same as that of the shell at ends.

Plate stems are to be supported by horizontal webs spaced not more than 1 m apart, and the web thickness is not to be less than the thickness of the adjacent shell plating. The webs are to be extended aft to be connected to frames or side stringers, but at least beyond the butts of stem plates and shell plating.

Where the radius of curvature of the stem is large, a centreline vertical web is to be fitted, having the same thickness as the horizontal webs.

2.14.1.3 Cast steel stems are to be easy for manufacture, and all fillets are to have adequate radii. The sectional area of cast steel stems is not to be less than that of bar stems required in 2.14.1.1 of this Section. Cast steel stems are to be provided with rib reinforcement.

2.14.2 Stern frames without rudder post

2.14.2.1 The stern frame without rudder post is composed of sole piece, propeller post and propeller boss.

2.14.2.2 The scantlings of fabricated propeller posts (as shown in Figure 2.14.2.2) are not to be less than those obtained from the following formulae:

$$\text{Length of stern frame: } a = 46\sqrt{L} \text{ mm}$$

$$\text{Thickness of stern frame: } t = 2.3\sqrt{L} + 3 \text{ mm}$$

where: L — length of ship, in m.

2.14.2.3 The scantlings of cast propeller posts (as shown in Figure 2.14.2.3) are not to be less than those obtained from the following formulae:

$$\text{Length of stern frame: } a = 41\sqrt{L} \text{ mm}$$

$$\text{Thickness of stern frame: } t_1 = 3\sqrt{L} \text{ mm}$$

$$t_2 = 4\sqrt{L} \text{ mm}$$

$$\text{Radius of fillet: } R = 4.9\sqrt{L} \text{ mm}$$

where: L — length of ship, in m.

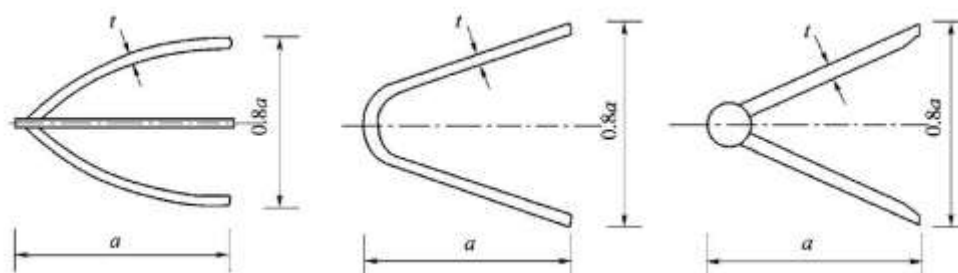


Figure 2.14.2.2(1) Figure 2.14.2.2(2) Figure 2.14.2.2(3)

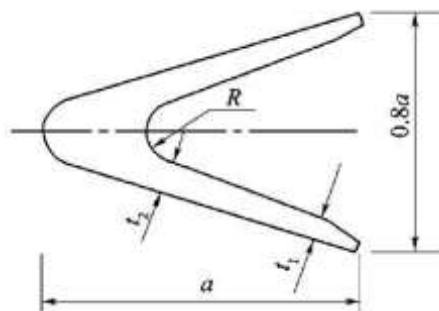


Figure 2.14.2.3

2.14.2.4 Fabricated or cast propeller posts are to be strengthened by horizontal brackets at positions depending upon the hull framing and the structural arrangements of propeller posts, but the spacing of the webs is not to exceed 650 mm. Cast steel stern frames are to be easy for manufacture, and all fillets are to have adequate radius; where the radius of curvature is large, a vertical web is to be fitted.

2.14.2.5 The section modulus W_z of sole pieces (see Figure 2.14.2.5) about the vertical neutral axis (z-axis) at any considered section, is not to be less than that obtained from the following formula:

$$W_z = \frac{K}{80} P x \quad \text{cm}^3$$

where: P — supporting force exerting by the sole piece on rudder blade, in N, to be calculated according to the relevant provisions of Section 1, Chapter 3 of this PART;

K — material factor according to 1.3.1.7 of this PART for fabricated sole pieces; material factor according to 3.1.1.3 of this PART for cast sole pieces;

x — distance between the axis of rudder stock and the section under consideration, in m, to be taken not less than $0.5/l_s$, l_s being the maximum distance, in m, (see Figure 2.14.2.5).

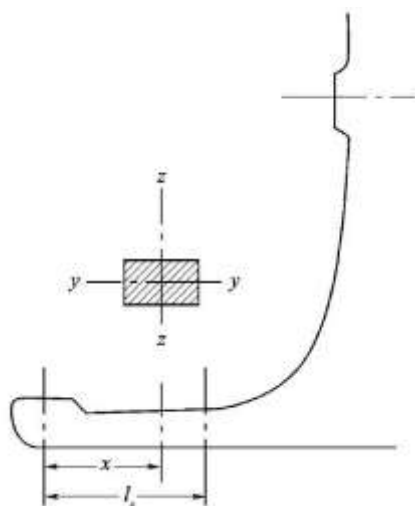


Figure 2.14.2.5

2.14.2.6 The section modulus W_y of sole pieces about the horizontal neutral axis (y-axis) at any considered section is not to be less than that obtained from the following formula:

$$W_y = 0.5 W_z \text{ cm}^3$$

where: W_z — section modulus, in cm^3 , to be calculated according to 2.14.2.5 of this Section.

2.14.2.7 The sectional area A_s at any section of the sole piece is not to be less than that obtained from the following formula:

$$A_s = \frac{K}{48} P \quad \text{mm}^2$$

where: P, K — see 2.14.2.5 of this Section.

2.14.2.8 Within the length l_s , the equivalent stress σ_e of any section of sole pieces is to be determined from following formula:

$$\sigma_e = \sqrt{\sigma^2 + 3\tau^2} \leq 115/K \quad \text{N/mm}^2$$

where:

$\sigma = \frac{Px}{W_z}$, in N/mm², where: P, x — see 2.14.2.5 of this Section, W_z being the section modulus of the considered section about z-axis, in cm³;

$\tau = \frac{P}{A_s}$, in N/mm², where: P — see 2.14.2.5 of this Section, A_s being the sectional area of the section under consideration, in mm²;

K — see 2.14.2.5 of this Section.

2.14.2.9 In fabricated sole pieces, transverse webs are to be fitted and spaced not more than 760 mm apart. Where the breadth of the fabricated sole pieces exceeds 900 mm, a centreline vertical web is to be fitted.

2.14.2.10 The sole piece is to extend forward from the fore end of the propeller boss for at least 3 frame spaces and to be efficiently connected to the plate keel. The sectional area of the extended portion may be reduced gradually to the area required for effective connection with the plate keel.

2.14.2.11 The stern tube shaft is to be efficiently connected to the floor or bulkhead, and the thickness of the floor is to be increased by 3 mm.

2.14.2.12 The finished thickness t of the propeller boss in way of the passage of the stern tube shaft or propeller shaft is not to be less than that obtained from the following formula:

$$t = 0.1d_s + 60 \text{ mm, but not greater than } 0.3d_s$$

where: d_s — diameter of stern tube shaft or propeller shaft, in mm.

2.14.3 Propeller posts of twin screw ships

2.14.3.1 The dimensions of propeller posts which are built integral with the hull of twin screw ships (see Figures 2.14.3.1(1), (2)) are not to be less than as given below:

Breadth of section: $b = 33\sqrt{L}$ mm

Thickness of section: $t_1 = 3.3\sqrt{L}$ mm

$$t_2 = 3.7\sqrt{L} \quad \text{mm}$$

$$t_3 = 4.5\sqrt{L} \quad \text{mm}$$

$$R = 4.4\sqrt{L} \quad \text{mm}$$

Radius of fillet:

where: L — length of ship, in m.

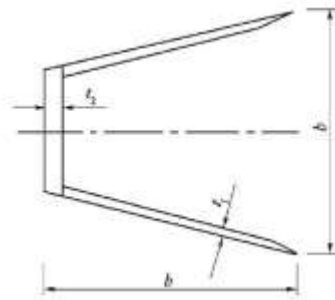


Figure 2.14.3.1(1)

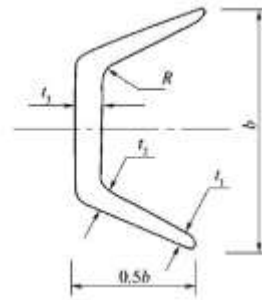


Figure 2.14.3.1(2)

2.14.4 Propeller clearances

2.14.4.1 It is recommended that the minimum clearances (see Figure 2.14.4.1) between the propeller and the stern frame or between the propeller and the rudder be not less than the following:

$$a = 0.12D \text{ m}$$

$$b = 0.20D \text{ m}$$

$$c = 0.14D \text{ m}$$

$$d = 0.04D \text{ m}$$

where: D — diameter of propeller, in m.

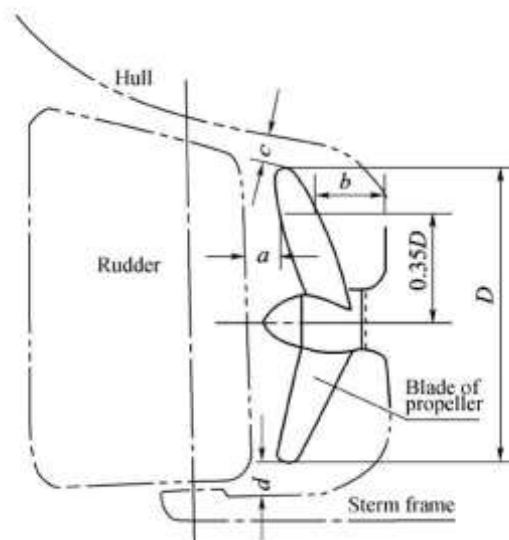


Figure 2.14.4.1

2.14.5 Bulbous bows

2.14.5.1 Where a bulbous bow is fitted, the structural arrangements are to be such that the bulb is adequately supported and integrated into the fore peak structure. The bulb is in general to be strengthened as follows:

- (1) At the fore end of the bulb, the structure is to be supported by horizontal diaphragm plates spaced about 1 m apart in conjunction with the center girder;
- (2) Vertical transverse diaphragm plates are to be arranged in way of the transition from the peak framing to the bulb framing;
- (3) In way of a long bulb, additional strengthening in the form of transverse wash bulkheads or web frames spaced about 5 frame spaces apart are generally to be fitted;
- (4) In way of a wide bulb, additional strengthening in the form of a centreline wash bulkhead is

generally to be fitted;

- (5) The shell plating is to be increased in thickness at the fore end of the bulb and in other areas likely to be damaged by the anchors and chain cables. The increased plate thickness may be the same as that required for plate stems.

2.14.6 Propeller shaft brackets

2.14.6.1 Propeller shaft brackets may be made of steel castings or fabricated from plates, or made of cast or forged pieces connected by welding. The connection of the arms to the bearing boss is to be made by full penetration welding.

2.14.6.2 The scantlings of each arm and shaft bossing of herringbone propeller shaft bracket are not to be less than as given below:

Thickness of arm:	$t = 0.45d_s$	mm
Cross sectional area of arm:	$A = 0.45 d_s^2$	mm ²
Thickness of shaft bossing:	$t = 0.33d_s$	mm
Length of shaft bossing:	$l = 3d_s$	mm

where: d_s — diameter of stern tube shaft or propeller shaft at the location of shaft bracket, in mm.

2.14.6.3 The hull framing in way of the bracket palm is to be strengthened and the shell plating in way is to be increased in thickness as required in 2.3.6.1 of this Chapter. Bracket arms are to be carried through the shell plating and efficiently attached to floors, girders and shell plating.

SECTION 15 - STRENGTHENING AT ENDS OF SHIP

2.15.1 Fore peak strengthening

2.15.1.1 Solid floors are to be fitted at every frame. The web depth h and thickness t and the face plate sectional area A of the floors are not to be less than those obtained from the following formulae:

$$h = 85D + 140 \text{ mm, but need not be greater than 1500 mm}$$

$$t = (0.03L + 6) \sqrt{K} \text{ mm}$$

$$A = 0.85BK \text{ cm}^2$$

where: B — breadth of ship, in m;

D — moulded depth of ship, in m;

L — length of ship, in m, to be taken as not greater than 200 m;

K — material factor.

2.15.1.2 Centreline keelson is to be fitted at the longitudinal centreline section. The web depth and thickness and the face plate sectional area are to be as those required in 2.15.1.1 of this Section for solid floors.

2.15.1.3 For the extremely narrow bottom, the centreline keelson not extended to the bottom may be accepted, but the depth of the keelson is to be approximately equal to 1/3 of the floor depth. Or alternatively, the centreline keelson may be entirely omitted provided that the web of floors is fitted with horizontal stiffeners and that a perforated flat, instead of a face plate, is fitted at the top edge of the web.

2.15.1.4 In the case as mentioned in 2.15.1.3 of this Section, a centreline keelson gradually tapered off over several frame spaces is to be fitted forward of the collision bulkhead as the continuation of the centreline girder or centreline keelson abaft the collision bulkhead.

2.15.1.5 Where the side shell is framed transversely, panting beams spaced not more than 2 m apart vertically are to be fitted at alternate frames, from the top of floors up to the lowest deck, and at least to 1 m above the full-load waterline. The cross-sectional area A and minimum section moment of inertia I of the panting beams are not to be less than:

$$A = (0.27L + 8)K \text{ cm}^2$$

$$I = ce h_j l^2 \text{ cm}^4$$

where: L — length of ship, in m, to be taken as not greater than 250 m;

c — horizontal spacing of panting beams, in m;

e — vertical spacing of panting beams, in m;

h_j — vertical distance, in m, measured from the beam to 3 m above the minimum bow height required by load line, and not to be less than that to upper deck;

l — span of panting beam, in m;

K — material factor.

2.15.1.6 Where a fore peak space is used as a tank and the breadth of the tank at its widest point exceeds $0.5B$ (B being the breadth of ship), efficient supporting members or wash bulkheads are to be fitted to support the panting beams. The wash bulkheads are to comply with the requirements of 2.13.10.2 of this Chapter.

2.15.1.7 Where the length of the fore peak space exceeds 10 m, additional transverse strengthening in the form of transverse wash bulkheads or web frames is to be provided. Transverse wash bulkheads are to comply with the provisions in 2.13.10.2 of this Chapter while web frames are to comply with the provisions in 2.7.2.8 of this Chapter.

2.15.1.8 Where the side shell is framed transversely, side stringers with flange or face plate are to be fitted at each panting beam, and are to have a web depth h and thickness t not less than:

$$h = 5.6L + 166 \text{ mm for } L < 90\text{m}$$

$$h = 3.0L + 400 \text{ mm for } L \geq 90\text{m}$$

$$t = 0.023L + 6 \text{ mm}$$

where: L — length of ship, in m, to be taken as not greater than 250 m.

2.15.1.9 Brackets are to be fitted at the lower edge of connections between side stringers and frames, the thickness of brackets is not to be less than that of the side stringer web and the brackets are to be extended to the flange or face plate of side stringers. Where panting beams are fitted, the arm length of brackets along the frames is not to be less than 75% the web depth of side stringers, and where no panting beams are fitted, the arm length is not to be less than 50% the web depth of side stringers. The webs of side stringers are to be welded to the frames.

2.15.1.10 Where the side shell is framed transversely and if perforated flats are fitted in lieu of the panting beams in association with stringers, the flats are to be spaced not more than 2.5 m apart and are to be fitted vertically from the top of floors to the lowest deck above the full-load waterline, but not below 1.0 m above the full-load waterline.

2.15.1.11 Where the side shell is framed transversely, the perforated flats are to comply with the following requirements:

- (1) The area of perforations in each flat is not to be less than 10% of the total area of the flat.
- (2) The plate thickness t of the perforated flat is not to be less than that obtained from the following formula:

$$t = 0.023L + 5 \text{ mm}$$

where: L — length of ship, in m.

- (3) Where the perforated flat is framed transversely, one beam is at least to be fitted at alternate frames below the perforated flat, and their sectional area A without attached plating is not to be less than that obtained from the following formula:

$$A = (0.13L + 4)CK \text{ cm}^2$$

where: L — length of ship, in m.

C — coefficient, $C = 1$ when beams are fitted at alternate frames; $C = 0.5$ when beams are fitted at every frame;

K — material factor.

Where the perforated flat is framed longitudinally, an appropriate number of transverses are to be fitted below the perforated flat, and the size of transverses and longitudinals is to be specially considered.

- (4) Scantlings of the brackets connecting the beams of the perforated flat to the frames are to comply with the requirements in 1.2.6 of this PART.

2.15.1.12 Where the side shell is framed longitudinally and the depth of the forepeak exceeds 10 m, one or more perforated flats are to be provided at suitable positions, or one or more panting beams as required in 2.15.1.5 of this Section are to be provided in way of each web frame.

2.15.1.13 Where the side shell is framed longitudinally, an adequate number of transverses are to be arranged at the top of the forepeak and at perforated flats (if fitted). The brackets connecting transverses to web frames are to be in accordance with the requirements of 1.2.7 of this PART.

2.15.1.14 Where the side shell is framed longitudinally, the perforated flats are to comply with the

requirements of 2.15.1.11(1) to (3) and brackets are to be fitted at the connection between the beams of perforated flats and the side plating and extended to the adjacent side longitudinals.

2.15.1.15 Brackets are to be fitted in way of fore edge of the connection between web frames and side longitudinals. The thickness of brackets is not to be less than the web thickness of web frames and the brackets are to be extended to the face plate of web frames. Where panting beams are fitted, the arm length of brackets along the side longitudinals is not to be less than 75% of the web depth of web frames and where no panting beams are fitted, the arm length of brackets along the side longitudinals is not to be less than 50% of the web depth of web frames.

2.15.1.16 Longitudinally framed bottom structure is to be specially considered.

2.15.2 Strengthening at sides abaft the fore peak tank

2.15.2.1 Where the side shell is framed transversely, side framing within the region from $0.15L$ from F.P. to the collision bulkhead is to be strengthened as follows:

- (1) Where the span of main frames does not exceed 9 m, intercostal side stringers are to be fitted in line with the side stringers or perforated flats in the fore peak tank.
- (2) Where the span of main frames does not exceed 9 m and if intercostal side stringers are omitted, the side shell plating in the region concerned is to be increased in thickness by the percentages given below:

where $L \leq 150$ m, by 15% of the thickness as required in this Chapter;

where $L \geq 200$ m, by 5% of the thickness as required in this Chapter.

For intermediate values of L , the percentage increase is to be obtained by interpolation.

- (3) Where the span of main frames exceeds 9 m, intercostal side stringers are to be fitted and to extend abaft to $0.2L$ from the F.P. in line with the side stringers or perforated flats in the fore peak tank.
- (4) Where the span of frames exceeds 2.6 m in the lower 'tween deck or 3 m in the upper 'tween deck, intercostal side stringers are to be fitted. Where the shell plating is increased according to the requirements in (2) above, the side stringers may be omitted.

2.15.2.2 The web depth of intercostal side stringers as required in 2.15.2.1 of this Section may be the same as that of frames. However, the web plate of such stringers is to be gradually increased in depth for at least two frame spaces to the collision bulkhead so that the depth at the bulkhead is the same as that of the side stringers in the fore peak tank. Where perforated flats are fitted in the fore peak tank, the depth of the web of side stringers is to be calculated according to 2.15.1.8 of this Section. The web thickness t and the face plate sectional area A of the intercostal side stringers are not to be less than those obtained from the following formulae:

$$t = 0.023L + 6 \text{ mm, but need not be greater than 12 mm}$$

$$A = 0.14L + 1 \text{ cm}^2, \text{ but not to be less than } 7 \text{ cm}^2$$

where: L — length of ship, in m.

2.15.3 Strengthening of bottom forward

2.15.3.1 Where the length L of the ship is equal to 65 m or over and the draught forward in

navigation is less than $0.04L$, the flat portion of bottom from F.P. is to be strengthened. The transverse extent of strengthening is not to be less than $0.014B$ (B being the breadth of the ship) above the base line, but need not be greater than 0.28 m, and the length X from the end line of the longitudinal extent of strengthening to F.P. is not to be less than that obtained from the following formula:

$$X = \left(0.65 - \frac{C_b}{2} \right) L \quad \text{m}$$

where: L — length of ship, in m;

C_b — block coefficient, to be taken as 0.7 for $C_b < 0.7$, and 0.8 for $C_b > 0.8$.

For every oil tanker subject to Regulation 18 of MARPOL Annex I, the minimum forward draught is to be determined according to the conditions in which only segregated ballast tanks are used.

2.15.3.2 Where strengthening is required, double bottom framed transversely is to be strengthened as follows:

- (1) Plate floors are to be fitted at every frame space.
- (2) Side girders are in general to be fitted not more than three frame spaces apart, and half-depth flanged side girders are to be fitted midway between the side girders. The side girders and half-depth side girders are to be extended as far forward as practicable.

2.15.3.3 Where strengthening is required, double bottom framed longitudinally is to be strengthened as follows:

- (1) Plate floors are to be fitted at alternate frames, and spaced not more than 2.5 m apart.
- (2) The section modulus of bottom longitudinals is to be increased by 10% above that obtained from the formula in 2.6.12.2 of this Chapter, and in this case, I in the formula is not to be less than 1.85 m.
- (3) Side girders are in general to be fitted not more than three times the spacing of longitudinals apart and are to be extended as far forward as practicable.

2.15.3.4 Where strengthening is required, single bottom framed transversely is to be strengthened as follows:

- (1) In addition to complying with the requirements of 2.15.1.1 of this Section, floors are to be increased gradually in depth towards the fore end as far as practicable, and the floor web is to be adequately increased in thickness so as to ensure its stability. The sectional area of the face plate of floors is to be increased by 50% over the value required in 2.15.1.1 of this Section and flanges are not to be substituted for face plates of floors.
- (2) Side keelsons are to be fitted not more than three frame spaces apart, and half-depth side keelsons or other equivalent bottom longitudinal stiffening members are to be fitted midway between the side keelsons and extended as far forward as practicable.

2.15.3.5 In the Where strengthening is required, the forward bottom plating is to be strengthened as follows:

- (1) The thickness t of the forward bottom plating is not to be less than that obtained from the

following formula:

$$t = C C_1 \left(1.8 - 26 \frac{d_1}{L} \right) \sqrt{\frac{s e K}{s_b}} \quad \text{mm}$$

where: L — length of ship, in m;

d_1 — minimum draught forward in navigation, in m;

s — spacing of frames, in m;

s_b — standard spacing of frames, in m;

e — correction coefficient of longitudinal position, see Table 2.15.3.5;

C — coefficient: $C = 7.3 + 0.081L$ for $65 \text{ m} \leq L \leq 145 \text{ m}$;

$C = 19.0$ for $145 < L \leq 200 \text{ m}$;

$C = 23.6 - 0.023L$ for $200 < L \leq 300 \text{ m}$;

$C = 16.7$ for $L > 300 \text{ m}$;

$C_1 = 1.2 - \frac{s}{2l}$, where l is the spacing of primary members, C_1 is to be taken as 1 for $C_1 > 1$

K — material factor.

Table 2.15.3.5 - Correction Coefficient e

Position	e
Between $X - 0.125L$ to X from F.P.	$\frac{2f - 1}{0.05 - C_b}$
Between F.P. and $X - 0.2L$ from F.P.	$0.5 + \frac{f}{0.9 - C_b}$
Others	1

where: C_b — see 2.15.3.1 of this Section;

f — the ratio of the distance of x , in m, from F.P. and length of ship L , in m, i.e. $f = X/L$;

X — see 2.15.3.1 of this Section.

(2) The strengthened forward bottom plating is to be gradually tapered to adjacent shell plating.

2.15.3.6 The forward bottom strengthening is to be verified by direct calculation assessment as specified in Appendix 4 of this Chapter if any of the following conditions applies:

- (1) where the minimum forward draught of a ship is less than $0.01L$;
- (2) where the arrangements of primary members do not comply with the relevant requirements of 2.15.3 of this Section.

2.15.3.7 In the strengthening region for single bottom framed longitudinally:

- (1) Plate floors complying with the provisions of 2.15.3.4 (1) are to be fitted at alternate frames.
- (2) The section modulus of bottom longitudinals is to be increased by 10% above that obtained from the formula in 2.6.12.2 of this Chapter, and in this case, l in the formula is not to be less than 1.85 m; side keelsons are to be fitted not more than three times the spacing of longitudinals apart and extended as far forward as practicable.

2.15.4 Aft peak strengthening

2.15.4.1 Plate floors are to be fitted at every frame space, the thickness of which is to be 1.5 mm thicker than that in the fore peak as required in this Section. In single screw ships, floors are to be carried well above the stern tube. In way of propeller posts, propeller shaft brackets and rudder

horns, the floors are generally to be carried to the top of the space and are to be increased in thickness.

2.15.4.2 Where the side shell is framed transversely, panting beams and side stringers spaced vertically not more than 2.5 m apart are to be fitted above the floors, or alternatively, perforated flats complying with the requirements of 2.15.1.11 of this Section are to be provided. The panting beams and side stringers as well as the connection of these members to frames are to comply with the requirements for the fore peak.

2.15.4.3 Where the side shell is framed longitudinally, suitable transverses are to be arranged at the top of the tank and the brackets connecting the transverses to web frames are to comply with the requirements of 1.2.7 of this PART.

2.15.4.4 A centreline wash bulkhead is in general to be arranged in tanks, the upper part of the after peak space and counter or cruiser stern. Where the overhang is very large, additional longitudinal wash bulkheads may be required port and starboard. The wash bulkheads are to comply with the requirements of 2.13.10.2 of this Chapter, and stiffeners are to be fitted at every frame space.

2.15.5 Side strengthening above the aft peak

2.15.5.1 Where the side shell of 'tween deck spaces above the after peak tank is transversely framed and the height of such spaces is more than 3 m, intercostal panting stringers are to be provided, of which the web depth is to be the same as that of frames. The web thickness and the sectional area of face plates of these intercostal stringers are to comply with the requirements of 2.15.2.2 of this Section. Where no intercostal side stringer is fitted, the thickness of shell plating within the region is to be increased in accordance with the requirements of 2.15.2.1(2) of this Section. 2.15.5.2

2.15.5.2 Where the side shell of 'tween deck spaces above the after peak tank is transversely framed, web frames are to be fitted not more than 4 frame spaces apart. The section modulus W of web frames is not to be less than that obtained from the following formula:

$$W = 3.5 S d h \sqrt{D} K \text{ cm}^3$$

where: S — spacing of web frames, in m;

d — draught of ship, in m;

h — height of 'tween deck spaces, in m;

D — moulded depth, in m;

K — material factor.

2.15.5.3 Where the side shell of 'tween deck spaces above the after peak tank is framed longitudinally, web frames supporting longitudinals are to be fitted. The spacing of web frames is not to be greater than 2.5 m for ships of 100 m in length or less; and not greater than 3.5 m for ships of 300 m or over in length; the intermediate values are to be obtained by interpolation. The section modulus W of the frames is not to be less than that obtained from the following formula:

$$W = 4.4 S d h \sqrt{D} K \text{ cm}^3$$

where: S , d , h , D and K — the same as those in 2.15.5.2 of this section.

2.15.6 Structural strengthening for bow flare

2.15.6.1 For container ships, ro-ro ships, passenger ships, car carriers and the ships with the similar bow flare, the side structural strengthening at bow is to meet the requirements of Section 8, Chapter 7 of this PART.

SECTION 16 - ENGINE SEATINGS AND SHAFT TUNNELS

2.16.1 Main engine seatings

2.16.1.1 The main engine seating is to be of ample strength and rigidity. It is generally to consist of two longitudinal girders with transverse diaphragms and transverse brackets fitted at every frame space. Transverse diaphragms are to be fitted between longitudinal girders and are to extend to the face plate of girders as far as practicable. Transverse brackets, the width of which is generally not to be less than their depth, are to be fitted at the outside of the longitudinal girders and welded to the face plate of the girders.

2.16.1.2 The longitudinal girders of the seating are to be in line with the bottom side girders. If it is impracticable to do so, partial girders of the same thickness as the bottom side girders are to be fitted under the longitudinal girders. In particular cases, the partial girder may be in the form of a half-depth girder welded to the inner bottom plating and floors only.

2.16.1.3 Scantlings of structural members of main engine seatings

- (1) For large low-speed diesel engines having a power of more than 1,470 kW, the horizontal face plate thickness t and the web thickness t_1 of longitudinal girders, and the thickness t_2 of transverse diaphragms and transverse brackets are not to be less than the values given below:

$$t = 1.44 \sqrt[3]{P} + 10s \text{ mm}$$

$$t_1 = 0.65t \left(1 + \frac{h-1}{10}\right) \text{ mm for } L \geq 90 \text{ m}$$

$$t_1 = 0.70t \text{ mm for } L < 90 \text{ m}$$

$$t_2 = 0.77t_1 \text{ mm for } L \geq 90 \text{ m}$$

$$t_2 = 0.80 t_1 \text{ mm for } L < 90 \text{ m}$$

where: P — main engine power, in kW;

s — spacing of frames, in m;

h — web depth of longitudinal girders, in m.

- (2) For main engines having a power of 1,470 kW or less, the web thickness of longitudinal girders is to be increased by 60% above that of the bottom side girders (for double bottom) or side keelsons (for single bottom) in way of the engine room in the case of diesel engines, and by 30% in the case of turbines or propulsion motors. In both cases, the longitudinal girders are to be provided with a continuous horizontal face plate having a thickness 40% greater than their web

thickness. The longitudinal girders are to be gradually tapered off at their ends. The thickness of the transverse diaphragms and transverse brackets is to be increased by 40% above that of the floors in the case of diesel engines, and by 30% in the case of turbines or propulsion motors. The transverse diaphragms and transverse brackets are to be provided with a face plate or flange.

- (3) The scantlings of main engine seatings may be suitably reduced in the case of high-powered turbines, propulsion motors or medium/high speed diesel engines.

2.16.1.4 The horizontal face plates of longitudinal girders are to be stiffened in way of holding-down bolts by a suitable number of vertical brackets, and the depth of the brackets is to be twice their breadth.

2.16.1.5 Where the main engine seating or the thrust seating is directly bolted to the inner bottom, the thickness t_3 of the inner bottom plating in way is not to be less than that required as follows:

- (1) for large low-speed diesel engines having a power of more than 1,470 kW, $t_3 = t$, t as defined in 2.16.1.3(1) of this Section;
- (2) for main engines having a power of 1,470 kW or less, t_3 is to be equal to twice the thickness of the inner bottom plating in the region, but is not to be less than 20 mm;
- (3) for high-powered turbines, t_3 will be specially considered. The double bottom tanks within the above regions are not to be used for carrying oil fuel or water. Partial or half-depth girders are to be fitted close to holding-down bolts. The longitudinal division bulkheads and side girders in the adjacent oil or water tanks may be regarded as the partial girders at holding-down bolts.

2.16.2 Shaft tunnels

2.16.2.1 Shaft tunnels are to be of watertight construction.

2.16.2.2 The thickness of tunnel plating is to comply with the requirements of 2.12.3.1 of this Chapter for watertight bulkheads. If the top plating is curved, the thickness may be reduced by 10% in dry cargo holds. If the top plating is flat, it is not to be less than 1.1 times the thickness required for the watertight bulkheads. The thickness of top plating of the tunnel under hatchways is to be increased by at least 2 mm, unless covered with wood ceiling as required in 3.3.1.5 of this PART.

2.16.2.3 Stiffeners of shaft tunnels are to be in line with the frames wherever possible, and their section modulus W is not to be less than that obtained from the following formula:

$$W = 6shl^2K \text{ cm}^3$$

where: s — spacing of stiffeners, in m;

h — the vertical distance, in m, measured from the mid-point of the vertical part of the stiffener to bulkhead deck;

l — the length of the vertical part of the stiffener, in m;

K — material factor.

Where the tunnel top is flat, the scantlings of the top beams are not to be less than those required for the beams in way of the steps in watertight bulkheads (see 2.12.8 of this Chapter).

The lower end of the vertical part of stiffeners is to be welded to the inner bottom.

2.16.2.4 Where shaft tunnels pass through or are adjacent to deep tanks, the adjacent bulkheads and their stiffeners are to comply with the requirements of Section 13 of this Chapter for deep tanks.

2.16.2.5 The structure of the thrust and tunnel recesses is to comply with the requirements for the steps in watertight bulkheads. Where these recesses are enclosed by deep tanks, the requirements for bulkheads and stiffeners of deep tanks are to be complied with.

2.16.2.6 The shaft tunnel is to be provided with an emergency exit leading to the weather deck, and the construction of the trunk of the exit is to comply with the requirements for watertight bulkheads. The closing appliance for the exit is to be capable of being operated from both sides.

SECTION 17 SUPERSTRUCTURES AND DECKHOUSES

2.17.1 General requirements

2.17.1.1 All ships are to be provided with forecastles or increased sheer to such a minimum bow height as to meet the requirements of their respective flag Administrations. The forecastles of bulk carriers, ore carriers and combination carriers are to be also in compliance with Section 13, Chapter 8 of this PART.

2.17.1.2 Where superstructures and deckhouses are subject to loading in excess of that as specified in this Section, the scantlings of their structural members are to be appropriately increased in addition to complying with the requirements of this Section.

2.17.1.3 Where long superstructures are provided within $0.5L$ midships, the deck structure of the 1st tier is to comply with the requirements for strength decks and side shell is to comply with the requirements for shell plating.

2.17.1.4 Where long deckhouses are provided within $0.5L$ midships, the thickness of plating and the size of framing of the 1st tier is to be increased according to the contribution of these deckhouses to the longitudinal bending of hull girders.

2.17.1.5 The deckhouses on forecastle deck of offshore supply ships are to comply with the requirements of Section 5, Chapter 11 of this PART.

2.17.1.6 Definitions of tiers of superstructures/deckhouses: The lowest, or first tier, is normally that tier which is directly situated on the uppermost continuous deck to which the Rule moulded depth D is to be measured. The second tier is the next tier above the lowest tier and so on.

2.17.1.7 The deck plating of No.N tier of superstructure/deckhouse is the top plating of this tier of superstructure/deckhouse.

2.17.1.8 Where a freeboard corresponding to or exceeding the uncorrected tabular values of the

International Convention on Load Lines, 1966 can be obtained for a ship with excessive freeboard, i.e. by considering the ship to have a virtual moulded depth D' at least one standard superstructure height less than the Rule moulded depth D (see Figure 2.17.1.8), the 1st tier erection may be treated as the 2nd tier, and the 2nd tier as the 3rd tier when applying the requirements of this Section. The standard superstructure height h_s is to be obtained as follows:

$$h_s = 1.05 + 0.01L_L \text{ m, and } 1.8 \leq h_s \leq 2.3$$

where: L_L — load line length of ship, in m.

However, this does not apply to type 'B' ships with reduced freeboard.

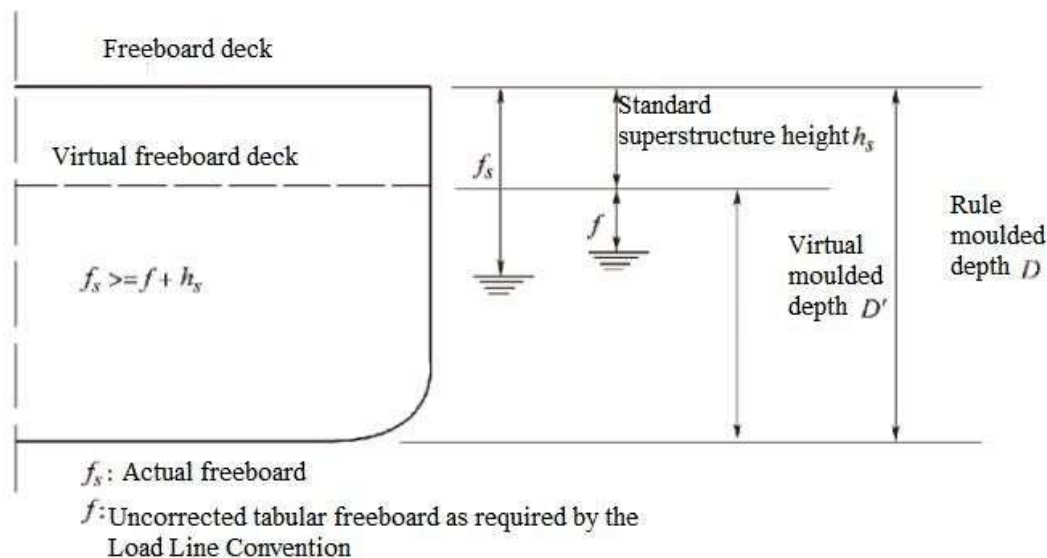


Figure 2.17.1.8

2.17.2 Design pressure head

2.17.2.1 The design pressure head h for end bulkheads of exposed superstructures and boundary bulkheads (end and side bulkheads) of deckhouses is to be obtained as follows and not less than the minimum value in Table 2.17.2.1:

$$h = \alpha \delta (\beta \lambda - \gamma) \text{ m}$$

where: α , β , λ and δ — coefficients, to be determined respectively according to 2.17.2.2, 2.17.2.3, 2.17.2.4 and 2.17.2.5 of this Section;

γ — vertical distance, in m, measured from summer load waterline to mid-span of stiffener or mid-point of panel.

Table 2.17.2.1

Length of ship L (m)	Design pressure head $h_{\min}$ (m)	
	Lowest tier of unprotected fronts	Elsewhere
$L \leq 50$	3.0	1.5
$50 < L < 250$	$0.01L + 2.5$	$0.005L + 1.25$
$L \geq 250$	5.0	2.5

2.17.2.2 Coefficient α is to be determined as follows:

$\alpha = 0.0083L_1 + 2.0$, lowest tier of unprotected fronts

$\alpha = 0.0083L_1 + 1.0$, second tier of unprotected fronts

$\alpha = 0.0067L_1 + 0.5$, third tier of unprotected fronts and above, protected fronts and sides of all tiers

$\alpha = 0.001L_1 - 0.8 (X/L) + 0.7$, aft ends of all tiers where aft of amidships

$\alpha = 0.001L_1 - 0.4 (X/L) + 0.5$, aft ends of all tiers where forward of amidships

where: L, L_1 — length of ship, in m; L_1 need not be taken greater than 300 m;

X — distance, in m, between bulkhead considered and A.P. When determining sides of a deckhouse, the deckhouse is to be subdivided into parts of approximately equal length, not exceeding $0.15L$ each and X is to be taken as the distance between A.P. and the centre of each part considered.

2.17.2.3 Coefficient β is to be determined as follows:

$$\beta = 1.0 + \left(\frac{X/L - 0.45}{C_b + 0.2} \right)^2, \text{ for } X/L \leq 0.45$$

$$\beta = 1.0 + 1.5 \left(\frac{X/L - 0.45}{C_b + 0.2} \right)^2, \text{ for } X/L > 0.45$$

where: L — length of ship, in m;

X — see 2.17.2.2;

C_b — block coefficient, where $C_b < 0.6$, to be taken as 0.6; where $C_b > 0.8$, to be taken as 0.8; where the aft end bulkhead of the superstructure is forward of amidships, C_b used in determining the value β for the aft end bulkhead is not to be taken as less than 0.8.

2.17.2.4 Coefficient λ is to be determined as follows:

$$\lambda = \frac{L}{10} e^{-L/300} - \left[1 - \left(\frac{L}{150} \right)^2 \right] \quad \text{for } 150 \text{ m} \leq L < 300 \text{ m}$$

$$\lambda = \frac{L}{10} e^{-L/300} \quad \text{where: } L \text{ — length of ship, in m.}$$

$$\lambda = 11.03 \quad \text{for } L \geq 300 \text{ m}$$

2.17.2.5 Coefficient δ is to be determined as follows:

$$\delta = 0.7 \frac{b}{B_1} + 0.3 \quad \text{and not less than 0.475}$$

where: b — breadth of deckhouse at the position considered, in m;

B_1 — actual maximum breadth of ship on the exposed weather deck at the position considered, in m.

For exposed parts of superstructures, machinery casings and deckhouses protecting pump room openings, δ is to be taken as 1.

2.17.3 End bulkheads of superstructures and boundary bulkheads of deckhouses

2.17.3.1 The thickness t of end bulkhead plating of superstructures and boundary bulkhead

plating of deckhouses is not to be less than:

$$t = 3s\sqrt{hK} \quad \text{mm}$$

The minimum thickness of the plate, $t_{\min}$, is to comply with the following requirements:

If $L_1 < 65$ m:

$$t = (0.01L_1 + 5.0)\sqrt{K} \quad \text{mm, for lowest tier}$$

$$t = (0.01L_1 + 4.0)\sqrt{K} \quad \text{mm, for upper tiers, and not less than 5 mm}$$

If $L_1 < 65$ m: $t_{\min} = 5.0$ mm, for the lowest unprotected front

$t_{\min} = 4.0$ mm, for all other cases

where: s — spacing of stiffeners, in m;

h — design pressure head, in m, to be calculated according to 2.17.2 of this Section;

L_1 — length of ship, in m, L_1 need not be taken greater than 300 m;

K — material factor.

2.17.3.2 The section modulus W of end bulkhead stiffeners of superstructures and boundary bulkhead stiffeners of deckhouses is not to be less than:

$$W = 3.5sh^2K \text{ cm}^3$$

where: s — spacing of stiffeners, in m;

l — span of stiffener, in m; to be taken as height of deckhouse,
but not less than 2.0 m in anycase;

h — calculated pressure head, in m, to be obtained according to 2.17.2 of this Section;

K — material factor.

Except as required in 2.17.3.3 and 2.17.3.4 of this Section, the end of stiffeners of enclosures of the deckhouse may not be fitted with brackets, provided that the webs of stiffeners are welded to the deck effectively. The section modulus of house side stiffeners need not be greater than that of side frames on the deck situated directly below, taking account of spacing and span.

2.17.3.3 The ends of following stiffeners are to be bracketed or connected by equivalent arrangements. The scantlings of brackets are to be determined according to the relevant provisions of 1.2.6 of this PART:

- (1) Front stiffeners of the lowest tier;
- (2) Front stiffeners of upper tiers in ships over 150 m in length;
- (3) Side stiffeners of single tier deckhouse;
- (4) Aft stiffeners of the lowest aft deckhouse;
- (5) Side stiffeners of upper deckhouses when the length of ship is greater than 150 m, side stiffeners of the lowest deckhouse if two or more tiers of deckhouses are fitted; where such stiffeners are not bracketed but directly welded to the deck, their section modulus is to be increased by 20%.

2.17.3.4 For exposed machinery and pump-room casings, the front stiffeners on amidships casing and all stiffeners on aft end casings which are situated on the deck to which the moulded depth D is measured are to be bracketed at top and bottom. Where such stiffeners are not bracketed but

directly welded to the deck, their section modulus is to be increased by 20% above that required for the stiffeners of deckhouses in the corresponding positions. All other stiffeners on exposed machinery and pump-room casings are to be welded to the decks at top and bottom.

2.17.4 Sides of superstructures

2.17.4.1 The side framing of superstructures is to comply with the following requirements:

- (1) Where the side shell is framed transversely, the relevant requirements of Section 7 of this Chapter are to be complied with.
- (2) Where the sides of superstructures are framed longitudinally and located within the range of $0.3L$ from A.P. forward the bow, the section modulus of longitudinals is not to be less than:

$$W = 6.5sl^2(0.6 + 0.167D_1)K \text{ cm}^3$$

where: s — spacing of longitudinals, in m;
 l — span of longitudinal, in m, not less than 1.5 m;
 $D_1 = d + H_b$, in m, not greater than 20 m,

where: H_b — the minimum bow height as required by load line assignment, in m;
 d — draught, in m;
 K — material factor.

The section modulus of web frames supporting the side longitudinals is not to be less than:

$$W = 8.8Sl^2(0.6 + 0.167D_1)K \text{ cm}^3$$

where: D_1 , K — the same as those in the above formula;
 S — spacing of web frames, in m;
 l — span of web frames, in m.

- (3) Where the sides of superstructures are framed longitudinally and located beyond the range of $0.3L$ from A.P forward the bow, the section modulus of longitudinals is not to be less than:

$$W = 7.5sl^2(0.6 + 0.167D_2)K \text{ cm}^3$$

where: s — spacing of longitudinals, in m;
 l — span of longitudinal, in m, not less than 1.5 m;
 $D_2 = d + H_b$, in m;

where: H_b — the minimum bow height as required by load line assignment, in m;
 d — draught, in m;
 K — material factor.

The section modulus of web frames supporting the side longitudinals is not to be less than:

$$W = 10Sl^2(0.6 + 0.167D_2)K \text{ cm}^3$$

where: D_2 , K — the same as those in the above formula;
 S — spacing of web frames, in m;
 l — span of web frames, in m.

Where the superstructure is located within the range of $0.4L$ amidships and contributes to the longitudinal strength, the relevant requirements of 2.2.7, Section 2 of this Chapter are also to be complied with.

2.17.4.2 The side plating of superstructures is to comply with the following requirements:

(1) The thickness t of side plating of forecastles is not to be less than:

$$t = (0.028L + 5.5) \sqrt{\frac{sK}{s_b}} \quad \text{mm}$$

where: L — length of ship, in m;

s — spacing of frames or longitudinals, in m, to be taken as not less than s_b ;

s_b — standard spacing of frames or longitudinals, in m;

K — material factor.

(2) The thickness t of side plating of bridge and poop is not to be less than:

$$t = (0.025L + 5) \sqrt{\frac{sK}{s_b}} \quad \text{mm}$$

where: L — length of ship, in m;

s — spacing of frames or longitudinals, in m, to be taken as not less than s_b ;

s_b — standard spacing of frames or longitudinals, in m;

K — material factor.

2.17.5 Decks

2.17.5.1 The deck framing of superstructures is to comply with the relevant requirements of Section 8 of this Chapter. The deck framing of the forecastle is also to comply with the following requirements:

- (1) Within the region forward of $0.075L$ from F.P., the spacing of deck girders supporting the beams is generally not to be more than 3.5 m, and that of the transverses supporting the deck longitudinals is generally not to be more than 2.5 m;
- (2) The web depth of deck girders and transverses is not to be less than twice the depth of cutouts for the passage of beams or longitudinals being supported.

2.17.5.2 The section modulus W of the deck longitudinals or beams of deckhouses is not to be less than:

$$W = 5shl^2K \text{ cm}^3, \text{ and not less than } 25s$$

where: s — spacing of deck longitudinals or beams, in m;

l — span of deck longitudinals or beams, in m;

h — design pressure head, in m, to be determined as follows:

0.9 m, for those on first tier deck;

0.6 m, for those on second tier deck;

0.45 m, for those on third tier deck and above;

K — material factor.

2.17.5.3 The scantlings of deck girders and transverses of deckhouses are to be calculated in accordance with the relevant requirements of Section 8 of this Chapter, but the design pressure head is to be as specified in 2.17.5.2 of this Section. The web thickness of girders of deckhouses is not to be less than 1% of their depth plus 2 mm, but not to be less than 4 mm.

2.17.5.4 The thickness t of deck plating of superstructures (except the forecastle) and deckhouses is not to be less than:

$$t = (0.02L + C) \sqrt{\frac{sK}{s_b}} - t_c \quad \text{mm, and not less than 5 mm}$$

where: L — length of ship, in m; not to be taken as greater than 100 m;

s — spacing of deck longitudinals or beams, in m, to be taken as not less than s_b ;

s_b — standard spacing of deck longitudinals or beams, in m;

C — coefficient, to be taken as follows:

5.5, for the first tier deck;

5.0, for the second tier deck;

4.5, for the third tier deck and above;

t_c — $t_c = 1$ for decks of dry spaces within superstructures or deckhouses;

$t_c = 0$ in other cases;

K — material factor.

2.17.5.5 The thickness t of forecastle deck plating is not to be less than:

$$t = (0.02L + 6) \sqrt{\frac{sK}{s_b}} \quad \text{mm}$$

where: L — length of ship, in m;

s — spacing of deck longitudinals or beams, in m, to be taken as not less than s_b ;

s_b — standard spacing of deck longitudinals or beams, in m;

K — material factor.

2.17.6 Local strengthening of superstructures

2.17.6.1 Web frames or partial bulkheads spaced about 9 m apart are to be fitted within the poop or bridge that have large deckhouses or other erections above, to support side and end bulkheads of the deckhouses. Appropriate strength members are also to be fitted in other areas under high loading.

2.17.6.2 The web frames or partial bulkheads within superstructures are to be arranged, where practicable, in line with the watertight bulkheads or other strength members below.

2.17.6.3 Pillars, diaphragms, bulkheads or other strength members are to be arranged under the ends of superstructures for support.

2.17.6.4 To reduce stress concentration in main hull structure in way of ends of superstructures

which are flush with ship's side, the side plating of the superstructures is to extend beyond their ends and the height of the side plating is to be gradually reduced to that of the sheer strake in a smooth transition (free edges of extension plating generally in an oval shape with horizontal axis, see Figure 2.17.6.4). This plating is to be supported by stiffened brackets and to be efficiently stiffened at the upper edge by a face plate having the same thickness as the extension plating and a breadth not less than 10 times its thickness. The extension plating is to comply with the following requirements:

- (1) For end bulkheads of superstructures situated within $0.5L$ amidships, the length of the extension plating is not to be less than 1.5 times that of the superstructure and its thickness is to be increased by 25%;
- (2) For end bulkheads of superstructures situated within $0.2L$ from the ship's ends, the length of the extension plating is not to be less than the height of the superstructure and its thickness need not be increased;
- (3) For end bulkheads of superstructures situated between $0.2L$ and $0.25L$ from the ship's ends, the increased length and thickness of the extension plating is to be obtained by interpolation.

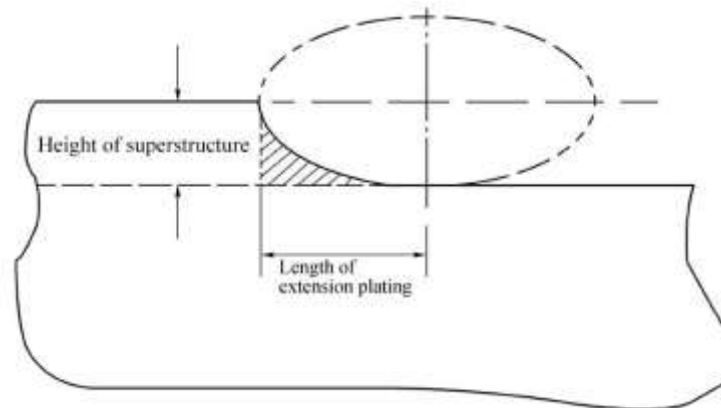


Figure 2.17.6.4

2.17.6.5 The thickness of the upper deck stringer plate and the sheer strake is to be increased at the ends of the superstructure from at least two frame spaces inside the superstructure to two frame spaces beyond the extension of side plating (see Figure 2.17.6.5) in accordance with the following requirements:

- (1) Where the end bulkheads of the superstructure are situated within $0.5L$ amidships, the thickness of stringer plates and sheer strakes is to be increased by 20%;
- (2) Where the end bulkheads of the superstructure are situated within $0.2L$ from the ship's ends, the thickness of stringer plates and sheer strakes need not be increased;
- (3) Where the end bulkheads of the superstructure are situated between $0.2L$ and $0.25L$ from the ship's ends, the increased thickness of stringer plates and sheer strakes is to be obtained by interpolation.

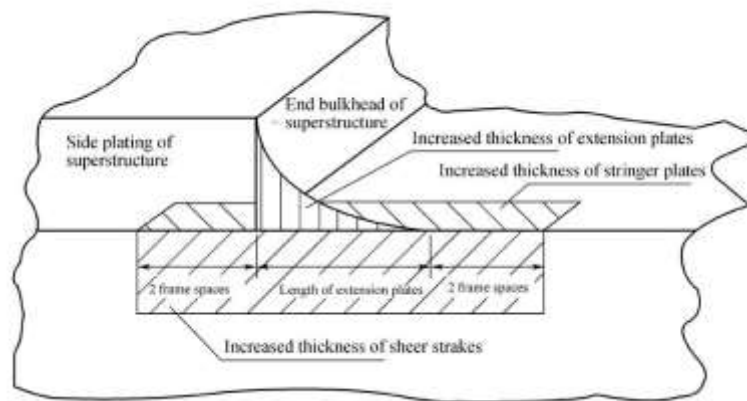


Figure 2.17.6.5

2.17.7 Local strengthening of deckhouses

2.17.7.1 Adequate support under the ends of deckhouses is to be provided in the form of pillars, diaphragms, bulkheads or other strength members. At the corners of houses and in way of supporting structures, attention is to be given to the connection to the deck, and inserts or equivalent arrangements are generally to be fitted.

2.17.7.2 All openings cut in the sides of long deckhouses are to be adequately strengthened and have well rounded corners. Continuous coamings with adequate height are to be fitted below and above doors or similar openings. House tops are to be strengthened in way of boats and davits. Special care is to be taken to minimize the size and number of openings in the side bulkheads in the region of the ends of deckhouses within 0.5L amidships.

2.17.7.3 The sides and ends of the long deckhouses on the lowest tier deck are generally to be strengthened by partial bulkheads or vertical webs spaced about 9 m apart, and these stiffening members are, as far as practicable, to be arranged in line with the strengthening members within the 'tween deck space below the deckhouse.

2.17.8 Raised quarterdecks

2.17.8.1 The scantlings of the main frames in way of the raised quarter deck are to be determined according to the requirements of Section 7 of this Chapter. In this case the span of the frame is to be measured to the raised quarter deck.

The scantlings of the deck frames in way of the raised quarter deck are to be determined in accordance with the relevant requirements for the strength deck as specified in Section 8 of this Chapter.

The thickness of the raised quarter deck sheer strake is to be determined according to the requirements of Section 3 of this Chapter, and the thickness of deck plating is to be determined in accordance with the relevant requirements for strength deck as specified in Section 4 of this Chapter. In such cases the moulded depth is to be taken as that at the raised quarter deck.

The thickness of break bulkheads and the scantlings of stiffeners are to be determined in accordance with the requirements for end bulkheads of corresponding superstructures.

2.17.8.2 Strengthening at the break within 0.5L amidships

- (1) For $L < 65$ m, the strength deck stringer plate and the raised quarter deck stringer plate are to extend respectively for 3 or 4 frame spaces on either side of the break bulkhead and are to be gradually tapered off;
- (2) For $L \geq 65$ m, the upper and raised deck plating at the break is to overlap for 2 or 3 frame spaces, and in this case the stringer plates of both decks are to extend forward for 2 or 3 frame spaces beyond the end of overlapped plating. Vertical diaphragm plates spaced not more than 1.5 m apart in parallel with the longitudinal centreline are to be fitted between the overlapped deck plating. The thickness of the diaphragm plates is to be the same as that of the break bulkhead plating, and the diaphragms are to be efficiently stiffened and their free edges are to be flanged or provided with a face plate.

2.17.8.3 Where the break is located outside of 0.5L amidships, the strength deck stringer plate is to extend for 3 frame spaces beyond the break and is to be gradually tapered off.

2.17.8.4 The sheer strake is to be increased in thickness by 30% for a distance of 3 to 5 frame spaces on either side of the break bulkhead. Where a raised quarter deck is connected to a long bridge, the sheer strake of side plating within the raised quarter deck area is to be increased in thickness by 25% for a distance of at least 2 frame spaces on either side of the break, and the side plating of the bridge is to be gradually tapered in a curve line from the end of the bridge deck stringer plate into the sheer strake of side plating within raised quarter deck area over a length more than 1.5 times the height of the bridge above the raised quarter deck.

2.17.9 Machinery casings

2.17.9.1 Machinery space openings in the exposed deck are to be protected by strong steel casings. Machinery casings situated on the freeboard or raised quarter deck are to be enclosed in the superstructures or deckhouses so far as practicable.

2.17.9.2 Doors in machinery casings are to be of steel and rigid construction, and are to be capable of being operated from both sides.

2.17.9.3 The scantlings of boundary bulkheads of exposed casings are to be determined in accordance with the requirements for those of the deckhouses in the corresponding positions.

2.17.9.4 The scantlings of boundary bulkheads of non-exposed casings are to comply with the following requirements:

- (1) The minimum thickness of boundary bulkheads of the casings is not to be less than 6.5 mm in way of cargo spaces and not to be less than 5 mm in way of accommodation spaces;
- (2) The section modulus W of the stiffeners of boundary bulkheads of the casings is not to be less than that obtained from the following formula:

$$W = 8s/K \text{ cm}^3$$

where: s — spacing of stiffeners, in m;

l — span of stiffener, in m;

K — material factor.

For ships of 65 m or over in length, the depth of stiffeners is not to be less than 60 mm.

2.17.9.5 Where casing stiffeners support the deck transverses or girders or where they are in line with pillars below, they are to be suitably strengthened.

2.17.9.6 Where the casing sides act as girders supporting decks above, the openings for doors, windows, etc., in the sides are to be effectively strengthened. Particular attention is to be paid to stiffening where the casing supports the funnel or exhaust uptakes.

2.17.10 Breakwater

2.17.10.1 The load under consideration is to be determined with the requirements for fronts of superstructures in 2.17.2 of this Section as reference.

2.17.10.2 The thickness of breakwater plating and the scantlings of breakwater stiffeners are to be determined according to 2.17.3 of this Section.

2.17.10.3 The scantlings of main members (horizontal girders and vertical webs) supporting breakwaters are to be determined by direct calculations, and the permissible stress is as follows:

$$[\sigma_e] = \sqrt{\sigma^2 + 3\tau^2} = 235 / K \quad \text{N/mm}^2$$

where: K — material factor.

SECTION 18 - HELICOPTER DECKS

2.18.1 General requirements

2.18.1.1 This Section applies to all ships fitted with areas and facilities for normal takeoff and landing of helicopters.

2.18.1.2 Helicopter decks covered by this Section mean helicopter deck structure only.

2.18.1.3 For helicopter deck connected by bolts and splice other than welding, special consideration is to be given to the requirements for structural strength.

2.18.2 Plans and documents

2.18.2.1 The following plans and documents are to be submitted for approval:

- (1) Detailed arrangement of helicopter deck, including overall dimensions, landing area/securing area, if any;
- (2) Structural plan for helicopter deck (appropriate strength calculations are submitted for information).

2.18.2.2 Loading manual is to include information on models and parameters of helicopters to be used, including maximum takeoff weight, overall length of helicopter (including rotation of rotor),

size of wheel print and tracking width.

2.18.3 Arrangement of helicopter deck

2.18.3.1 The arrangement and construction of helicopter deck is to meet the applicable standards accepted by the flag Administration, such as the annex to IMO MSC/Circ.895 and MSC.1/Circ.1524—Recommendation on Helicopter Landing Areas on Ro-Ro Passenger Ships, International Chamber of Shipping (ICS)- Guide to Helicopter/Ship Operations, International Aeronautical and Maritime Search and Rescue Manual (IAMSAR) and Offshore Helicopter Landing Areas-Guidance on Standards (CAP437).

2.18.4 Design conditions

2.18.4.1 The supporting structure of the helicopter platform is to be designed to the following three conditions: overall distributed loading, helicopter landing impact loading and stowed helicopter loading (if provisions are made to accommodate the helicopter secured to the deck in a predetermined position):

(1) Overall distributed loading:

① a minimum distributed loading of 2 kN/m^2 is to be taken over the entire helicopter deck.

(2) Helicopter landing impact loading: Combination of the following loads is to be taken into account:

① for normal landing, vertical impact loading $P_H = 1.5P$ (P being the maximum takeoff weight), uniformly distributed on both wheel prints when landing (landing of both wheels at the same time is generally assumed). Where no data on actual size of wheel prints are available, the size of each print may be taken as a square area of $0.30 \text{ m} \times 0.30 \text{ m}$. The structural members are to be designed according to the worst landing position with regard to forces acting on them. Where the upper deck of a superstructure or deckhouse is used as a helicopter platform deck and the spaces below are normally manned (control room, quarters, etc.), the above vertical impact loading $P_H = 1.75P$;

② the structural weight of the helicopter deck;

③ where necessary, a uniformly distributed loading of 0.5 kN/m^2 , representing wet snow, ice or other environmental loading, is to be considered.

(3) Stowed helicopter loading: Combination of the following loads is to be taken into account:

① wheel loading at maximum takeoff weight, with landing area being assumed as that for helicopter landing impact loading;

② the structural weight of the helicopter deck;

③ where necessary, a uniformly distributed loading of 0.5 kN/m^2 , representing wet snow, ice or other environmental loading, is to be considered;

④ in addition, where stowage of helicopters is possible, the inertial forces of helicopter and helicopter platform due to ship's motion under corresponding environmental conditions are to be considered. If no proper data are available, both the horizontal and vertical inertial forces may be taken as 0.5 times the loading corresponding to the weight of helicopter and helicopter platform structure.

2.18.4.2 For helicopters fitted with landing gear other than wheels, the landing area is to be determined according to the data provided by manufacturers.

2.18.5 Helicopter deck plating

2.18.5.1 The initial plate thickness of the helicopter deck may be calculated in accordance with 2.21.2.1(1) of this Chapter, with loading being the wheel impact loading required for the above design conditions.

2.18.5.2 Where the helicopter deck is the strength deck within $0.4L$ amidships, the wheel impact loading obtained according to 2.18.5.1 of this Section is to be multiplied by a factor of 1.18. This factor is linearly reduced to 1.00 within $0.4L$ amidships aft or forward along ship's length.

2.18.5.3 The helicopter deck plate thickness is to be based on the initial thickness calculated according to 2.18.4.1 or 2.18.4.2, and is to comply with the strength verification of the entire helicopter deck structure by direct calculation.

2.18.5.4 Hatch covers used as helicopter deck are to comply with this Section and in addition, Section 20 of this Chapter.

2.18.5.5 Where the helicopter deck forms part of a weather deck or other decks, the scantlings are not to be less than those required for decks in the same position.

2.18.6 Strength verification by direct calculation

2.18.6.1 Direct calculation of helicopter deck structure is to be preformed by 3-dimensional finite element structural analysis, and recognized programs and structural idealization methods are to be used.

2.18.6.2 The permissible bending stress $[\sigma]$, shear stress $[\tau]$ of helicopter deck plating, deck framing and their supporting structure and the permissible stress $[\sigma_{cb}]$ of compressed components are as follows:

(1) The permissible bending stress $[\sigma]$ is to be determined according to Table 2.18.6.2.

Table 2.18.6.2 - Permissible Bending Stress $[\sigma]$

Structural member Design Condition	Deck Plating	Longitudinals, transverses and other secondary deck members	Girders, web beams and other main deck members Stanchions, supports and other truss supports of platform
Overall Distributed Loading	$0.6 R_{eH}^{(3)}$	$0.6 R_{eH}$	$0.6 R_{eH}^{(1)}$
Helicopter Landing Impact Loading	$R_{eH}^{(2)}$	R_{eH}	$0.9 R_{eH}^{(1)}$
Stowed Helicopter Loading	R_{eH}	$0.9 R_{eH}$	$0.9 R_{eH}^{(1)}$

Notes: R_{eH} — yield stress of material, in N/mm^2 ; for aluminium alloy, taken as $Rp0.2$, see Section 3, Chapter 1 of this PART.

① Components under axial compression are to be checked to the lesser of permissible bending stress and permissible

critical buckling stress.

- ② For helicopter landing impact loading, where the stress of helicopter deck plating is obtained according to a four-sides supported plate subjected to vertically distributed loading, the permissible stress may be taken as $1.1 ReH$.
- ③ For overall distributed loading, the helicopter deck plating thickness is not to be less than the minimum thickness required by 2.18.5 and the Rules.

(2) Permissible shear stress $[\tau]$: $[\tau] = [\sigma] / 3$.

(3) Permissible compressive stress $[\sigma_{cb}]$ is to be calculated according to 2.2.7.5(1) and 2.2.7.6 of this Chapter.

2.18.6.3 The value of the permissible bending stress for framing and girders of strength deck used as helicopter deck is to be multiplied by a reduction factor in Table 2.18.6.3.

Table 2.18.6.3 - Reduction Factor

Location of helicopter deck	Reduction factor	Location of helicopter deck	Reduction factor
Area $0.4L$ amidships	0.7	A.P./F.P. area	1.0
Area between A.P. and F.P.	Linear interpolation		

SECTION 19 - BULWARKS AND GUARDRAILS

2.19.1 General requirements

2.19.1.1 Guardrails or bulwarks are to be fitted around all exposed decks. The height of the bulwarks or guardrails is to be at least 1 m from the deck, provided that where this height would interfere with the normal operation of the ship, a lesser height may be approved, if the Administration is satisfied that adequate protection is provided.

2.19.1.2 The ship designed for the carriage of timber deck cargoes is to be fitted either with permanent bulwarks at least 1 m in height, specially stiffened on the upper edge and supported by strong bulwark stays attached to the deck and provided with necessary freeing ports, or with efficient rails of the same height and of specially strong construction.

2.19.2 Bulwarks

2.19.2.1 The plating thickness of bulwarks on freeboard decks is not to be less than 5 mm for ships having a length less than 65 m and not to be less than 6 mm for ships having a length equal to 65 m or over. The plating thickness of bulwarks elsewhere may be suitably reduced.

2.19.2.2 The top edge of bulwarks is to be stiffened by a flat bar or profile steel.

2.19.2.3 Bulwarks are to be supported by stays with flange or face plate from the deck in line with the beams or beam webs. Where the frame spacing does not exceed 620 mm, the spacing of stays is not to exceed 3 frame spaces. Where the frame spacing exceeds 620 mm or where the ship is intended for the carriage of timber deck cargoes, the spacing of stays is not to be greater than 2 frame spaces. Where the bulwarks on the forecastle deck have a great flare, stays are to be fitted at every frame.

2.19.2.4 The section modulus W at the bottom of bulwark stays is not to be less than that obtained from the following formula:

$$W = (30 + 0.45L)SH^2K \text{ cm}^3$$

where: S — spacing of stays, in m;

L — length of ship, in m, not to be taken as greater than 100 m;

H — height of bulwark, in m;

K — material factor.

Where the flange of the stay is not welded to the deck, such a flange is not to be considered for the section modulus.

2.19.2.5 Bulwarks are to be adequately strengthened in way of mast shrouds or eyeplates for cargo gear and in way of fairleaders.

2.19.2.6 Where bulwarks are cut to form a gangway or other openings, stays of increased strength are to be fitted at the ends of the openings. Bulwarks are not to be cut for gangway or other openings near the breaks of superstructures.

2.19.2.7 Bulwarks are as far as practicable not to be welded to the sheer strake amidships so as to ensure their freedom from the longitudinal bending of the hull.

2.19.3 Guardrails

2.19.3.1 Guardrails fitted on superstructure and freeboard decks are to have at least three courses. The opening below the lowest course of the guardrails is not to exceed 230 mm. The other courses are to be not more than 380 mm apart. In the case of ships with rounded gunwales the guardrail supports are to be placed on the flat of the deck. In other locations, guardrails with at least two courses are to be fitted.

2.19.3.2 Where external glass balustrades are fitted, reference may be made to relevant requirements of Section 8, Chapter 9 of this PART.

SECTION 20 - HATCHWAYS AND HATCH COVERS

2.20.1 General requirements

2.20.1.1 In addition to the requirements of this Section, exposed hatchways and hatch covers are to comply with the relevant requirements of the Amendments to Annex I to Annex B of the Protocol of 1988 Relating to the International Convention on Load Lines, 1966.

2.20.1.2 The structural scantlings of non-exposed hatch covers may be determined according to the relevant requirements of this Section, depending on their structural configuration and with only permissible cargo loads being taken into account.

2.20.1.3 The scantlings of steel hatch covers for deep tanks may be determined according to the relevant requirements of this Section and depending on the position of hatch covers, but in no case are to be less than those required in Section 13 of this Chapter for deep tank deck and its framing.

2.20.1.4 Where wheeled vehicles are to be stowed on hatch covers or used for cargo handling, the scantlings of hatch covers are also to comply with the requirements for vehicle deck in Section 21 of this Chapter.

2.20.1.5 The scantlings of hatch covers used as helicopter deck are also to comply with the requirements for helicopter decks in Section 18 of this Chapter.

2.20.1.6 Except as otherwise provided, the width of the attached plating of hatch cover stiffeners and girders is to be determined according to 1.2.2 of Section 2, Chapter 1 of this PART. However, the areas of stiffeners are not to be included in the area of the attached plating of girders.

2.20.1.7 For the hatch covers on the lower deck within cargo holds, the strength is to be checked according to the requirements of 2.20.3.

2.20.1.8 Height of hatch coamings

- (1) at Position 1, the height is not to be less than 600 mm;
- (2) at Position 2, the height is not to be less than 450 mm;
- (3) for ships provided with steel weathertight hatch covers, with the consent of the flag State Administration, the height of hatch coamings may be suitably reduced provided that efficient measures have been taken and that the safety of the ship is not impaired;
- (4) for hatchways on unexposed freeboard decks or exposed superstructure decks, hatchway coamings with a suitable height may be provided depending upon the position of the hatchways and the protection necessitated by such hatchways.

2.20.1.9 Hatch cover types

(1) Single skin cover

A hatch cover made of steel or equivalent material that is designed to comply with ICLL Regulation 16. The cover has continuous top and side plating, but is open underneath with the stiffening structure exposed. The cover is to be weathertight and fitted with gaskets and clamping devices unless specifically exempted from such fittings.

(2) Double skin cover

A hatch cover as above but with continuous bottom plating such that all the stiffening structure and internals are protected from the environment.

(3) Pontoon type cover

A special type of portable cover, secured weathertight by tarpaulins and battening devices. Such covers are to be designed in accordance with ICLL Regulation 15.

Note: Modern designs of lift-away hatch covers are in many cases called pontoon covers. This definition does not fit to the (3) above. Modern lift-away hatch covers are to fall into one of the two categories of single skin covers and double skin covers.

2.20.2 Weathertight steel hatch covers

2.20.2.1 General requirements

- (1) These requirements apply to all ships except CSR bulk carriers, and are for all cargo hatch covers and coamings on exposed decks. As specified in this Section, parts of the requirements are for some specific ship types as categorized below:
 - ① Type-1 ships, including all ships except bulk carriers, self-unloading bulk carriers, ore carriers and combination carriers.
 - ② Type-2 ships, including all bulk carriers, self-unloading bulk carriers, ore carriers and combination carriers.
- (2) The strength requirements are applicable to hatch covers and hatch coamings of stiffened plate construction and their closing arrangements.
- (3) These requirements are applicable to hatch covers and coamings made of steel. The materials of hatch covers and hatch coamings are to meet the relevant requirements of Section 3, Chapter 1 of this PART. The material class I is to be applied for top plate, bottom plate and primary supporting members of hatch covers. Equivalent materials and novel designs subject to approval by ISC.
- (4) Primary supporting members and secondary stiffeners of hatch covers are to be continuous over the breadth and length of hatch covers, as far as practical. When this is impractical, sniped end connections are not to be used and appropriate arrangements are to be adopted to provide sufficient load carrying capacity.

The spacing of primary supporting members parallel to the direction of secondary stiffeners is not to exceed $1/3$ of the span of primary supporting member. When strength calculation is carried out by FE analysis using plane strain or shell elements, this requirement may be relaxed appropriately. Secondary stiffeners of hatch coamings are to be continuous over the breadth and length of hatch coamings.

- (5) Unless stipulated otherwise, the thickness t in these requirements is net thickness.
 The net thicknesses are the member thicknesses necessary to obtain the minimum net scantlings required by 2.20.2.3 to 2.20.2.6 and 2.20.2.8 of this Section.
 The required gross thickness is obtained by adding the corrosion addition t_s , given in 2.20.2.10 of this Section, to the net thickness t_s .
 Strength calculations using FEM are to be performed with net scantlings.

2.20.2.2 Hatch cover and coaming load model

The structural strength evaluation of hatch covers and hatch coamings is to be carried out using the design loads defined as follows:

Definitions:

L = length of ship, in m;

LL = load line length, in m;

x = longitudinal distance measured from midpoint of structural member to the aft end of L or L_L , in m;

D_{min} = the least moulded depth, in m, as defined in Regulation 3 of ICLL Annex I;

h_N = standard superstructure height, in m, to be calculated as follows:

$h_N = 1.05 + 0.01L_L$, and $1.8 \leq h_N \leq 2.3$.

(1) Vertical weather design load

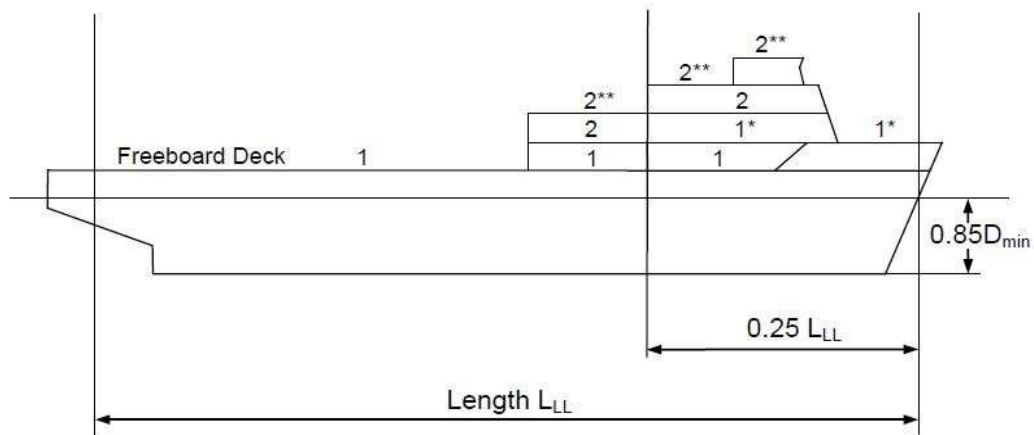
The pressure p_H , in kN/m^2 , on the hatch cover panel is given by ICLL. This may be taken from Table 2.20.2.2(1). The vertical weather design load is not to be combined with cargo loads in 2.20.2.2(3) and (4).

For Position 1 and Position 2, see Figure 2.20.2.2(1).

Where an increased freeboard is assigned, the design load for hatch covers on the actual freeboard deck may be as required for a superstructure deck, provided that the summer freeboard is such that the resulting draught will not be greater than that corresponding to the minimum freeboard calculated from an assumed freeboard deck situated at a distance at least equal to the standard superstructure height h_N below the actual freeboard deck, see Figure 2.20.2.2(2).

Table 2.20.2.2(1) - Vertical Design Load p_H of Weather Deck Hatches

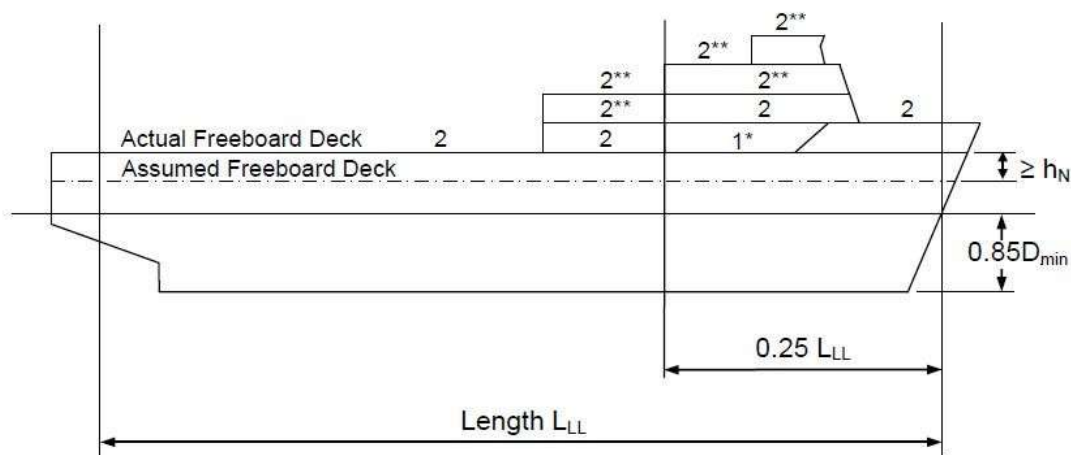
Position	Vertical design load p_H , kN/m^2	
1	$\frac{x}{L_L} \leq 0.75$	$0.75 < \frac{x}{L_L} \leq 1.0$
	For $24\text{m} \leq L_L \leq 100\text{m}$	
	$\frac{9.81}{76}(1.5L_L + 116)$	On freeboard deck: $\frac{9.81}{76} \left[(4.28L_L + 28) \frac{x}{L_L} - 1.71L_L + 95 \right]$
		Upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck: $\frac{9.81}{76}(1.5L_L + 116)$
	For $L_L \leq 100\text{m}$	
	9.81×3.5	On freeboard deck for type B ships according to ICLL: $9.81 \left[(0.0296L_L + 3.04) \frac{x}{L_L} - 0.0222L_L + 1.22 \right]$
		On freeboard deck for ships with less freeboard than type B according to ICLL: $9.81 \left[(0.1452L_L - 8.52) \frac{x}{L_L} - 0.1089L_L + 9.89 \right]$ $L_L = L_L$, but not more than 340 m
		Upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck: 9.81×3.5
2	For $24\text{m} \leq L_L \leq 100\text{m}$	
	$\frac{9.81}{76}(1.1L_L + 87.6)$	
	For $L_L > 100\text{m}$	
	9.81×2.6	
	Upon exposed superstructure decks located at least one superstructure standard height above the lowest Position 2 deck: 9.81×2.1	



* — reduced load upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck;

** — reduced load upon exposed superstructure decks of vessels with $LL > 100$ m located at least one superstructure standard height above the lowest Position 2 deck.

Figure 2.20.2.2(1) Positions 1 and 2



* — reduced load upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck;

** — reduced load upon exposed superstructure decks of vessels with $LL > 100$ m located at least one superstructure standard height above the lowest Position 2 deck.

Figure 2.20.2.2(2) Positions 1 and 2 for an Increased Freeboard

(2) Horizontal weather design load

① General horizontal weather design load

The horizontal weather design load p_A , in kN/m^2 , for determining the scantlings of outer edge girders (skirt plates) of weather deck hatch covers and of hatch coamings is to be calculated by the following formula:

$$p_A = ac(bfc_L - z) \quad \text{kN/m}^2$$

where:

$$f = \frac{L}{25} + 4.1, \quad \text{for } L < 90 \text{ m};$$

$$f = 10.75 - \left(\frac{300 - L}{100} \right)^{1.5}, \text{ for } 90\text{m} \leq L < 300\text{m};$$

$$f = 10.75, \text{ for } 300\text{m} \leq L < 350\text{m};$$

$$f = 10.75 - \left(\frac{L - 350}{150} \right)^{1.5}, \text{ for } 350\text{m} \leq L \leq 500\text{m};$$

$$c_L = 1, \text{ for } L < 90 \text{ m};$$

$$C_L = 1, \text{ for } L \geq 90\text{m};$$

$$a = 20 + \frac{L_1}{12}, \text{ for unprotected front coamings and hatch cover skirt plates};$$

$$a = 10 + \frac{L_1}{12}, \text{ for unprotected front coamings and hatch cover skirt plates, where the distance from the actual freeboard deck to the summer load line exceeds the minimum non-corrected tabular freeboard according to ICLL by at least one standard superstructure height};$$

$$a = 5 + \frac{L_1}{15}, \text{ for side and protected front coamings and hatch cover skirt plates};$$

$$a = 7 + \frac{L_1}{100} - \frac{8x'}{L}, \text{ for aft ends of coamings and aft hatch cover skirt plates abaft amidships};$$

$$a = 5 + \frac{L_1}{100} - \frac{4x'}{L}, \text{ for aft ends of coamings and aft hatch cover skirt plates forward of amidships};$$

$$L_1 = L, \text{ but need not be taken as greater than } 300 \text{ m};$$

$$b = 1.0 + \left(\frac{\frac{x'}{L} - 0.45}{C_b + 0.2} \right)^2, \text{ for } \frac{x'}{L} < 0.45;$$

$$b = 1.0 + 1.5 \left(\frac{\frac{x'}{L} - 0.45}{C_b + 0.2} \right)^2, \text{ for } \frac{x'}{L} \geq 0.45;$$

C_b — block coefficient, $0.6 \leq C_b \leq 0.8$, when determining scantlings of aft ends of coamings and aft

hatch cover skirt plates forward of amidships, C_b taken less than 0.8;

x' — distance in m, between the transverse coaming or hatch cover skirt plate considered and aft

end of the length L . For side coamings or side hatch cover skirt plates, the side is to be subdivided into parts of approximately equal length, not exceeding $0.15 L$ each, and “ x ” is to be taken as the distance between aft end of the length L and the centre of each part considered;

z — vertical distance, in m, from the summer load line to the midpoint of stiffener span, or to the middle of the plate field;

$c = 0.3 + 0.7 \frac{b'}{B'}$, the $\frac{b'}{B'}$ is not to be less than 0.25;

b' — breadth of coaming, in m, at the position considered;

B' — actual maximum breadth of ship, in m, on the exposed weather deck at the position considered.

The horizontal design load is not to be taken less than the minimum values given in Table 2.20.2.2(2).

Table 2.20.2.2(2) - Minimum Horizontal Design Load P_{Amin}

L	Unprotected Fronts	Elsewhere
≤ 50 m	30	15
> 50 m and < 250 m	$25 + L/10$	$12.5 + L/20$
≥ 250 m	50	25

② Horizontal weather design load applicable to coamings of Type-2 ships

The pressure P_{coam} , in kN/m^2 , on the No. 1 forward transverse hatch coaming is given by:

$P_{coam} = 220 \text{ kN/m}^2$, when a forecastle is fitted in accordance with Section 13, Chapter 8 of this PART;

$P_{coam} = 290 \text{ kN/m}^2$ in the other cases;

The pressure P_{coam} , in kN/m^2 , on the other coamings is given by:

$P_{coam} = 220 \text{ kN/m}^2$

Note: The horizontal weather design loads p_A and P_{coam} need not be included in the direct strength calculation of the hatch cover, unless it is utilized for the design of substructures of horizontal support according to 2.20.2.9(2) ③.

(3) Cargo loads

① Distributed loads

The uniform cargo load on hatch covers due to cargo loads p_L , resulting from heave and pitch (i.e. ship in upright condition) is to be determined according to the following formula:

$$p_L = p_C(1 + a_V) \quad \text{kN/m}^2$$

where: p_C — uniform cargo load, in kN/m^2 ;

a_V — vertical acceleration addition as follows:

$$a_V = Fm;$$

$$F = \frac{0.11v_0}{\sqrt{L}};$$

$$m = m_0 - 5(m_0 - 1)\frac{x}{L} \quad \text{for } 0 \leq \frac{x}{L} \leq 0.2;$$

$$m = 1.0 \quad \text{for } 0.2 < \frac{x}{L} \leq 0.7;$$

$$m = 1 + \frac{m_0 + 1}{0.3} \left[\frac{x}{L} - 0.7 \right] \quad \text{for } 0.7 < \frac{x}{L} \leq 1.0;$$

$$m_0 = 1.5 + F;$$

v_0 — maximum speed at summer load line draught, is not to be taken less than $\sqrt{L}$, in kn.

② Point loads

The load P , in kN, due to a concentrated force P_S , in kN, except for container load, resulting from heave and pitch (i.e. ship in upright condition) is to be determined as follows:

$$P = P_S(1 + a_V) \quad \text{kN}$$

(4) Container loads

① The loads defined in ② to ④ are to be applied where containers are stowed on the hatch cover.

② Corner loads for ship in upright condition

The load P , in kN, applied at each corner of a container stack, and resulting from heave and pitch (i.e. ship in upright condition) is to be determined as follows:

$$P = 9.81 \frac{M}{4} (1 + a_V) \quad \text{kN}$$

where:

a_V — vertical acceleration addition according to (3) ①;

M — maximum designed mass of container stack, in t.

③ Corner loads for ship in heel condition

Where containers are stowed on hatch covers, the loads due to heave, pitch and the ship's rolling motion are to be determined as follows (see Figure 2.20.2.2(4)):

$$A_z = 9.81 \frac{M}{2} (1 + a_V) \left(0.45 - 0.42 \frac{h_m}{b} \right) \quad \text{kN}$$

$$B_z = 9.81 \frac{M}{2} (1 + a_V) \left(0.45 + 0.42 \frac{h_m}{b} \right) \quad \text{kN}$$

$$B_y = 2.4M \quad \text{kN}$$

where:

a_V — vertical acceleration addition according to 2.20.2.2(3);

M — maximum designed mass of container stack, in t;

h_m — designed height of centre of gravity of stack above hatch cover top, in m, may be calculated as weighted mean value of the stack, where the centre of gravity of each tier is assumed to be located at the centre of each container, = $\frac{\sum W_i Z_i}{\sum W_i}$;

Z_i — distance from hatch cover top to the centre of i th container, in m;

W_i — mass of i th container, in t;

b — distance between foot points, in m;

A_z, B_z — support forces in z-direction at the forward and aft stack corners;

B_y — support forces in y-direction at the forward and aft stack corners.

Values of A_z and B_z applied for the hatch cover strength evaluation are to be shown in the drawings of the hatch covers.

Note: It is recommended that container loads as calculated above are considered as limit for foot point loads of container stacks in the calculations of cargo securing (container lashing).



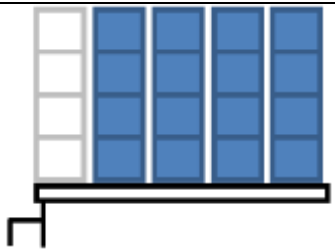
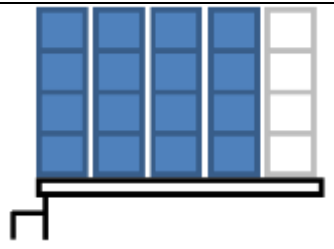
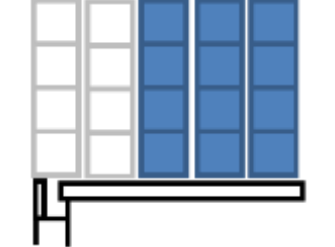
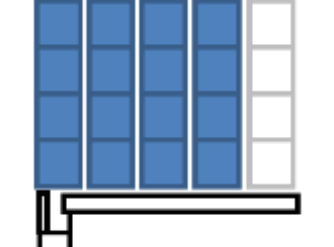
Figure 2.20.2.2(4)

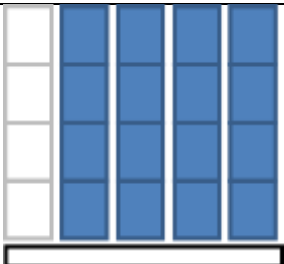
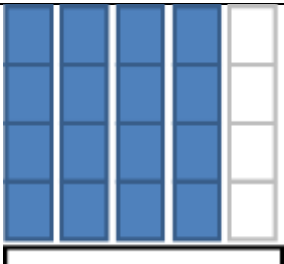
④ Load cases with partial loading

The load cases in ② and ③ above are also to be considered for partial non-homogeneous loading which may occur in practice, e.g. where specified container stack places are empty. For each hatch cover, the heel directions, as shown in Table 2.20.2.2(4), are to be considered. The load case of partial loading of container hatch covers may be evaluated using a simplified approach, where the hatch cover is loaded without the outermost stacks that are located completely on the hatch cover. If there are additional stacks that are supported partially by the hatch cover and partially by container stanchions then the loads from these stacks may be neglected, refer to Table 2.20.2.2(4) Partial loading of container hatch covers. In addition, the case where only the stack places supported partially by the hatch cover and partially by container stanchions are left empty is to be assessed in order to consider the maximum loads in the vertical hatch cover supports.

It may be necessary to also consider partial load cases where more or different container stack places are left empty. Therefore, ISC may require that additional partial load cases other than those in Table 2.20.2.2(4) be considered.

Table 2.20.2.2(4)-Partial loading of container hatch covers

Heel direction		
Hatch covers supported by the longitudinal hatch coaming with all container stacks located completely on the hatch cover		
Hatch covers supported by the longitudinal hatch coaming with the outermost container stack supported partially by the hatch cover and partially by container stanchions		

Hatch covers not supported by the longitudinal hatch coaming (center hatch covers)		

⑤ Mixed stowage of 20' and 40' containers on hatch cover

In the case of mixed stowage (20'+40' container combined stack), the foot point forces at the fore and aft end of the hatch cover are not to be higher than resulting from the design stack weight for 40' containers, and the foot point forces at the middle of the cover are not to be higher than resulting from the design stack weight for 20' containers.

- (5) Hatch covers, which in addition to the loads according to (1) to (4) above are loaded in the ship's transverse direction by forces due to elastic deformations of the ship's hull, are to be designed such that the sum of stresses does not exceed the allowable value given in 2.20.2.5.

2.20.2.3 The net structural scantling of weathertight steel hatch covers is to be in compliance with the following requirements:

(1) Local net plate thickness

The local net plate thickness of the hatch cover top plating is not to be less than that obtained from the following formulae, and not less than 6 mm:

$$t = 0.0158 F_p s \sqrt{\frac{p}{0.95 R_{eH}}} \quad \text{mm}$$

$$t = 0.01s \quad \text{mm}$$

where:

F_p — factor for combined membrane and bending response, calculated as follows:

$F_p = 1.5$ in general;

$F_p = 1.9 \frac{\sigma}{\sigma_a}$ for $\frac{\sigma}{\sigma_a} \geq 0.8$ for the attached plate flange of primary supporting members;

s — stiffener spacing, in mm;

p — pressure

p_H and p_L , calculated according to 2.20.2.2 of this Section, in kN/m²;

σ — maximum normal stress of hatch cover top plating, in N/mm², determined according to Figure 2.20.2.3;

σ_a — permissible stress, see Table 2.20.2.5., in N/mm²;

R_{eH} — yield stress of materials, in N/mm².

For flange plates under compression, the buckling strength requirements of 2.20.2.6 of this Section are to be complied with.

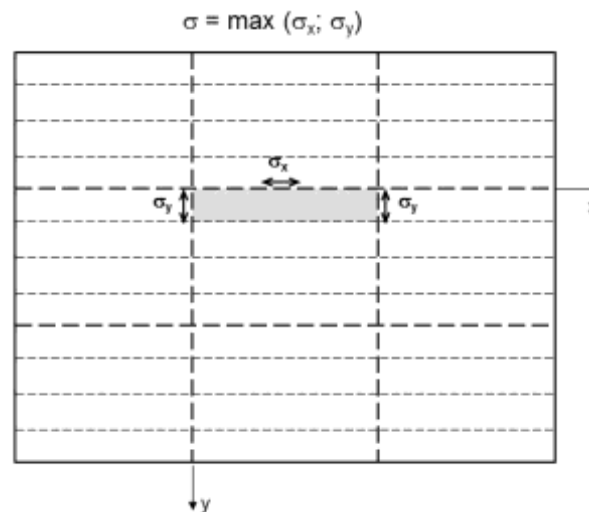


Figure 2.20.2.3

- ① The local net plate thickness of hatch covers for wheel loading is also to meet the relevant requirements of Section 21 of this Chapter.
- ② The local net plate thickness of lower plating of double skin hatch covers and box girders are to comply with the following requirements:

The thickness to fulfill the strength requirements is to be obtained from the calculation according to 2.20.2.4 under consideration of allowable stresses according to 2.20.2.5 of this Section. When the lower plating is taken into account as a strength member of the hatch cover, the net thickness, in mm, of lower plating is to be taken not less than 5 mm. When project cargo is intended to be carried on a hatch cover, the net thickness is not to be less than:

$$t = 6.5s \times 10^{-3} \quad \text{mm}$$

where: s — stiffener spacing, in mm.

When the lower plating is not considered as a strength member of the hatch cover, the thickness of the lower plating is not to be less than 5 mm.

Note: Project cargo means especially large or bulky cargo lashed to the hatch cover. Examples are parts of cranes or wind power stations, turbines, etc. Cargoes that may be considered as uniformly distributed over the hatch cover, e.g. timber, pipes or steel coils need not to be considered as project cargo.

- (2) The stiffeners of hatch covers are to comply with the following requirements:

The net section modulus Z and net shear area A_{shr} of uniformly loaded hatch cover stiffeners constrained at both ends are not to be less than:

$$Z = \frac{psl^2}{f_{bc}\sigma_a} \quad \text{cm}^3$$

$$A_{shr} = \frac{8.7psl}{\sigma_a} 10^{-3} \quad \text{cm}^2$$

where: l — secondary stiffener span, in m, to be taken as the spacing of primary supporting members or the distance between a primary supporting member and the edge support, as applicable. When brackets are fitted at both ends of all stiffener spans,

the secondary stiffener span may be reduced by an amount equal to 2/3 of the minimum brackets arm length, but not greater than 10% of the unsupported span, for each bracket;

s — spacing of stiffeners, in mm;

p — p_H and p_L , to be calculated according to 2.20.2.2 of this Section, in kN/m²;

f_{bc} — boundary coefficient of stiffener, taken equal to:

$f_{bc} = 8$, in the case of stiffener simply supported at both ends or simply supported at one end and clamped at the other end;

$f_{bc} = 12$, in the case of stiffener clamped at both ends.

σ_a — allowable stress as defined in Tab.2.20.2.5, in N/mm².

For secondary stiffeners of lower plating of double skin hatch covers, requirements mentioned above are not applied due to the absence of lateral loads. For double skin hatch covers of holds designed for ballast or liquid cargo, the stiffeners on lower plating are to be strengthened according to ISC requirements.

The net thickness, in mm, of the stiffener (except U-beams/trapeze stiffeners) web is not to be less than 4 mm.

The net section modulus of secondary stiffeners is to be determined based on an attached plate width assumed equal to the stiffener spacing.

Stiffeners parallel to primary supporting members are to be continuous at crossing primary supporting members, and may be considered for calculations regarding cross-sectional properties of primary members. It is to be verified that the combined stress of those stiffeners induced by the bending of primary supporting members and lateral pressures does not exceed the allowable stresses according to 2.20.2.5 of this Section. When the lower plating is not taken into account as a strength member of the hatch cover, the requirements of this paragraph are not necessary for the stiffeners of lower plating.

For hatch cover stiffeners under compression, sufficient safety against lateral and torsional buckling according to 2.20.2.6 of this Section is to be verified.

For hatch covers subject to wheel loading, the relevant requirements of Section 21 of this Chapter are to be complied with. For hatch covers subject to point loads, stiffener scantlings are to be determined by direct calculations under consideration of the allowable stresses as required in 2.20.2.5 of this Section.

(3) The net scantlings of primary supporting members are to comply with the following requirements:

- ① Scantlings of primary supporting members are to be obtained from direct calculations according to 2.20.2.4 under consideration of allowable stresses according to 2.20.2.5 of this Section.

For all components of primary supporting members sufficient safety against buckling is to be verified according to 2.20.2.6 of this Section. For biaxially compressed flange plates, the buckling strength is to be verified within the effective width according to 2.20.2.6(3)② of this Section.

The net thickness, in mm, of webs of primary supporting members is not to be less than:

$$t = 6.5s \times 10^{-3} \quad \text{mm}$$

$$t = 5 \quad \text{mm}$$

where: s — spacing of stiffeners, in mm.

- ② The net scantlings of edge girders are to comply with the following requirements:
 Scantlings of edge girders are to be verified according to 2.20.2.4 under consideration of allowable stresses according to 2.20.2.5 of this Section.
 The net thickness of the outer edge girders exposed to wash of seawater is not to be less than the largest of the following values:

$$t = 0.0158s \sqrt{\frac{P_A}{0.95R_{eH}}} \quad \text{mm}$$

$$t = 8.5s \times 10^{-3} \quad \text{mm}$$

$$t = 6 \quad \text{mm}$$

where: s — spacing of stiffeners, in mm;

P_A — horizontal weather design pressure, calculated according to 2.20.2.2 of this Section, in kN/m²;

For the required moment of inertia of edge girders, refer to 2.20.2.9(1) ④.

2.20.2.4 Strength calculation

The stresses in hatch covers are to be determined by FE analysis.

The stress calculation model in this section is to be used for both yielding and buckling strength assessments in accordance with 2.20.2.5 and 2.20.2.6, respectively.

The net scantlings as defined in 2.20.2.1(5) are to be used.

(1) General requirements for FEM calculations

For strength calculations of hatch covers by means of finite elements, the cover geometry is to be idealized as realistically as possible. In no case element width is to be larger than stiffener spacing. In way of force transfer points and cutouts the mesh has to be refined where applicable. The ratio of element length to width is not to exceed 3.

The element height of webs of primary supporting members is not to exceed one-third of the web height. Stiffeners, which support plates subjected to lateral pressure loads, are to be included in the FE model idealization. Stiffeners may be modelled by using beam elements, or shell/plate elements. Buckling stiffeners may be disregarded for the stress calculation.

Hatch covers fitted with U-type stiffeners as shown in Figure 2.20.2.4(1) are to be assessed by means of FE analysis. The geometry of the U-type stiffeners is to be accurately modelled using shell/plate elements. Nodal points are to be properly placed on the intersections between the webs of a U-type stiffener and the hatch cover plate, and between the webs and flange of the U-type stiffener.

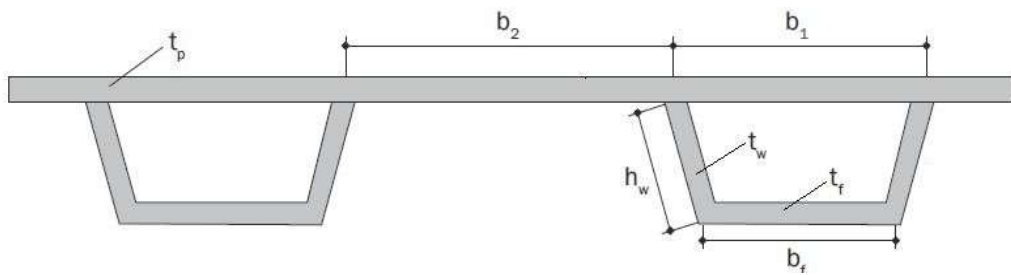


Figure. 2.20.2.4(1) Example of hatch cover fitted with U-type stiffeners

- ① A right-handed coordinate system is to be used with:
 - the x-axis measured in the longitudinal direction, positive forward;
 - the y-axis measured in the transverse direction, positive to port from the centerline;
 - the z-axis measured in the vertical direction, position upward.
- ② The FEM is to be performed with net scantlings.
- ③ The finite element model is to be limited as follows:
 - (a) for symmetry of the hatch cover girders, loads and supporting boundary conditions about only the x-axis or y-axis, it may be limited to a half of the hatch cover for check;
 - (b) for non-symmetry of hatch cover girders, loads or supporting boundary conditions about any of the axes, the whole hatch cover may be taken for strength evaluation, see Figure 2.20.2.4(2).

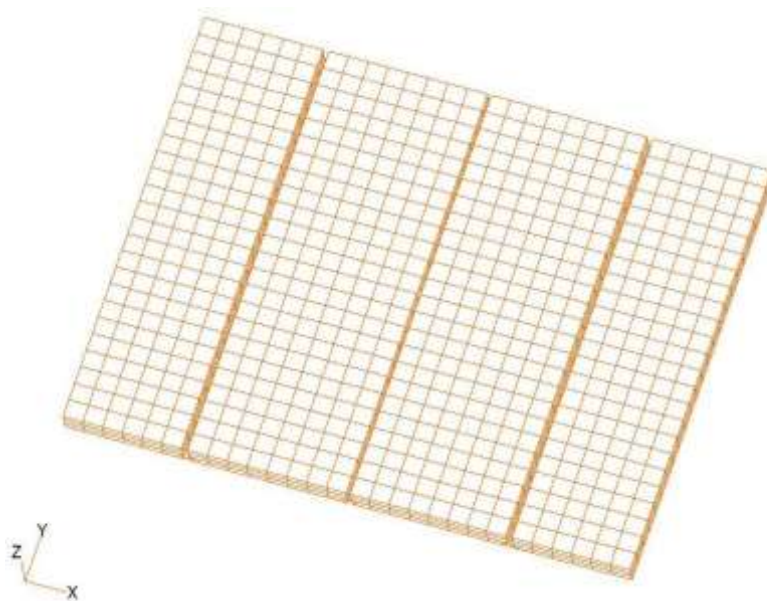


Figure 2.20.2.4(2) Finite Element Hatch Cover Model

- ④ The model element is to comply with the following requirements:
 - (a) all plating, including girders and stiffeners, is to be represented by the finite element model;
 - (b) all plating, such as top plates, bottom plates, brackets, and girder webs, face plates of primary supporting members is to modeled using plate elements, triangular elements are to be avoided where possible;
 - (c) all stiffeners are to be modeled using beam, rod or plate elements.

- ⑤ The element mesh size is to be controlled as follows:
- (a) the mesh size is not to be greater than the spacing of stiffeners;
 - (b) the girders are to be represented by at least 3 elements in the depth;
 - (c) triangular and distorted quadrilateral elements with corner angles less than 60 degrees and greater than 120 degrees are to be avoided.
- ⑥ Boundary conditions are to be determined as follows:
- (a) for symmetry of the hatch cover girders and loads about the xz-plane, the longitudinal displacement of nodes in the symmetric plane and the rotations about the y and z axes are to be taken as 0 respectively, i.e. $\delta_x = \theta_y = \theta_z = 0$, as shown in Figure 2.20.2.4(3);
 - (b) for symmetry of the hatch cover girders and loads about the yz-plane, the transverse displacement of nodes in the symmetric plane and rotation about the x and z axes are to be taken as 0 respectively i.e. $\delta_y = \theta_x = \theta_z = 0$, as shown in Figure 2.20.2.4(3);
 - (c) boundary nodes in way of bearing pads on the hatch coamings are generally to be fixed against displacement in the z direction, i.e. $\delta_z = 0$;
 - (d) lifting stoppers are to be fixed against displacements in the direction determined by the stoppers;
 - (e) hinges in folding type hatch covers are to be represented as rigid links which tie together displacements in the z direction.

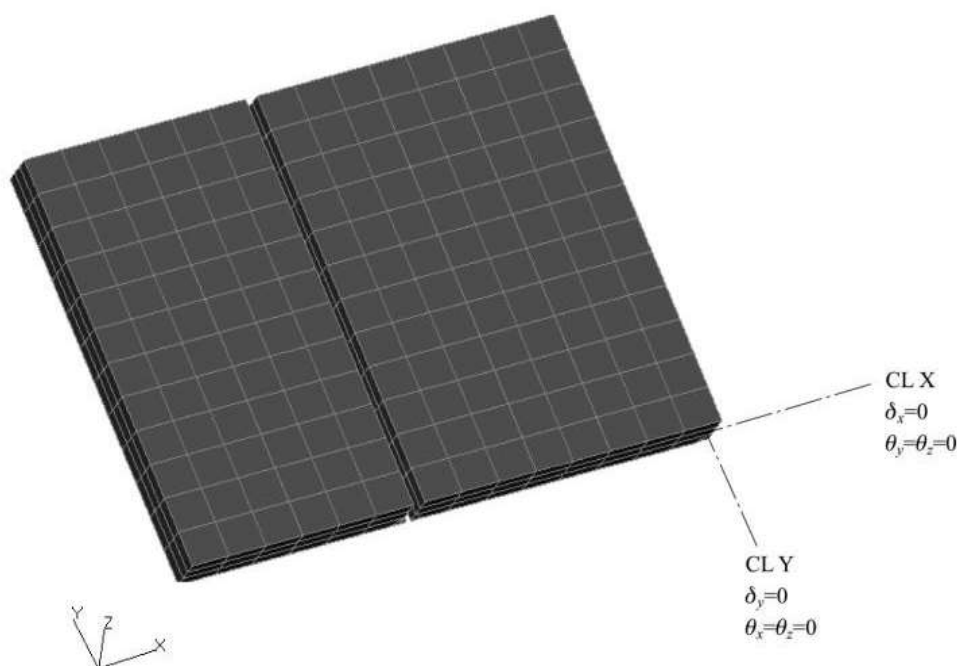


Figure 2.20.2.4(3) Boundary Conditions of Hatch Cover Model

2.20.2.5 Yield strength and deflection criteria of hatch cover structures

(1) Allowable stresses

All hatch cover structures are to comply with the following formulae:

$$\sigma_{vm} \leq \sigma_a, \text{ for shell element;}$$

$\sigma_{axial} \leq \sigma_a$, for rod or beam elements.

where: σ_a — allowable stress in Table 2.20.2.5;

R_{eH} — yield stress of the material;

σ_{vm} — the equivalent stress may be taken as follows:

$$\sigma_v = \sqrt{\sigma_x^2 - \sigma_x \cdot \sigma_y + \sigma_y^2 + 3\tau^2} \quad \text{N/mm}^2$$

where: σ_x — normal stress, in N/mm², in x-direction;

σ_y — normal stress, in N/mm², in y-direction;

τ — shear stress, in N/mm², in the x-y plane;

σ_{axial} — axial stress in rod or beam elements, in N/mm².

In case of FEM calculations using shell elements, the stresses are to be read from the centre of the individual element. It is to be observed that, in particular, at flanges of unsymmetrical girders, the evaluation of stress from element centre may lead to non-conservative results. Thus, a sufficiently fine mesh is to be applied in these cases or, the stress at the element edges is not to exceed the allowable stress. Where shell elements are used, the stresses are to be evaluated at the mid plane of the element.

For steels with a yield stress of 390 N/mm², it is taken as 368 N/mm² for calculation.

Stress concentrations are to be evaluated according to the actual conditions.

Table 2.20.2.5 - Allowable stress

Members of	Subject to	σ_a , in N/mm ²
Hatch cover structure	External pressure, as defined in 2.20.2.2(1)	$0.80R_{eH}$
	Other loads, as defined in 2.20.2.2(2)~(5)	$0.90R_{eH}$ for static+dynamic load case $0.72R_{eH}$ for static load case

(2) Deflection

The vertical deflection of primary supporting members due to the load stipulated in 2.20.2.2 of this Section is to be not more than $0.0056 l_g$, where l_g is the greatest span of primary supporting member.

Note: Where containers are arranged on hatch covers and mixed stowage is allowed, i.e., a 40'-container stowed on top of two 20'-containers, particular attention is to be paid to the deflections of hatch covers. Further the possible contact of deflected hatch covers with cargo in hold has to be considered.

2.20.2.6 Buckling strength of hatch cover structures

(1) General

Buckling strength of all hatch cover structures is to be checked. Buckling assessments are to be

performed in compliance with the requirements in Appendix 5.

The net scantlings as defined in 2.20.2.1(5) are to be used for buckling check.

(2) Slenderness requirements

The slenderness requirements are to be in accordance with those specified in Sec 2 of Appendix 5. The slenderness requirements need not be applied to the lower boundary of double skin hatch covers unless the cargo hold is designed for carriage of ballast or liquid cargo.

The breadth of the primary supporting member flange is to be not less than 40% of their depth for laterally unsupported spans greater than 3.0 m. Tripping brackets attached to the flange may be considered as a lateral support for primary supporting members.

(3) Buckling requirements

① These requirements apply to the buckling assessment of hatch cover structures subjected to compressive and shear stresses and lateral pressures. The buckling assessment is to be performed for the following structural elements:

- Stiffened and unstiffened panels, including curved panels and panels stiffened with U-type stiffeners.
- Web panels of primary supporting members in way of opening.

The buckling strength assessment of coaming parts is to be done according to this paragraph.

For rule application, the panel types and assessment methods, the applied lateral pressure and stresses, safety factors and buckling check criteria are defined in 2.20.2.6(3) ②-2.20.2.6(3) ⑤, respectively. The procedure and detailed requirements for buckling assessment are given in Section 4 of Appendix 5, including idealization of irregular plate panels, definition of reference stresses and buckling criteria.

Unless otherwise specified, the symbols used in 2.20.2.6(3) are defined in Appendix 5.

② Panel types and assessment methods

The plate panel of a hatch cover structure is to be modelled as stiffened panel (SP) or unstiffened panel (UP) as defined in 4.2, Section 4 of Appendix 5. Assessment Method A (-A) and Method B (-B) as defined in 1.3, Section 1 of Appendix 5 are to be used in accordance with Table 2.20.2.6(3) ①, Figure 2.20.2.6(3) ① and Figure 2.20.2.6(3) ②. For a web panel with opening, the procedure for opening should be used for its buckling assessment.

For a hatch cover fitted with U-type stiffeners, the additional buckling assessment requirements specific for panels with U-type stiffeners in 5.2.5, Section 5 of Appendix 5 are also to be followed.

Table 2.20.2.6(3) ① - Structural members and assessment methods

Structural Elements	Assessment Method ⁽¹⁾⁽²⁾	Normal Panel Definition
Hatch cover top/bottom plating structures (see Figure 2.20.2.6(3) ①)		
Hatch cover top/bottom plating	SP-A	Length: between transverse girders Width: between longitudinal girders
Irregularly stiffened panels	UP-B	Plate between local stiffeners / PSM
Hatch cover web panels of primary supporting members (see Figure 2.20.2.6(3) ②)		
Web of transverse/longitudinal girder (single skin type)	UP-B	Plate between local stiffeners / face plate / PSM

Web of transverse/longitudinal girder (double skin type)	SP-B(3)	Length: between PSMWidth: full web depth
Web panel with opening	Procedure for opening	Plate between local stiffeners / face plate / PSM
Irregularly stiffened panels	UP-B	Plate between local stiffeners / face plate / PSM
Notes: 1. SP and UP stand for <i>stiffened panel</i> and <i>unstiffened panel</i> respectively. 2. A and B denote <i>Method A</i> and <i>Method B</i> respectively. 3. In cases where buckling carlings or brackets are irregularly arranged in the web of a transverse or longitudinal girder, the UP-B method may be used.		

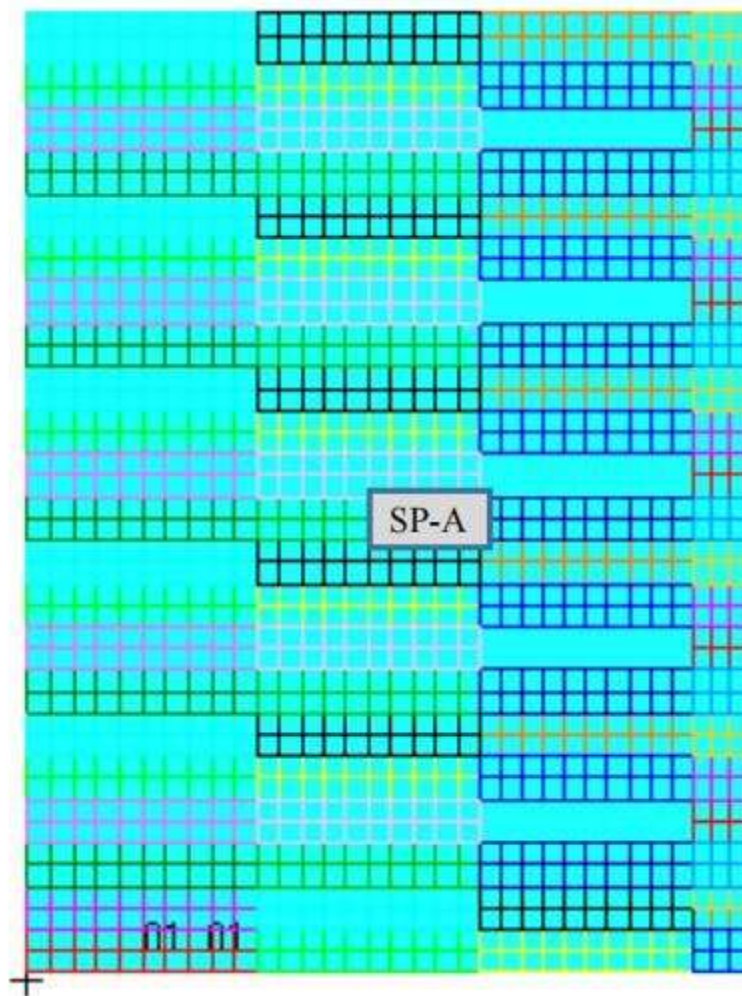


Figure 2.20.2.6(3)①

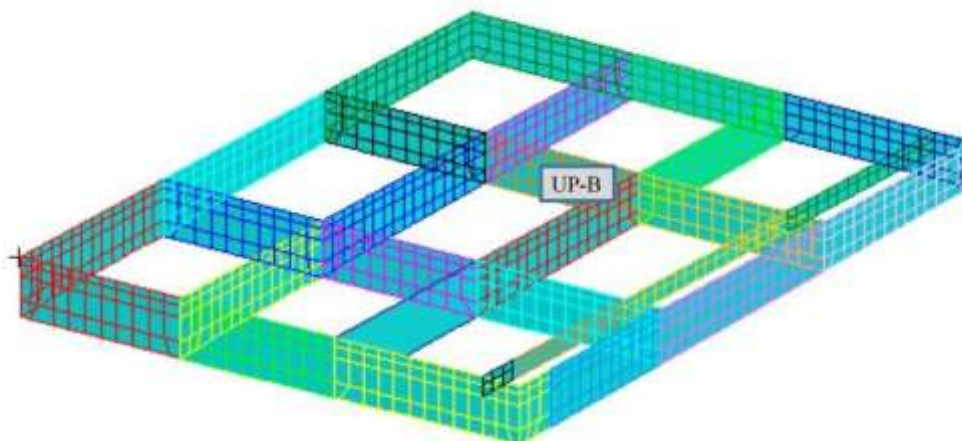


Figure 2.20.2.6(3) ②

③ Applied lateral pressure and stresses

The buckling assessment of hatch covers is based on the lateral pressure as defined in 2.1 and 2.2, and stresses obtained from FE analysis, refer to 2.20.2.4.

④ Safety factors

For all hatch cover structural members, safety factor $S=1.0$ is to be applied to both of the plating and stiffener buckling capacity formulas as defined in 5.2.2, Section 5 of Appendix 5 and 5.2.3, Section 5 of Appendix 5, respectively.

⑤ Buckling acceptance criteria

A structural member is considered to have an acceptable buckling strength if it satisfies the following criterion:

$$\eta_{act} \leq \eta_{all}$$

where: η_{act} —Buckling utilisation factor based on the applied stress, as defined in 1.3.2.2, Section 1 of Appendix 5 and Section 4 of Appendix 5, and calculated per Section 5 of Appendix 5.

η_{all} —Allowable buckling utilisation factor, taken as given in Tab.2.20.2.6(3) ⑤.

Table 2.20.2.6(3) ⑤ - Allowable buckling utilisation factors

Structural component	Subject to	η_{all} , allowable buckling utilisation factor
Plates and stiffeners Web of PSM	External pressure, as defined in 2.20.2.2(1)	0.80
	Other loads, as defined in 2.20.2.2(2)~(5)	0.90 for static+dynamic load case 0.72 for static load case

2.20.2.7 Details of hatch covers

(1) Container foundation on hatch covers

Container foundations on hatch covers are to be in compliance with the relevant requirements of Appendix 1 of Chapter 7 of this PART. The calculated stresses of substructures of container foundations under cargo and container loads according to 2.20.2.2 of this Section are to comply with the requirements of 2.20.2.5 of this Section.

(2) Weathertightness

In addition to the following requirements, the hatch covers are also to meet the relevant requirements of IACS REC14.

① Packing material (general)

The packing material is to be suitable for all expected service conditions of the ship and is to be compatible with the cargoes to be transported. The packing material is to be selected with regard to dimensions and elasticity in such a way that expected deformations may be carried. Forces are to be carried by the steel structure only.

The packings are to be compressed so as to give the necessary tightness effect for all expected operating conditions. Special consideration is to be given to the packing arrangement in ships with large relative movements between hatch covers and coamings or between hatch cover sections.

② Dispensation of weathertight gaskets

For hatch covers of cargo holds intended solely for the transport of containers, upon request by the Owner and subject to compliance with the following conditions, the fitting of weathertight gaskets according to 2.20.2.7(2) may be dispensed with:

- The hatchway coamings are to be not less than 600 mm in height
- For weather deck hatch covers located above a depth $H(x)$, $H(x)$ is to comply with the following criterion:

$$H(x) \geq T_{fb} + f_b + h \text{ m}$$

where: T_{fb} — draught, in m, corresponding to the assigned summer load line;

f_b — minimum required freeboard, in m, determined in accordance with ICLL

$$h = 4.6 \text{ m} \quad \text{for } \frac{x}{L_t} \leq 0.75;$$

$$h = 6.9 \text{ m} \quad \text{for } \frac{x}{L_t} > 0.75.$$

Regulation 28 as modified by further regulations as applicable;

- Labyrinths, gutter bars or equivalents are to be fitted proximate to the edges of each panel in way of the coamings. The clear profile of these openings is to be kept as small as possible.
- Where a hatch is covered by several hatch cover panels, the clear opening of the gap in between the panels is to be not wider than 50 mm.
- The labyrinths and gaps between hatch cover panels are to be considered as unprotected openings with respect to the requirements of intact and damage stability calculations.
- With regard to drainage of cargo holds and the necessary fire-fighting system, refer to the relevant requirements of Chapter 6, PART EIGHT of the Rules.
- Bilge alarms are to be provided in each hold fitted with non-weathertight covers.
- Furthermore, Chapter 3 of IMO MSC/Circ.1087 is to be complied with for the storage and segregation of containers carrying dangerous goods.

③ Cross-joint of multi-panel covers are to be provided with efficient drainage arrangements.

2.20.2.8 Hatch coamings are to comply with the following requirements:

(1) The net thickness of weather deck hatch coamings is not to be less than the larger of the following values:

- For Type-1 ships:

$$t = 0.0142s \sqrt{\frac{P_A}{0.95R_{eH}}} \quad \text{mm}$$

$$t = 6 + \frac{L_1}{100} \quad \text{mm}$$

- For Type-2 ships:

$$t = 0.016s \sqrt{\frac{p_{coam}}{0.95R_{eH}}} \quad \text{mm}$$

$$t_{\min} = 9.5 \quad \text{mm}$$

where: s — stiffener spacing, in mm;

P_A — horizontal weather design load, in kN/m^2 , to be calculated according to 2.20.2.2(2)

① of this Section;

p — horizontal weather design load, in kN/m^2 , to be calculated according to 2.20.2.2(2)

② of this Section;

$L_1 = L$, but need not be taken as greater than 300 m.

The continuous longitudinal hatch coamings within 0.4L amidships are also to comply with the relevant requirements of Section 2 of this Chapter.

(2) The stiffeners of hatch coaming are to meet the following requirements: The stiffeners are to be continuous at the coaming stays. For stiffeners with both ends constrained, the net section modulus Z and net shear area A_{shr} , calculated on the basis of net thickness, are not to be less than:

- For Type-1 ships:

$$Z = \frac{P_A s l^2}{f_{bc} R_{eH}} \quad \text{cm}^3$$

$$A_{shr} = \frac{P_A s l^2}{R_{eH}} 10^{-2} \quad \text{cm}^2$$

where: $f = 12$ in general

= 8 for the end spans of stiffeners sniped at the coaming corners;

l — stiffener span, in m, to be taken as the spacing of coaming stays;

s — stiffener spacing, in mm;

P_A — horizontal weather design load, in kN/m^2 , to be calculated according to

2.20.2.2(2) ① of this Section.

For sniped stiffeners of coaming at hatch corners, section modulus and shear area at the fixed support have to be increased by 35%. The gross thickness of the coaming plate at the sniped stiffener end is not to be less than:

$$t_{gr} = 19.6 \sqrt{\frac{P_A s (l - 0.0005s)}{1000 R_{eH}}} \quad \text{mm}$$

- For Type-2 ships:

$$Z = 1.21 \frac{P_{coam} s l^2}{f_{bc} c_p R_{eH}} \quad \text{cm}^3$$

where: f_{bc} — 16 in general, 12 for the end spans of stiffeners sniped at the coaming corners;

l — stiffener span, in m, to be taken as the spacing of coaming stays;

s — stiffener spacing, in mm;

P_A — horizontal weather design load, in kN/m^2 , to be calculated according to 2.20.2.2(2) ① of this Section;

P_{coam} — horizontal weather design load, in kN/m , to be calculated according to 2.20.2.2(2) ② of this Section;

C_p — ratio of the plastic section modulus to the elastic section modulus of the stiffeners with an attached plate breadth, in mm, equal to $40t$, where t is the plate net thickness

C_p — 1.16 in the absence of more precise evaluation

The horizontal stiffeners of continuous longitudinal hatch coamings within $0.4L$ amidships are also to comply with the relevant requirements of Section 2 of this Chapter.

- (3) Coaming stays are to be designed for the loads transmitted through them and are to comply with the following requirements, in addition to the allowable stresses stipulated in 2.20.2.5 of this Section.

① Coaming stay section modulus and web thickness

At the connection with deck, the net section modulus Z , in cm^3 , and the gross thickness t_w , in mm, of the coaming stays designed as beams with flange (examples 1 and 2 are shown in Figure 2.20.2.8(3)) are to be taken not less than:

$$Z = \frac{P s_c H_c^2}{1.9 R_{eH}} \quad \text{cm}^3$$

$$t_w = \frac{2 P s_c H_c}{h R_{eH}} \quad \text{mm}$$

where: H_c — stay height, in m;

s_c — stay spacing, in mm;

h — stay depth, in mm, at the connection with the deck;

p — pressure on coaming, in kN/m^2 , taken as p_A defined in 2.20.2.2(2)① in general and as P_{coam} defined in 2.20.2.2(2)② for Type-2 ships.

For other designs of coaming stays, such as those shown in Figure 2.20.2.8(3), examples 3 and 4, the stresses are to be determined through a grillage analysis or FEM. The calculated stresses are to comply with the permissible stresses according to 2.20.2.5 of this Section. Coaming stays are to be supported by appropriate substructures. Face plates may only be included in the calculation of section modulus of coaming stays if an appropriate substructure is provided and welding provides an adequate joint.

Webs are to be connected to the deck by fillet welds on both sides with a throat thickness of not less than $0.44 t_w$. For Type-2 ships, toes of stay webs are to be connected to the deck plating with full or partial penetration double bevel welds extending over a distance not less than 15% of the stay width. For other ship types the size of welding for toes of webs at the lower end of coaming stays is to comply with the relevant requirements of Chapter 1 of this PART.

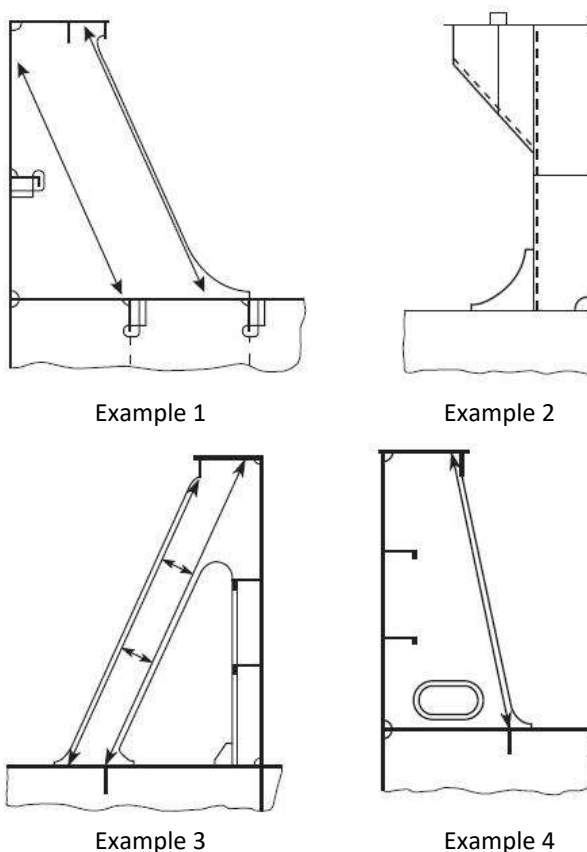


Figure 2.20.2.8(3) Examples of coaming stays

- ② For coaming stays, which transfer friction forces at hatch cover supports, fatigue strength is to be considered.
- (4) (The hatch coaming is also to comply with the following requirements:
 - ① Hatch coamings which are part of the longitudinal hull structure are to be designed according to the relevant requirements of Section 2 of this Chapter.
 - ② For structural members welded to coamings and for cutouts in the top of coamings, sufficient fatigue strength is to be verified.
 - ③ Longitudinal hatch coamings with a length exceeding $0.1L$ are to be provided with tapered brackets or equivalent transitions and a corresponding substructure at both ends. At the end of the brackets, they are to be connected to the deck by full penetration welds of minimum 300 mm in length.
 - ④ The local details are to be designed to transfer the loads on the hatch covers to the hatch coamings, and, through them, to the deck structures below. Hatch coamings and supporting structures are to be adequately stiffened to accommodate the loading from hatch covers, in longitudinal, transverse and vertical directions. Structures under deck are to be checked against the load transmitted by the stays. Unless otherwise stated, welding and material are to comply with the relevant requirements of ISC.
 - ⑤ On ships carrying cargo on deck, such as timber, coal or coke, the stays are to be spaced not more than 1.5 m apart.
 - ⑥ Coaming plates are to extend to the lower edge of the deck beams or hatch side girders are to be fitted that extend to the lower edge of the deck beams. Extended coaming plates and hatch side girders are to be flanged or fitted with face bars or half-round bars. See Figure 2.20.2.8(4).

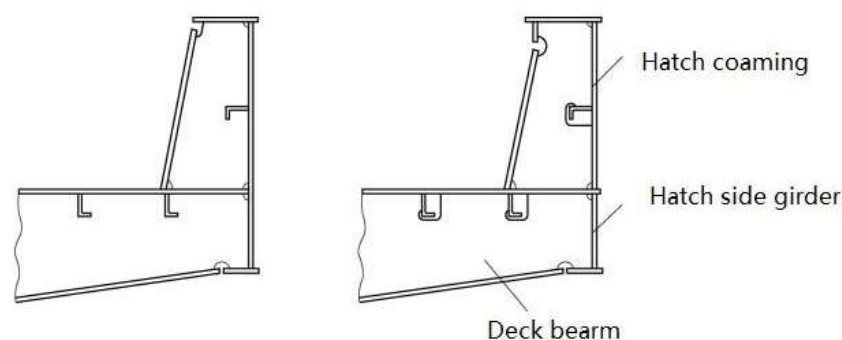


Figure 2.20.2.8(4) Example for the Extension of Coaming Plates

- ⑦ Drainage arrangement at the coaming is to comply with the following requirements:

If drain channels are provided inside the line of gasket by means of a gutter bar or vertical extension of the hatch side and end coaming, drain openings are to be provided at appropriate positions of the drain channels.

Drain openings in hatch coamings are to be arranged with sufficient distance to areas of stress concentration (e.g. hatch covers, transitions to crane posts).

Drain openings are to be arranged at the ends of drain channels and are to be provided with non-return valves to prevent ingress of water from outside. It is unacceptable to connect

fire hoses to the drain openings for this purpose.

If a continuous outer steel contact between cover and ship structure is arranged, drainage from the space between the steel contact and the gasket is also to be provided.

2.20.2.9 Closing arrangements of weathertight steel hatch covers

(1) Securing arrangements

① General requirements

Securing devices between cover and coaming and at cross-joints are to be installed to provide weathertightness. Sufficient packing line pressure is to be maintained. Securing devices are to be appropriate to bridge displacements between cover and coaming due to hull deformations.

Securing devices are to be of reliable construction and effectively attached to the hatchway coamings, decks or covers. Individual securing devices on each cover are to have approximately the same stiffness characteristics. According to the requirements of 2.20.2.3(3)② of this Section, a sufficient number of securing devices is to be provided at each side of the hatch cover, including that consisting of several parts.

The materials of stoppers, securing devices and their welding are to comply with the relevant requirements of ISC Rules for Materials and Welding. Specifications of the materials are to be shown in the drawings of the hatch covers.

② Rod cleats

Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

③ Hydraulic cleats

Where hydraulic cleating is adopted, a positive means is to be provided so that it remains mechanically locked in the closed position in the event of failure of the hydraulic system.

④ Cross-sectional area of the securing devices

The gross cross-sectional area of the securing devices is not to be less than:

$$A = 0.28qS_{SD}k_t \quad \text{cm}^2$$

where: q — packing line pressure, in N/mm, minimum 5 N/mm;

S_{SD} — spacing between securing devices, in m, not to be taken less than 2 m;

$$k_t = \left(\frac{235}{R_{eH}}\right)^e;$$

R_{eH} — the minimum yield stress of material, in N/mm², but not to be taken greater than $0.7R_m$;

R_m — tensile strength of material, in N/mm²;

$e = 0.75$ for $R_{eH} > 235$ N/mm²;

$e = 1.00$ for $R_{eH} \leq 235$ N/mm².

Rods or bolts are to have a gross diameter not less than 19 mm for hatchways

exceeding 5m² in area. Securing devices of special design in which significant bending or shear stresses occur may be designed as anti-lifting devices according to 2.20.2.9(1)⑤. The design load is taken as the packing line pressure q multiplied by the spacing SSD between securing devices.

⑤ Anti-lifting devices

The securing devices of hatch covers, on which cargo is to be lashed, are to be designed for the lifting forces resulting from loads according to 2.20.2.2(4) of this Section, refer to Figure 2.20.2.9(1). Unsymmetrical loadings, which may occur in practice, are to be considered. Under these loadings the equivalent stress in the securing devices is not to exceed:

$$\sigma_F = \frac{150}{k_l} \quad \text{N/mm}^2$$

where: k_l — as in 2.20.2.9(1)④.

Note: The partial load cases given in Table 2.20.2.2(4) may not cover all unsymmetrical loadings, critical for hatch cover lifting.

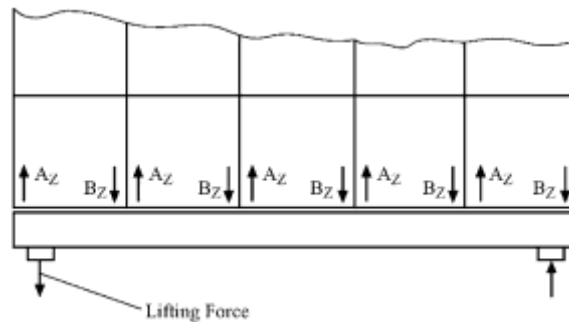


Figure 2.20.2.9(1) Lifting Forces at a Hatch Cover

The anti-lifting devices may be dispensed with according to the following requirements:

In the absence of hatch cover lifting under loads arising from the ship's rolling motion, securing devices for hatch covers may be omitted. In such cases, it is to be proven by means of grillage or finite element analysis that an equilibrium condition is achieved using compression only boundary elements for the vertical hatch cover supports. If securing devices are omitted, transverse cover guides are to be effective up to a height h_E , as shown in Figure 2.20.2.9(2), where h_E is not to be less than:

$$h_E = 1.75(2se + d^2)^{0.5} - 0.75d \quad \text{mm}$$

$$h_{E \min} = \text{height of the cover edge plate} + 150 \quad \text{mm}$$

where: e — largest distance from the inner edge of the transverse cover guide to the end of the cover edge plate, in mm;

s — total clearance within the transverse cover guide, with $10 \leq s \leq 40$, in mm;

d — distance between upper edge of transverse stopper and hatch cover support, in

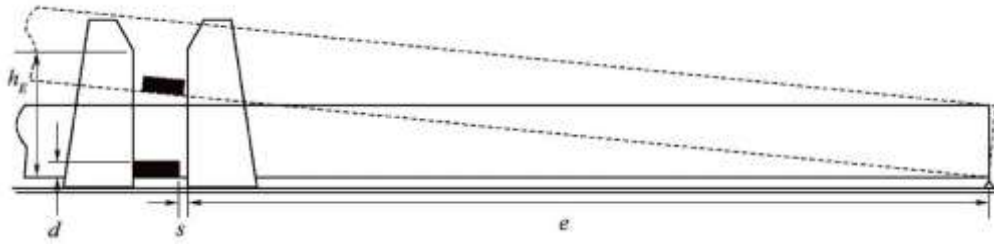


Figure 2.20.2.9(2) Height of Transverse Cover Guide

The transverse cover guides and their substructure are to be dimensioned in accordance with the transverse loads acting at a height h_E .

(2) Hatch cover supports, stoppers and supporting structures

① Horizontal mass forces

For the design of hatch cover supports, the horizontal mass force is to be taken as follows:

$$F_h = ma$$

where: F_h — horizontal mass force, in kN;

$a_x = 0.2g$ in longitudinal direction;

$a_y = 0.5g$ in transverse direction;

m — sum of mass of cargo lashed on the hatch cover and mass of hatch cover.

The accelerations in longitudinal direction and in transverse direction need not be considered as acting simultaneously.

② Hatch cover supports

For the transmission of the support forces resulting from the load cases specified in 2.20.2.2 of this Section and of the horizontal mass forces specified in (2)①, supports are to be provided which are to be designed such that the nominal surface pressures in general do not exceed the values obtained from the following formula:

$$p_{nmax} = dp_n \quad \text{N/mm}^2$$

where: $d = 3.75 - 0.015L$;

$d_{max} = 3.0$;

$d_{min} = 1.0$, in general;

$d_{min} = 2.0$, for partial loading conditions, see 2.20.2.2(5);

p_n — Allowable nominal surface pressure, see Table 2.20.2.9(2).

Table 2.20.2.9(2) - Allowable Nominal Surface Pressure P_n

Support Material	P_n (N/mm ²) when loaded by	
	Vertical Force	Horizontal Force (on stoppers)
Hull structural steel	25	40
Hardened steel	35	50
Lower friction materials	50	—

For metallic supporting surfaces not subjected to relative displacements, the following nominal surface pressure applies:

$$p_{n\max} = 3p_n \text{ N/mm}^2$$

Note: When the maker of vertical hatch cover support material can provide proof that the material is sufficient for the increased surface pressure, not only statically but under dynamic conditions including relative motion for adequate number of cycles, permissible nominal surface pressure may be relaxed at the discretion of ISC. However, realistic long term distribution of spectra for vertical loads and relative horizontal motion is to be assumed and agreed with ISC.

Drawings of the supports are to be submitted for approval. In the drawings of supports, the permitted maximum pressure given by the material manufacturer is to be indicated. Where large relative displacements of the supporting surfaces are to be expected, the use of material having low friction properties is recommended. The substructures of the supports are to be of such a design that a uniform pressure distribution is achieved. Irrespective of the arrangement of stoppers, the supports are to be able to transmit the following force P_h in the longitudinal and transverse direction:

$$P_h = \mu \cdot \frac{P_v}{\sqrt{d}}$$

where: P_v — vertical supporting force;

μ — frictional coefficient;

$\mu = 0.5$ steel to steel.

For non-metallic, low-friction support materials on steel, the friction coefficient μ may be reduced but not to be less than 0.35 and it is to be submitted to ISC for approval. Supports as well as the adjacent structures and substructures are to be designed such that the allowable stresses in 2.20.2.5 of this Section are not exceeded. For substructures and adjacent structures of supports subjected to horizontal forces P_h , a fatigue strength is to be considered.

③ Hatch cover stoppers

Hatch covers are to be sufficiently secured against horizontal shifting. Stoppers are to be provided for hatch covers on which cargo is carried.

The greater of the loads resulting from 2.20.2.2(2) of this Section and 2.20.2.9(2) ① is to be applied for the dimensioning of the stoppers and their substructures.

The allowable stress in stoppers and their substructures, in the cover, and of the coamings is to be determined according to 2.20.2.5 of this Section and in addition, the requirements in

2.20.2.9(2)② are to be taken into consideration.

Specifically for Type-2 ships, the following additional requirements are to be complied with:

Hatch covers are to be effectively secured, by means of stoppers, against the transverse forces arising from a pressure of 175 kN/m².

With the exclusion of No.1 hatch cover, hatch covers are to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 175 kN/m².

No. 1 hatch cover is to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 230 kN/m².

This pressure may be reduced to 175 kN/m² when a forecastle is fitted in accordance with Section 13, Chapter 8 of this PART.

The equivalent stress in stoppers and their supporting structures, and calculated in the throat of the stopper welds is not to exceed the allowable value of $0.8R_{eH}$.

2.20.2.10 Corrosion addition and steel renewal

(1) Corrosion addition for hatch covers and hatch coamings

For scantlings of hatch cover components, the general corrosion additions t_s , as shown in Table 2.20.2.10, is required.

Table 2.20.2.10 - Corrosion Addition t_s for Hatch Covers and Hatch Coamings

Application	Structure	t_s [mm]
Weather deck hatches of container ships, car carriers, paper carriers and passenger vessels	Hatch covers	1
	Hatch coamings	1.5 for $t \leq 10$
		$\frac{0.1t}{\sqrt{K}} + 0.5$, but not greater than 3, for $t > 10$
Weather deck cargo hatches of Type-2 ships	Hatch covers in general	2
	Top and bottom plating of double skin hatch covers	2
	Internal structure of double skin hatch covers	1.5
	Hatch coamings and coaming stays	1.5
Weather deck hatches of all other ships	Hatch covers in general	2
	Weather-exposed plating and bottom plating of double skin hatch covers	1.5
	Internal structure of double skin hatch covers and closed box girders	1
	Hatch coamings not part of the longitudinal hull structure	1.5
	Hatch coamings part of the longitudinal hull structure	1.5 for $t \leq 10$
		$\frac{0.1t}{\sqrt{K}} + 0.5$, but not greater than 3, for $t > 10$
	Coaming stays and stiffeners	1.5

Notes: t : net thickness of hatch coaming required by the Rules.
 K : material factor.

(2) Steel renewal

Steel renewal is required where the gauged thickness is less than $t_{net} + 0.5$ mm for

- single skin hatch covers,
- the plating of double skin hatch covers, and
- coaming structures the corrosion additions t_S of which are given in Table 2.20.2.10.

Coating is to be maintained in GOOD condition, as defined in 5.1.5.1(15), Chapter 5 of PART ONE of the Rules.

For internal structure of double skin hatch covers, thickness gauging is required when hatch cover top or bottom plating renewal is to be carried out or when it is deemed necessary by ISC surveyor, on the basis of the plating corrosion or deformation. In these cases, steel renewal for the internal structures is to be required where the gauged thickness is less than t_{net} .

For corrosion addition $t_S = 1.0$ mm, the thickness for steel renewal is t_{net} and coating or annual gauging may be used for substitution of renewal when gauged thickness is between t_{net} and $t_{net} + 0.5$ mm.

For coaming structures, the corrosion additions t_S of which are not given in Table 2.20.2.10, steel renewal and coating or annual gauging are to be in accordance with the relevant requirements of ISC.

2.20.3 Steel pontoon covers

2.20.3.1 The design load of steel pontoon covers is to comply with the following requirements:

- (1) The design load of vertical exposed hatch covers is to be calculated according to Table 2.20.2.2(1) of this Section.
- (2) The permissible cargo load p on hatch covers is to be specified by the Owner or designer and included in the loading manual, complying with the following requirements:
 - ① The permissible cargo load p for 'tween deck hatch covers is not to be less than:

$$p = 7.06h \text{ kN/m}^2$$

where: h — the vertical distance, in m, measured from the hatch cover to the underside of hatch cover stiffeners on deck above.

This requirement does not apply to multi-purpose ships of which the 'tween deck hatch covers are used as 'tween deck, see Figure 2.20.3.1(2) of this Section.

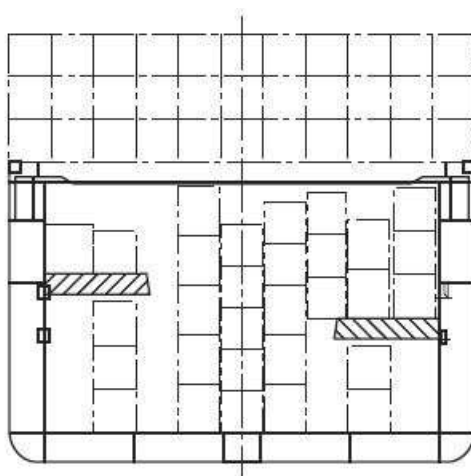


Figure 2.20.3.1(2)

- ② The permissible cargo load p for hatch covers in the accommodation spaces is not to be less than 12.7 kN/m^2 .

2.20.3.2 The local scantlings of hatch covers are to comply with the following requirements:

- (1) The thickness t of the top plating of steel hatch covers is not to be less than that obtained from the following formula:

$$t = 0.01s \quad \text{mm, but in no case to be less than 6 mm.}$$

where: s — spacing of stiffeners, in mm.

- (2) The scantlings of stiffeners and girders of steel pontoon covers are to comply with the following requirements:

- ① Where the uniformly distributed design load of vertical exposed hatch covers is applied, the section modulus W and the section moment of inertia I of stiffeners are not to be less than:

$$W = 7.82 K s p l^2 \times 10^{-4} \quad \text{cm}^3$$

$$I = 1.44 s p l^3 \times 10^{-3} \quad \text{cm}^4$$

where: p — vertical weather design load, in kN/m^2 ; s — spacing of stiffeners, in mm;
 l — span of stiffener, in m; K —material factor.

- ② Where the uniformly distributed cargo load is applied, the section modulus W and the section moment of inertia I of stiffeners are not to be less than:

$$W = 1.064 K s p l^2 \times 10^{-3} \quad \text{cm}^3$$

$$I = 1.8 s p l^3 \times 10^{-3} \quad \text{cm}^4$$

where: p —permissible cargo load, in kN/m^2 ; s —spacing of stiffeners, in mm;
 l —span of stiffener, in m; K —material factor.

- ③ Where the ends of stiffeners are effectively bracketed or continuous, the values of section modulus and moment of inertia may be reduced respectively by 33% and 80% than those obtained from ① or ②.
- ④ The scantlings of girders of steel pontoon covers are to be determined by direct calculations. Where steel pontoon covers are subject to uniformly distributed loading and girders are fitted in one direction only, however, the scantlings of girders may also be determined according to ① and ②.

2.20.3.3 The direct strength calculation of steel pontoon covers is to be in compliance with the requirements of 2.20.2.4 of this Section.

2.20.3.4 Yield strength and deformation criteria of steel hatch covers of steel pontoon covers. The yield strength and deflection of steel pontoon covers are to meet the requirements of Table 2.20.3.4.

Table 2.20.3.4 - Steel Pontoon Covers

Load	Allowable Positive Stress $[\sigma]$ (N/mm^2)	Allowable Deflection (m)
Vertical weather design load	0.70 R_{eH}	0.0049 /
Loads other than vertical weather design load	0.65 R_{eH}	0.0044 /

2.20.3.5 The buckling strength of steel pontoon covers is to meet the requirements of Table 2.20.3.5(1).

Table 2.20.3.5(1) - Buckling Strength Criteria of Steel Pontoon Covers

Structural Member		Criteria
Top panels of hatch covers	Girders fitted in uni-axial direction:	The normal stress of top panels in compression of girders is not to exceed 0.8 times the critical buckling stress, σ_c . σ_c may be calculated according to 2.20.3.5(1).
	Girders fitted in bi-axial directions:	The biaxial compressive stress of top panels, when calculated by means of a finite plate element model, is to comply with the relevant requirements in 2.20.2.6(1) of this Section.
Girder webs		The shear stress of girder web panels is not to exceed 0.8 times the critical shear buckling stress, τ_c . τ_c may be calculated according to 2.20.3.5(3).
Stiffeners parallel to girders		The normal stress of the attached plating of stiffeners, in compression of girders parallel to stiffeners, is not to exceed 0.8 times the critical buckling stress, σ_c . σ_c may be calculated according to 2.20.3.5(2).

(1) Hatch cover plating critical stress

The compressive stress σ in the hatch cover plate panels, induced by the bending of primary supporting members parallel to the direction of secondary stiffeners, is not to exceed 0.8 times the critical buckling stress σ_{c1} , to be evaluated as defined below:

$$\sigma_{c2} = \sigma_{E2} \quad \text{for } \sigma_{E2} \leq \frac{R_{eH}}{2}$$

$$\sigma_{c2} = R_{eH} \left(1 - \frac{R_{eH}}{4\sigma_{E2}}\right) \quad \text{for } \sigma_{E2} > \frac{R_{eH}}{2}$$

where: R_{eH} — yield stress of the material, in N/mm²;

$$\sigma_{E2} = 0.9mE\left(\frac{t}{1000s_s}\right)^2, \text{ in N/mm}^2;$$

$$m = c\left[1 + \left(\frac{s_s}{l_s}\right)^2\right]^2 \frac{2.1}{\psi + 1.1}$$

E — modulus of elasticity, in N/mm², = 2.06×10^5 for steel;

t — net thickness of plate panel, in mm;

s_s — length of the shorter side of the plate panel, in m;

l_s — length of the longer side of the plate panel, in m;

ψ — ratio between smallest and largest compressive stress;

c = 1.3 when plating is stiffened by primary supporting members;

c = 1.21 when plating is stiffened by secondary stiffeners of angle or T type;

c = 1.1 when plating is stiffened by secondary stiffeners of bulb type;

c = 1.05 when plating is stiffened by flat bar.

The biaxial compressive stress in the hatch cover panels, when calculated by means of FEM shell element model, is to be in accordance with the requirements of 2.20.2.6, Chapter 2 of this PART.

(2) Hatch cover secondary stiffeners critical stress

The compressive stress σ in the top flange of secondary stiffeners, induced by the bending of primary supporting members parallel to the direction of secondary stiffeners, is not to exceed 0.8 times the critical buckling stress σ_{cS} , to be evaluated as defined below:

$$\sigma_{CS} = \sigma_{ES} \quad \text{for } \sigma_{ES} \leq \frac{R_{eH}}{2}$$

$$\sigma_{CS} = R_{eH} \left(1 - \frac{R_{eH}}{4\sigma_{ES}}\right) \quad \text{for } \sigma_{ES} > \frac{R_{eH}}{2}$$

where: R_{eH} — yield stress of the material, in N/mm²;

σ_{ES} — ideal elastic buckling stress of the secondary stiffener, in N/mm², = minimum between σ_{E3} and σ_{E4} ;

$$\sigma_{E3} = \frac{0.001EI_a}{Al^2}, \text{ in N/mm}^2;$$

E — modulus of elasticity, in N/mm², = 2.06×10^5 for steel;

I_a — moment of inertia of the secondary stiffener, in cm⁴, including a top flange equal to the spacing of secondary stiffeners;

A — cross-sectional area of the secondary stiffener, in cm², including a top flange equal to the spacing of secondary stiffeners;

l — span of the secondary stiffener, in m;

$$\sigma_{E4} = \frac{\pi^2 EI_w}{10^4 I_p l^2} \left(m^2 + \frac{K}{m^2}\right) + 0.385E \frac{I_t}{I_p}, \text{ N/mm}^2;$$

$$K = \frac{Cl^4}{\pi^4 EI_w} \times 10^6;$$

m — number of half waves, given by Table 2.20.3.5(2);

I_w — sectorial moment of inertia of the secondary stiffener about its connection with the plating, in cm⁶:

$$I_w = \frac{h_w^3 t_w^3}{36} \times 10^{-6}, \text{ for flat bar secondary stiffeners;}$$

$$I_w = \frac{t_f b_f^3 h_w^2}{12} \times 10^{-6}, \text{ for "Tee" secondary stiffeners;}$$

$$I_w = \frac{b_f^3 h_w^2}{12(b_f + h_w)^2} [t_f(b_f^2 + 2b_f h_w + 4h_w^2) + 3t_w b_f h_w] \times 10^{-6}, \text{ for angles and bulb}$$

secondary stiffeners;

I_p — polar moment of inertia of the secondary stiffener about its connection with the plating, in cm⁴:

$$I_p = \frac{h_w^3 t_w}{3} \times 10^{-4}, \text{ for flat bar secondary stiffeners;}$$

$$I_p = \left(\frac{h_w^3 t_w}{3} + h_w^2 b_f t_f\right) \times 10^{-4}, \text{ for flanged secondary stiffeners;}$$

I_t — St Venant's moment of inertia of the secondary stiffener without top flange, in cm⁴:

$$I_t = \frac{h_w t_w^3}{3} \times 10^{-4}, \text{ for flat bar secondary stiffeners;}$$

$$I_t = \frac{1}{3} [h_w t_w^3 + b_f t_f^3 (1 - 0.63 \frac{t_f}{b_f})] \times 10^{-4}, \text{ for flanged secondary stiffeners;}$$

h_w — web height of the secondary stiffener, in mm;

t_w — web net thickness of the secondary stiffener, in mm;

b_f — width of the secondary stiffener bottom flange, in mm;

t_f — net thickness of the secondary stiffener bottom flange, in mm;

s — spacing of secondary stiffeners, in m;

C — spring stiffness exerted by the hatch cover top plating, calculated by the following formula:

$$C = \frac{k_p E t_p^3}{3s(1 + \frac{1.33k_p h_w t_p^3}{1000s t_w^3})} \times 10^{-3};$$

$k_p = 1 - \eta_p$, to be taken not less than zero; for flanged secondary stiffeners, k_p need

not be taken as less than 0.1;

$$\eta_p = \frac{\sigma}{\sigma_{E1}};$$

σ — normal stress of the attached plate of the wing plate of the primary supporting member;

σ_{E1} — as given in 2.20.3.5(1);

t_p — net thickness of the hatch cover plate panel, in mm.

Table 2.20.3.5(2) - Number of Half Waves (m value)

K	$0 < K \leq 4$	$4 < K \leq 36$	$36 < K \leq 144$	$(m-1)^2 m < K \leq m^2(m+1)^2$
m	1	2	3	m

(3) Web panels of hatch cover primary supporting members critical stress

This check is to be carried out for the web panels of primary supporting members, formed by web stiffeners or by the crossing with other primary supporting members, the face plate (or the bottom cover plate) or the attached top cover plate.

The shear stress τ in the hatch cover primary supporting member web panels is not to exceed 0.8 times the critical buckling stress τ_c , to be evaluated as defined below:

$$\begin{aligned} \tau_c &= \tau_E & \text{for } \tau_E \leq \frac{\tau_F}{2} \\ \tau_c &= \tau_F (1 - \frac{\tau_F}{4\tau_E}) & \text{for } \tau_E > \frac{\tau_F}{2} \end{aligned}$$

where:

τ_F — yield stress of the material, in N/mm²;

τ_E — spacing of stiffeners, in m;

E — span of stiffener, in m;

$t_{pr, n}$ — material factor.

$$k_t = 5.35 + 4.0 \left(\frac{d}{a} \right)^2$$

a — greater dimension of web panel of primary supporting member, in m;

d — smaller dimension of web panel of primary supporting member, in m.

For primary supporting members parallel to the direction of secondary stiffeners, the actual dimensions of the panels are to be considered.

For primary supporting members perpendicular to the direction of secondary stiffeners or for hatch covers built without secondary stiffeners, a presumed square panel of dimension d is to be taken for the determination of the stress τ_c . In such a case, the average shear stress τ between the values calculated at the ends of this panel is to be considered.

2.20.3.6 Steel pontoon covers are to be provided with tarpaulins and securing devices in accordance with the following requirements:

- (1) At least two layers of tarpaulin in good condition are to be provided for each hatchway in exposed freeboard and superstructure decks.
- (2) Tarpaulins are to be free from jute, and the minimum weight in unit area of the material before treatment is to be:
 - 0.65 kg/mm², if the material is tarred;
 - 0.65 kg/mm², if the material is chemically dressed;
 - 0.55 kg/mm², if the material is dressed with black oil.
- (3) Cleats are to be welded to the hatch coamings or the horizontal stiffeners, and the cleats are to be so set as to fit the taper of the wedges. The width of cleats is not to be less than 65 mm, and the cleats are to be spaced not more than 600 mm from centre to centre. The first and last cleats along each side or end are to be arranged not more than 150 mm from the hatch covers.
- (4) Wedges are to be of tough wood. They are to have a taper of not more than 1 in 6 and are not to be less than 13 mm in thickness at the point.
- (5) For all hatchways situated in exposed freeboard and superstructure decks, steel bars or other equivalent means are to be provided in order to efficiently secure each section of hatch covers after the tarpaulins are battened down. Hatch covers of more than 1.5 m in length are to be secured by at least two such securing appliances.
- (6) For all hatchways situated in other exposed positions, ring bolts or other fittings for lashings are to be provided.

2.20.3.7 The hatch coamings of steel pontoon covers are to comply with the following requirements:

(1) Construction of exposed hatch coamings

- ① The thickness t of hatch coamings is not to be less than that obtained from the following formula:

$$t = 0.05L + 6.5 \text{ mm}$$

where: L — length of ship, in m, need not be greater than 90 m.

- ② Coamings of 600 mm or more in height are to be stiffened on their upper edges or at about 250 mm below the upper edge by a horizontal bulb flat or equivalent strength member. The web depth of the horizontal bulb flat is not to be less than 180 mm, and an additional support is to be afforded by fitting vertical stays or brackets from the bulb flat to the deck at intervals of not more than 3 m. The web depth of the stiffeners or brackets is to be not less than that of the horizontal bulb flat and they are to be flanged or fitted with a face plate. Where the coamings are more than 900 mm in height, the spacing of the above-mentioned stays or brackets is to be suitably reduced. Where the coamings are equal to or more than 1,200 mm in height, an additional horizontal bulb flat or equivalent strength member is to be fitted in way of half height of the coaming. Where the coamings are subject to loaded containers, the hatch coamings and their supporting members are to be strengthened correspondingly.
- ③ Where no face plate is fitted, the upper edges of coamings are to be stiffened by half round bars or other rolled bars to ensure the rigidity of coamings and the smoothness of their upper edges.
- ④ Where the deck plating does not extend inside the coamings, the coamings at the corners of hatchways are to be rounded. For openings within 0.5L amidships, the radius of the rounded corner is to comply with the requirements of 2.4.4 of this Chapter.
If the deck plating extends inside the coamings, the coamings at the corners of hatchways may be square provided that the corners of deck openings are in compliance with the requirements of 2.4.4 of this Chapter and that the longitudinal coamings at hatch corners are extended in the form of a tapered bracket.
- ⑤ Extension brackets or rails arranged approximately in line with the cargo hatch side coamings and intended for the stowage of steel covers are not to be welded to a deckhouse or masthouse, unless upon calculation it shows that the hatch coamings may be used as longitudinal strength members of the hull.
- ⑥ Where the exposed hatch coamings act as deck girders, they are also to comply with the relevant requirements of 2.8.8 of this Chapter.
- (2) Where the 'tween deck hatch coamings act as deck girders, they are also to comply with the relevant requirements of 2.8.8 of this Chapter.

2.20.4 Hatch covers with portable beams

2.20.4.1 The design load of hatch covers with portable beams is to comply with the following requirements:

- (1) The vertical weather design load of exposed hatch covers is to comply with Table 2.20.2.2(1) of this Section.
- (2) The permissible cargo load on hatch covers is to comply with the requirements of 2.20.3.1(2) of this Section.

2.20.4.2 Hatch covers with portable beams are to be in compliance with the following requirements:

- (1) Hatch covers with portable beams, where the cover is made of steel, are to meet the requirements of 2.20.3.2(1) of this Section; where the cover is made of wood, the thickness t is not

to be less than that obtained from the following formula:

$$t = 40S \text{ mm, but in no case to be less than 60 mm}$$

where: S — spacing of portable hatch beams, in m.

Where the design load exceeds 18.4 kN/m^2 , the thickness of wood covers is to be increased in direct proportion to the load.

Both ends of wood hatch covers are to be protected by encircling galvanized steel bands, about 65 mm wide and 3 mm thick, efficiently secured.

(2) Where the vertical design load is applied, the exposed hatch covers with portable beams are to comply with the following requirements:

- ① The section modulus W and the section moment of inertia I of the portable beams are not to be less than:

$$W = 0.782KSpI^2 \text{ cm}^3$$

$$I = 1.44SpI^3 \text{ cm}^4$$

where:

- p — vertical weather design load, in kN/m^2 , to be calculated according to 2.20.4.1 of this Section;
- S — spacing of stiffeners, in m;
- I — span of stiffener, in m;
- K — material factor.

- ② The ends of web plates are to be doubled, or inserts fitted for at least 180 mm along length of web.
- ③ The portable beams are to be stiffened at their upper and lower edges by continuous face plates. The width of the upper face plate is to be sufficient to provide a bearing surface of not less than 65 mm for hatch covers, and a vertical flat bar with a height of 50 mm is to be arranged on the upper face plate.
- ④ Carriers or sockets are to provide means for the efficient fitting and securing of portable hatch beams. The width of bearing surface is at least to be 75 mm.
- ⑤ The section modulus W and the section moment of inertia I of stiffeners of steel covers are not to be less than:

$$W = 0.664KSpI^2 \text{ cm}^3$$

$$I = 1.13SpI^3 \text{ cm}^4$$

where:

- p — vertical weather design load, in kN/m^2 , to be calculated according to 2.20.4.1 of this Section;
- I — span of stiffener, in m;
- s — spacing of stiffeners, in m;
- K — material factor.

(3) Where the uniformly distributed cargo load is applied, the hatch covers with portable beams are to comply with the following requirements:

- ① The section modulus W and the section moment of inertia I of portable beams are not to be less than:

$$W = 1.064KSp/l^2 \quad \text{cm}^3$$

$$I = 1.8Spl^3 \quad \text{cm}^4$$

where:

p	—	permissible cargo load, in kN/m ² ;
S	—	spacing of portable beams, in m;
l	—	span of portable beam, in m;
K	—	material factor.

- ② Portable beams are also to comply with the requirements of 2.20.4.2(2) ② to ④.

- ③ The section modulus W and the section moment of inertia I of portable beams are not to be less than:

$$W = 1.064KSp/l^2 \quad \text{cm}^3$$

$$I = 1.8Spl^3 \quad \text{cm}^4$$

where:

p	—	permissible cargo load, in kN/m ² ;
l	—	span of portable beam, in m;
s	—	spacing of portable beams, in m;
K	—	material factor.

(4) The scantling of stiffeners and girders with a variable cross-section for hatch covers with portable beams are to comply with the requirements of 2.20.3.2(3) of this Section.

2.20.4.3 The direct strength calculation of hatch covers with portable beams is to comply with the requirements of 2.20.2.4 of this Section.

2.20.4.4 The yield strength and deformation of hatch covers with portable beams is to comply with the requirements of 2.20.3.4 of this Section.

2.20.4.5 The buckling strength of hatch covers with portable beams is to comply with the requirements of 2.20.3.5 of this Section.

2.20.4.6 The closing appliances of hatch covers with portable beams are to comply with the requirements of 2.20.3.6 of this Section.

2.20.4.7 The hatch coamings of hatch covers with portable beams are to comply with the requirements of 2.20.3.7 of this Section.

2.20.5 Miscellaneous openings

2.20.5.1 Miscellaneous openings are to comply with the requirements of 1.12.7 of Chapter 1 of this PART.

2.20.5.2 Small hatchways on exposed decks are also to comply with the following requirements:

- (1) The height of coamings of small hatchways is to comply with the requirements of 2.20.1.8 of this Section. The thickness of the coamings is not to be less than the minimum thickness as required in this Chapter for the deck inside the line of openings for that position, or 11 mm, whichever is the lesser;
- (2) Small hatchways are to be provided with steel weathertight hatch covers and reliable securing devices. The means of securing are to be such that weathertightness can be maintained in any condition. The thickness of the hatch covers is not to be less than the minimum thickness required by this Chapter for the deck inside the line of openings for that position, or 8 mm, whichever is the lesser;
- (3) Strength and securing of small hatches on the exposed fore deck are also to comply with the relevant requirements of Section 7, Chapter 1 of this PART.

SECTION 21 - VEHICLE DECKS

2.21.1 General requirements

2.21.1.1 Where wheeled vehicles are to be stowed on the deck or used for cargo handling, the scantlings of the deck or hatch covers are to comply with the relevant requirements in this PART and in addition, are to be checked for strength in accordance with the requirements of this Section.

2.21.1.2 Where wheeled vehicles are to be stowed on the inner bottom or used for cargo handling, the strength of inner bottom plating in way may also be checked by reference to the requirements of this Section.

2.21.2 Deck plating

2.21.2.1 The thickness of deck plating is to comply with the following requirements:

- (1) The thickness t of deck plating is not to be less than that obtained from the following formula:

$$t = CJ\sqrt{PK} + 1.5 \text{ mm}$$

where:

- p — load, in t, on the tyre print. Two closely spaced wheels may be regarded as a combined wheel print and the sum of loads on both tyre prints is to be taken;
- K — material factor.
- C, J — coefficients, to be calculated as follows:

For $0.5 \leq \frac{u}{v} < 1$:

$$J = 0.73 \left(0.85 - \frac{u}{v} \right) + \frac{4.58}{\frac{v}{s} + 0.62}$$

$$C = 1 - \left(0.099 \frac{v}{s} + 0.013 \right) \left(2.5 - \frac{l}{s} \right)$$

For $1 \leq \frac{u}{v} < 2$:

$$J = 0.51 \left(0.79 - \frac{u}{v} \right) + \frac{4.58}{\frac{v}{s} + 0.62}$$

$$C = 1 - \left(0.156 \frac{v}{s} + 0.009 \right) \left(2.5 - \frac{l}{s} \right)$$

For $2 \leq \frac{u}{v} < 3$:

$$J = 0.4 \left(0.66 - \frac{u}{v} \right) + \frac{4.30}{\frac{v}{s} + 0.57}$$

$$C = 1 - \left(0.196 \frac{v}{s} + 0.013 \right) \left(2.5 - \frac{l}{s} \right)$$

where:

$\frac{u}{v}$ — aspect ratio of tyre print, see Figure 2.21.2.1(1). For 2 tyre prints on one plate panel, see Figure 2.21.2.1(2), $u' = 2u$; where $\frac{u'}{v} \geq 3$,

calculating by $u_1 = v_1 = \sqrt{u'v}$;

l — span of frames, in m;

s — spacing of frames, in m; when $l/s > 2.5$, to be taken as 2.5.

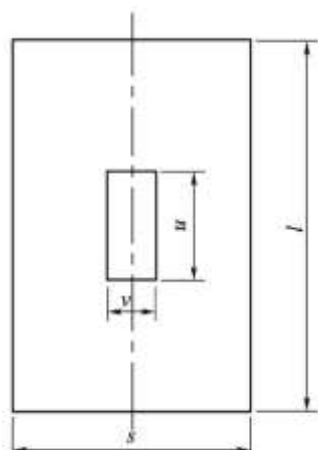


Figure 2.21.2.1(1)

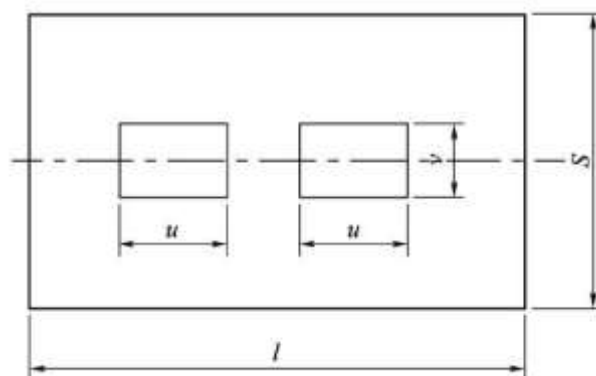


Figure 2.21.2.1(2)

- (2) Where forklift trucks are to be used for cargo handling on decks and no data for tyre print and deadweight, etc., are available, the thickness of deck plating may be obtained in accordance with the following formula:

$$\frac{s}{t} \leq \frac{111}{P+1} + 27$$

where:

- t — thickness of deck plating, in mm;
 s — spacing of deck longitudinals or beams, in mm;
 P — cargo weight lifted by the forklift truck, in t.

- (3) Where wheeled vehicles are to be stowed or used on insulated decks, attention is to be paid to the effect on the insulation coating due to deck deformation when the permissible loading of decks is determined based on the thickness of deck plating.

2.21.2.2 The section modulus of deck beams and longitudinals are to comply with the following requirements:

- (1) Where forklift trucks are to be used for cargo handling on cargo deck, the section modulus W of deck beams or longitudinals is not to be less than that obtained from the following formula:

$$W = (0.375J_1Pl + 1.25J_2hsl^2)K \text{ cm}^3$$

where:

- P — total weight of forklift truck, in t;
 h — design head on the deck, in m, see 2.8.1.1 of this Chapter;
 s — spacing of frames, in m;
 l — span of frames, in m;
 K — material factor;
 J_1, J_2 — coefficients, to be taken according to Table 2.21.2.2.

Table 2.21.2.2 - Coefficients J_1 and J_2

J	0.1	0.2	0.3	0.4	0.5 and over
J_1	15.4	14.6	13.35	11.8	10.1
J_2	1.89	1.85	1.73	1.55	1.30

Note: J = wheel spacing/span of frame, where wheel spacing is to be taken as the spacing between the two outermost wheels on the same axle.

- (2) Where decks are permanently intended for the carriage of vehicles, the section modulus W of deck beams or longitudinals is not to be less than that obtained from the following formula:

$$W = (0.536J_1Pl + 1.25J_2shl^2)K \text{ cm}^3$$

where:

- P — load on one axle, in t, i.e. total weight of the vehicle divided by the number of axles. Where the distribution of weight is not uniform, P is to be taken as the maximum axle load.
 h — design head on deck, in m, in accordance with 2.8.1.1 of this Chapter, but h need not be more than 2.5 m;
 s — spacing of frames, in m;
 l — span of frames, in m;
 K — material factor;
 J_1, J_2 — coefficients, to be taken according to Table 2.21.2.2.

- (3) In addition to the above-mentioned requirements, the strength of deck beams or longitudinals is to be checked according to the following requirements: the allowable bending stress is not to exceed $104/K$, in N/mm^2 if it is assumed that both ends of beams or longitudinals are fixed rigidly and that the beam is only subjected to the concentrated load of wheels.

2.21.2.3 The section modulus of deck transverses or girders is to comply with the following requirements:

- (1) Where the deck transverses or girders are subject to uniformly distributed loading, the section modulus W is not to be less than that obtained from the following formula:

$$W = 4.75bhl^2K \text{ cm}^3$$

where:

- P — spacing of transverses or girders, in m;
- h — span of transverse or girder, in m;
- s — design head on deck, in m, in accordance with 2.8.1.1 of this Chapter;
- K — material factor;

- (2) Where the deck girders or transverses are subject to concentrated loads, with or without the addition of uniformly distributed load, the section modulus is to be determined by calculations. During the calculation, 100% end fixity is to be assumed, and the permissible bending stress is to be taken as $118/K$, in N/mm^2 .

2.21.3 Hatch covers

2.21.3.1 Where wheeled vehicles are to be stowed or used for cargo handling on hatch covers, the thickness of hatch cover plating is to comply with the provisions in 2.21.2.1 of this Section.

2.21.3.2 Where wheeled vehicles are to be stowed or used for cargo handling on hatch covers, the section modulus W of hatch cover stiffeners is not to be less than that obtained from the following formula:

$$W = (J_3Pl + 1.67J_4shl^2)K \text{ cm}^3$$

where:

- P — load on one axle, in t, see 2.21.2.2 of this Section;
- h — design head on the hatch cover, in m; $h = 0.14 p$, where p is the vertical weather design load on the hatch cover given in 2.20.2.2(1) of this Chapter;
- s — spacing of stiffeners, in m;
- K — material factor;
- J_3, J_4 — coefficients, to be taken according to Table 2.21.3.2.

Table 2.21.3.2 - Coefficients J_3 and J_4

J	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
J_3	11.96	10.69	9.58	8.46	7.46	6.51	5.55	4.23	2.38
J_4	2.32	1.89	1.55	1.28	1.07	0.91	0.73	0.36	0.11

Note: J = wheel spacing/span of stiffeners, where wheel spacing is to be taken as the spacing between the two outermost wheels on the same axle.

SECTION 22 - STRENGTHENED FOR HEAVY CARGOES

2.22.1 General requirements

2.22.1.1 Ships complying with the requirements of this Section will be assigned the class notation: Strengthened for Heavy Cargoes.

2.22.1.2 Ships of loading rate γ not greater than 0.833m³/t (see 1.1.2.15 of Chapter 1) are to comply with the requirements of this Section, except when loaded by steel coils on a wooden support.

2.22.1.3 Special considerations are to be given to the strengthening requirements where the inner bottom plating of the cargo hold is loaded by bulky cargo or bearing concentrated load.

2.22.2 Requirements for hull structures

2.22.2.1 The strength deck and bottom in way of cargo holds are to be framed longitudinally, and the ship is to be provided with a double bottom within the region of cargo spaces.

2.22.3 Strengthening of bottom framing

2.22.3.1 The plate floors are generally to be spaced not more than 2.5 m apart, and the thickness of the floors is not to be less than that required in 2.6.11.2 of this Chapter.

2.22.3.2 The bottom girders are generally to be spaced not more than 3.6 m apart, and the thickness of side girders is not to be less than that required in 2.6.10.2 of this Chapter.

2.22.3.3 The thickness of watertight or oiltight floors is to comply with the requirements of 2.6.11.2 of this Chapter.

2.22.3.4 The thickness t of inner bottom plating is not to be less than that obtained from the following formulae:

$$t = (0.04L + 5s + 1.1)\sqrt{K} + 5 \quad \text{mm}$$

$$t = 4.65s\sqrt{\frac{HK}{\gamma}} \quad \text{mm}$$

where:

L — length of ship, in m, L need not be taken greater than 400 m;

s — spacing of inner bottom longitudinals, in m;

- γ — stowage rate, in m³/t, but not to be greater than 0.833;
 H — vertical distance, in m, measured from the inner bottom plating to deck at side amidships;
 K — material factor.

2.22.3.5 The section modulus W of inner bottom longitudinals is not to be less than 85% of that of bottom longitudinals as required in 2.6.12.2 of this Chapter, nor to be less than that obtained from the following formula:

$$W = \frac{8.5}{\gamma} H s l^2 K \text{ cm}^3$$

where: γ , H and s — same as defined in 2.22.3.4 of this Section;

l — span of inner bottom longitudinal, in m;

K — material factor.

2.22.3.6 Where vertical stays are fitted in way of the mid-span of inner bottom longitudinals and the inner bottom longitudinals are subject to uniformly distributed loading, the scantlings of bottom longitudinals and stays may be determined by direct calculations.

2.22.3.7 The construction of the duct keel is to comply with the requirements of 2.6.3 of this Chapter. But the section modulus W of the inner bottom stiffening members is not to be less than the values derived from 2.22.3.5 of this Section, and in this case s is the spacing of the stiffening members, in m, and l is the span of stiffening members, in m.

SECTION 23 - STRENGTHENING FOR GRABS

2.23.1 General requirements

2.23.1.1 This Section applies to ships intended to carry dry cargo in bulk, and include such types as bulk carriers, ore carriers and combination carriers.

2.23.2 Class notation

2.23.2.1 The class notation Grab*(X) is assigned to ships with holds designed for loading/unloading by grabs having a maximum specific weight up to X tons, in compliance with the requirements of this Section.

2.23.3 Structural strengthening

2.23.3.1 The thickness t_{GR} , in mm, of the inner bottom plating is not to be less than that obtained from the following formula:

$$t_{GR} = 0.28(M_{GR} + 50)\sqrt{sK} + 5.0 \text{ mm}$$

where: M_{GR} — mass of unladen grab, in tons;

s — spacing, in m, of ordinary stiffeners, measured at mid-span;

K — material factor.

2.23.3.2 The thickness t_{GR} , in mm, of hopper tank sloping plate, transverse lower stool, transverse bulkhead plating and inner hull up to a height of 1.5 m above the lowest point of the inner bottom, excluding bilge wells, is to be not less than the value obtained from the following formula:

$$t_{GR} = 0.28(M_{GR} + 42)\sqrt{sK} + 3.5 \text{ mm}$$

where: M_{GR} — mass of unladen grab, in tons;

s — spacing, in m, of ordinary stiffeners, measured at mid-span;

K — material factor.

SECTION 24 - ANALYSIS OF TEMPERATURE FIELD AND THERMAL STRESS OF CARGO TANK STRUCTURE

2.24.1 General requirements

2.24.1.1 This Section applies to ships carrying liquefied gases in bulk, ships carrying dangerous liquid chemicals having a temperature higher than 80°C at atmospheric pressure in bulk, oil tankers and asphalt carriers, and contains specific requirements for cargo tank thermal stress calculation as required in Chapter 10, PART EIGHT of the Rules, Chapter A4 of ISC Rules for Construction and Equipment of Ships Carrying Dangerous Liquid Chemicals in Bulk, Chapter A4, PART TWO of ISC Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, and other relevant rules of ISC.

2.24.1.2 Unless approved by ISC, the following two loading modes are not to be used:

- (1) cargoes of different temperatures and natures are carried simultaneously in adjacent tanks or in the cargo tank area;
- (2) liquid cargo and ballast water of high (low) temperature are carried simultaneously in cargo tanks and adjacent ballast tanks.

2.24.1.3 In this Section, the thermal stress calculation for cargo tanks include two steps which are to be performed in sequence. At step 1, the distribution of temperature field of cargo tanks and associated structures is to be obtained through heat transferring analysis with the given temperatures of hot/cold sources of liquid cargo and the given ambient temperatures. Step 2 is to use the distribution of temperature field so obtained as input condition for thermal analysis, so as to obtain the thermal-expansion-induced thermal stress of any structure in the temperature field due to temperature difference.

2.24.1.4 The heat transferring calculation in this Section is based on an assumed steady state heat transferring in three-dimensional space, no change of material parameters and boundary conditions is made in conjunction with any temperature change in the analysis of linear heat

transferring, and only the effects of transferring through structures and insulation are considered.

2.24.1.5 The thermal calculation in this Section is based on the assumption of a “sequentially coupled heat-structure (sequentially coupled problem)”, i.e., the effects of changes in the temperature field on the machinery field are considered without taking account of the effects of the latter on the former. Moreover, the high temperature creeping effects of structures are not considered.

2.24.1.6 In calculation, it is assumed that heat is transferred between hull structural members by conduction, and that heat exchange between air and hull structural members exposed to it is natural convection only.

2.24.1.7 In heat transferring calculation and thermal stress analysis, recognized finite element thermal analysis programs and finite element structural analysis programs are to be used.

2.24.1.8 Where methods or assumptions other than those specified in the Rules are to be used in calculation, they are to be approved by ISC.

2.24.2 Plans and documents

2.24.2.1 In addition to calculations as generally required by relevant ISC documents for direct finite element structural calculation, the following heat transferring calculation and thermal stress analysis documents together with associated drawings and documents are to be submitted:

- (1) Arrangement of insulation layers and details of their connection;
- (2) Thermal parameters of insulation layers (coefficient of thermal conductivity, etc.);
- (3) Heat balance calculation and analysis report, including the following:
 - a. maximum design temperature of liquid cargo to be carried (the temperature indicated in class notation);
 - b. design target values of external surface temperature of steel plating of inner side, inner bottom and deck, if any;
 - c. lowest/highest ambient temperature (atmosphere and seawater) for intended operating route;
 - d. distribution of temperature field under consideration.
- (4) Thermal stress calculation report: thermal stress calculation based on the distribution of temperature field as obtained according to (3) and performed according to this Section, including check of resultant stresses for combinations of thermal stress with corresponding sea conditions and loading conditions.

2.24.3 Model for analysis

2.24.3.1 Scope of model: For integral tanks, it is to be in accordance with the requirements of Appendix 1, Chapter 5 of this PART. If necessary (temperature gradient is large), modeling of the fore end area of the foremost cargo tank and that of the aft end area of the aftermost cargo tank are to be considered. For independent tanks, at least the entire tank structure is to be taken. For the effects of temperature on the supporting structure of cargo tanks and on the hull, see the relevant requirements of Appendix 1, PART TWO of ISC Rules for Construction and Equipment of

Ships Carrying Liquefied Gases in Bulk. For heat transferring analysis, the model is to cover all contributing heat insulation materials and structures, except that stainless liner may be neglected; for thermal stress analysis, the model is merely a structural one.

2.24.3.2 Structural elements: The principled requirements for modeling in respect to types of elements and meshing, etc., are as given in Appendix 1, Chapter 5 of this PART.

2.24.3.3 Insulation elements: For rock wool thermal insulation, the elements are generally of solid-element type, thickness is taken as that of the insulation layer (excluding stainless liner), and other principles for modeling, e.g. element type selection and meshing, are similar to those for structures. However, simplification is allowed, as appropriate, in way of complex intersection of certain structures (insulation), e.g. connection of a longitudinal or transverse corrugated bulkhead with upper stool.

2.24.3.4 Boundary conditions for heat transferring analysis:

- (1) The thermal transferring analysis for the determination of steel grades required for structural materials used at low temperatures is to be in accordance with the following requirements:
 - a. For ships carrying dangerous chemicals in bulk, to which ISC Rules for Construction and Equipment of Ships Carrying Dangerous Liquid Chemicals in Bulk apply and for which thermal stress calculation is to be performed, the boundary conditions regarding external atmospheric temperature and seawater temperature are to be taken in accordance with Chapter A4 of ISC Rules for Construction and Equipment of Ships Carrying Dangerous Liquid Chemicals in Bulk. For ships carrying liquefied gases in bulk, to which ISC Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk apply and for which thermal stress calculation is to be performed, the boundary conditions regarding external atmospheric temperature and seawater temperature are to be taken in accordance with Chapter A4, PART TWO of ISC Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.
 - b. For ships not covered by a. above, the boundary conditions regarding external atmospheric temperature and seawater temperature are as follows:
 - portions of hull below draught line – the defined surface temperature is the lowest temperature in water and if icing is possible for the intended operating route, this temperature is to be taken as 0°C; portions of hull above draught line – the defined surface temperature is the possibly lowest atmospheric temperature for the intended operating route, e.g. -20°C.
- (2) In respect to the determination of maximum thermal stress, the temperature load condition applied as input for the thermal analysis is to be the maximum difference between the liquid cargo temperature and the ambient temperature for the intended operating route.
- (3) For the side of cargo tank insulation or bare structural shell which is in direct contact with liquid cargo, the defined surface temperature is the highest stable temperature of liquid cargo being carried.
- (4) For the space within double bottom and double side skin, the ambient temperature may be directly taken a little higher than the external temperature, and the assumed convective heat transfer between air and steel plating as mentioned above (heat transferring by air is assumed

to be little) is defined in respect to external surfaces of inner side shell and inner bottom (the surfaces not exposed to liquid cargo). Alternatively, this space may be taken as a three-dimensional finite element model of air elements and incorporated into the finite element heat transferring model. The heat transferring calculation is performed according to the assumption of 2.24.1.6, without taking account of the heat transferring by air. Where there are special requirements for the highest temperature criterion regarding periphery of cargo tanks, the surface temperature is to be defined as so required.

- (5) The external surface temperature of the independent tank structure is to be defined according to the above requirements, as applicable.
- (6) The gas temperature in cargo tanks in the half-loaded condition may be assumed as the liquid cargo temperature, and the boundary conditions for heat convection of gas are to be used to simulate the effects of gas on structure.

2.24.3.5 In thermal analysis, the structural boundary conditions for the integral tank model are to be in accordance with the requirements of Appendix 1, Chapter 5 of this PART. For independent tanks, the model structural boundary conditions are to be taken as those for the loading conditions corresponding to temperature loads. In addition, restraint of linear displacement Δx in the direction of ship's length is to be released at a certain end (e.g. end B) of section model for the structural boundary condition of above model.

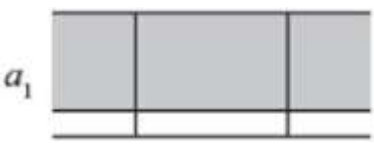
2.24.4 Thermal calculation and loading conditions

2.24.4.1 The distribution values of the three-dimensional temperature field obtained from heat transferring analysis are to be used as temperature loads in structural strength calculation. For tankers as stipulated in the Rules, where independent tanks are fitted, temperature loads in the full load condition are to be calculated; where integral tanks are fitted, the load conditions are to be as shown in Figure 2.24.4.1, and the following are to be complied with:

- (a) — only sagging mode is considered;
- (b), (c) — sagging and hogging modes are considered respectively.

And for (a), (b) and (c), both full and half load conditions in the above modes are to be considered. The half load condition means the loading height of liquid cargo is half the height of tank.

Where any loading condition specified in the loading manual or occurring in service is worse than the above conditions under consideration, the temperature load calculated to such loading condition is to be included. For cargo tanks of other ship types, temperature loads in relevant loading conditions are to be calculated in accordance with the requirements of the applicable rules.

Horizontal section	Longitudinal section
	

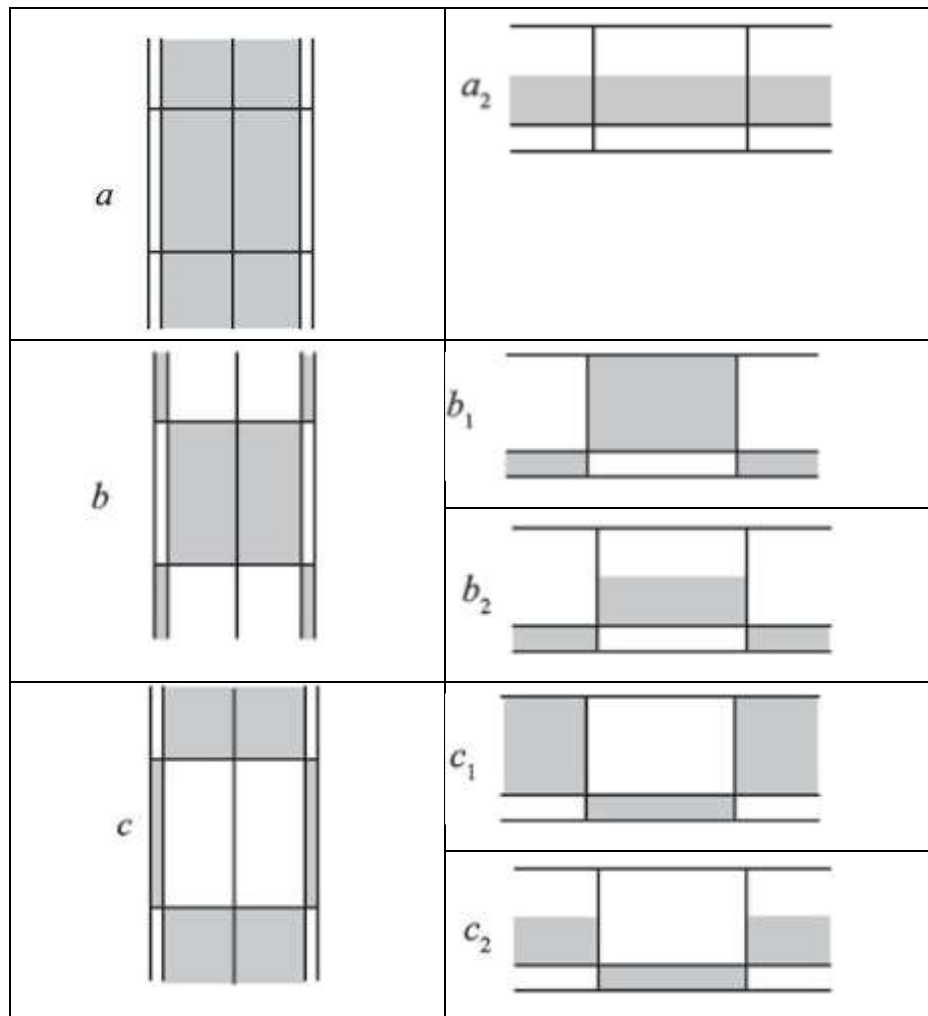


Figure 2.24.4.1

2.24.4.2 The temperature loads as calculated above are to be applied to the model of each corresponding loading condition. The calculation and application of routine loading conditions are to follow the applicable requirements in Appendix 1, Chapter 5 of this PART, Appendix 1 and Appendix 2 of PART TWO of ISC Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk and other relevant documents or routine practice.

2.24.4.3 Where only longitudinal tension and compression stresses less than $42/K \text{ N/mm}^2$ (K being material factor) are applied in regard to thermal stresses induced by temperature loads, the longitudinal bending moment of hull girder may not to be applied to both ends of the model under consideration, subject to agreement of ISC.

2.24.4.4 The heat conduction coefficient and linear expansion coefficient of steel as well as the convective heat exchange coefficient of air are to be provided by designer. For asphalt carriers during preliminary design, reference may be made as follows:

Heat conduction coefficient of carbon steel: $60.6 \text{ W/(m}\cdot\text{K)}$ – for heat transferring calculation (thermal analysis);

Linear expansion coefficient of carbon steel: $11 \times 10^{-6} (1/K)$ – for heat stress calculation (structural

analysis);

Convective heat exchange coefficient of air: $11.6 \text{ W}/(\text{m}^2 \cdot \text{K})$ – for heat transferring calculation (thermal analysis). Where the length of the finite element model is measured in mm, the value taken is to be multiplied by 10^{-6} .

The heat conduction coefficient for insulation material is to be taken according to the actual design.

2.24.5 Strength criteria

2.24.5.1 For an integral tank model, the criteria are as given in Appendix 1, Chapter 5 of this PART; for hull portion of an independent tank model, the criteria are as given in Appendix 1 and Appendix 2 of PART TWO of ISC Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk; for construction materials of independent tanks of petroleum asphalt carriers, the criteria are as given in Section 2 of Chapter 10, PART EIGHT of the Rules.

2.24.5.2 Where wave loads are obtained by direct calculation on the basis of dynamic loading, the permissible stress taken according to 2.24.5.1 may be multiplied by 1.1 and the minimum buckling safety factor may be multiplied by 0.9.

2.24.5.3 For a finite element model, for which the longitudinal hull girder bending moment is not taken into account, the permissible stress is to be adjusted as follows on the basis of Appendix 1, Chapter 5 of this PART, without any change to other requirements:

For all plating	$[\sigma_e] = 175/K$
For longitudinal plating	$[\sigma_l] = 110/K$
For longitudinal girders	$[\tau] = 83/K$
For transverse members (including floors, transverse bulkheads)	$[\tau] = 93/K$

where: K — material factor.

SECTION 25 - STRUCTURAL STRENGTHENING LOADED BY STEEL COILS ON A WOODEN SUPPORT

2.25.1 General requirements

2.25.1.1 The thickness of inner bottom plating, bilge hopper sloping plate and inner hull plating up to a height not less than the one corresponding to the top of upper tier in touch with hopper or inner hull plating as well as section modulus and shear area of stiffeners for ships intended to carry steel coils are to comply with the requirements of this Section.

2.25.1.2 The provision is determined based on the assumption of Figure 2.25.1.2 as the standard means of securing steel coils on the dunnage.

2.25.1.3 All steel coils are presumed to be of the same characters.

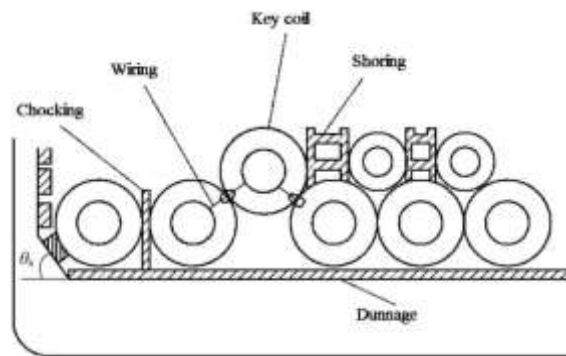


Figure 2.25.1.2 Inner Bottom Loaded by Steel Coils

2.25.2 Accelerations

2.25.2.1 In order to calculate the accelerations, the following coordinates are to be used for the transverse and vertical positions of calculated point:

$$y_{G-SC} = \begin{cases} B_h/4 & \text{for port} \\ -B_h/4 & \text{for starboard} \end{cases}$$

$$z_{G-SC} = h_{DB} + \left\{ 1 + (n_1 - 1) \frac{\sqrt{3}}{2} \right\} \frac{d_{SC}}{2}$$

where:

- B_h — breadth in m, at the mid of the hold, of the cargo hold at the level of connection of bilge hopper plate with side shell or inner hull;
- d_{SC} — diameter of steel coils, in m;
- h_{DB} — depth of double bottom, in m.

Vertical acceleration a_V , in m/s^2 , are to be calculated by the formulae defined in 1.5.2 of Section 5, Chapter 1 of this PART and tangential acceleration a_R due to roll, in m/s^2 , is to be calculated by the following formula:

$$a_R = \varphi_m \left(\frac{2\pi}{T_R} \right)^2 \sqrt{y_{G-SC}^2 + R^2}$$

where: φ , maximum angle of roll, T_R , roll period — see the formulae defined in 1.5.2 of Section 5, Chapter 1 of this PART;

$$R = z_{G-SC} - \min \left(\frac{D}{4} + \frac{d}{2}, \frac{D}{2} \right)$$

where: d — draught, in m.

2.25.3 Inner bottom plating

2.25.3.1 The thickness of plating of longitudinally framed inner bottom is not to be less than the

value obtained, in mm, from the following formula:

$$t = K_1 \sqrt{\frac{(g + 0.5a_v) F_{SC}}{\lambda_p R_{eH}}} + t_c \quad \text{mm}$$

where: K_1 — coefficient taken equal to:

$$K_1 = \sqrt{\frac{1.7slK_2 - 0.73s^2K_2^2 - (l-l')^2}{2l'(2s + 2lK_2)}}$$

t_c — corrosion addition, in mm, generally taken 2.5 mm, to be taken 5 mm where the cargo holds are designed for loading/unloading by grabs;

a_v — vertical acceleration, in m/s^2 , calculated according to the formula defined in 1.5.2, Section 5, Chapter 1 of this PART

g — acceleration due to gravity, $g = 9.81 \text{ m/s}^2$;

F_{SC} — equivalent mass of steel coils, in kg, taken equal to:

$$F_{SC} = K_S \frac{W_{SC} n_1 n_2}{n_3}$$

λ_p — permissible bending stress coefficient of plating, generally taken 0.8, to be taken 0.9 as the calculated structural member is not contributing to the hull girder longitudinal strength;

l — length of long edge of elementary plate panel taken along the side length, in m;

s — length of short edge of elementary plate panel taken along the side length in way of middle of span l , in m;

K_S — coefficient, taken equal to:

$K_S = 1.4$ when steel coils are lined up in one tier with a key coil;

$K_S = 1.0$ in other cases;

W_{SC} — mass of one steel coil, in kg;

R_{eH} — minimum yield stress of material, in N/mm^2 ;

n_1 — number of tiers of steel coils;

n_2 — number of load points per elementary plate panel of inner bottom (see Figure 2.25.3.1). For steel coil loading related to floor plates of inner bottom (see Figure 2.25.3.1(2)), $n_2 = n_3$; for steel coil loading irrelevant to floor plates of inner bottom (see Figure 2.25.3.1(1)), $2n$ is to be consistent with Table 2.25.3.1(1). For cases not included in Table 2.25.3.1(1), $2n$ is to be determined in accordance with the following formula:

$$\frac{n_2 - 1}{n_3} + \text{INT}\left(\frac{n_2 - 1}{n_3}\right) \cdot 0.2 < \frac{l}{l_z} \leq \frac{n_2}{n_3} + \text{INT}\left(\frac{n_2}{n_3}\right) \cdot 0.2$$

where: $\text{INT}()$ is the integral function, taking the integral parts of values.

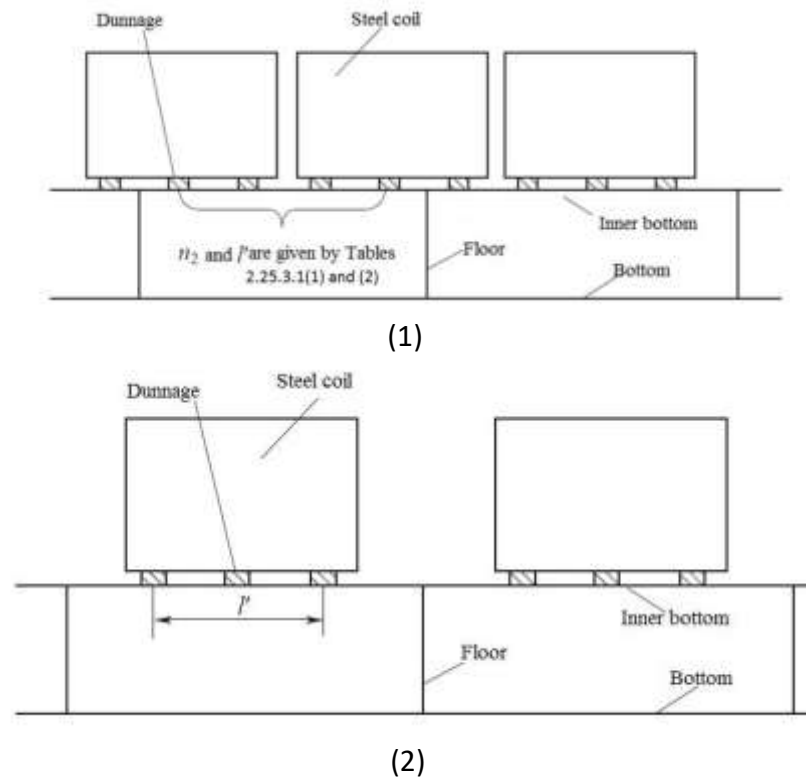


Figure 2.25.3.1 Loading Condition of Steel Coils

- n_3 — number of dunnages supporting one steel coil;
- l_s — length of a steel coil, in m;
- K_2 — coefficient taken equal to:
- l' — distance, in m, between outermost load points per elementary plate panel in ship's length (see Figure 2.25.3.1). For steel coil loading related to floor plates of inner bottom (see Figure 2.25.3.1(2)), l' is to be the distance between the dunnages of the external ends supporting the steel coils; for steel coil loading irrelevant to floor plates of inner bottom (see Figure 2.25.3.1(1)), l' is to be consistent with Table 2.25.3.1(2). For cases not included in Table 2.25.3.1(2), l' is to be determined in accordance with the following formula:

$$l' = \left[\frac{n_2 - 1}{n_3} + 0.2 \cdot \text{INT} \left(\frac{n_2 - 1}{n_3} \right) \right] l_s$$

where: INT () is the integral function, taking the integral parts of values.

Table 2.25.3.1(1) - Number n_2 of Load Points per Elementary Plate Panel

n_2	$n_3 = 2$	$n_3 = 3$	$n_3 = 4$	$n_3 = 5$
1	$0 < \frac{l}{l_s} \leq 0.5$	$0 < \frac{l}{l_s} \leq 0.33$	$0 < \frac{l}{l_s} \leq 0.25$	$0 < \frac{l}{l_s} \leq 0.2$
2	$0.5 < \frac{l}{l_s} \leq 1.2$	$0.33 < \frac{l}{l_s} \leq 0.67$	$0.25 < \frac{l}{l_s} \leq 0.5$	$0.2 < \frac{l}{l_s} \leq 0.4$
3	$1.2 < \frac{l}{l_s} \leq 1.7$	$0.67 < \frac{l}{l_s} \leq 1.2$	$0.5 < \frac{l}{l_s} \leq 0.75$	$0.4 < \frac{l}{l_s} \leq 0.6$
4	$1.7 < \frac{l}{l_s} \leq 2.4$	$1.2 < \frac{l}{l_s} \leq 1.53$	$0.75 < \frac{l}{l_s} \leq 1.2$	$0.6 < \frac{l}{l_s} \leq 0.8$
5	$2.4 < \frac{l}{l_s} \leq 2.9$	$1.53 < \frac{l}{l_s} \leq 1.87$	$1.2 < \frac{l}{l_s} \leq 1.45$	$0.8 < \frac{l}{l_s} \leq 1.2$
6	$2.9 < \frac{l}{l_s} \leq 3.6$	$1.87 < \frac{l}{l_s} \leq 2.4$	$1.45 < \frac{l}{l_s} \leq 1.7$	$1.2 < \frac{l}{l_s} \leq 1.4$
7	$3.6 < \frac{l}{l_s} \leq 4.1$	$2.4 < \frac{l}{l_s} \leq 2.73$	$1.7 < \frac{l}{l_s} \leq 1.95$	$1.4 < \frac{l}{l_s} \leq 1.6$
8	$4.1 < \frac{l}{l_s} \leq 4.8$	$2.73 < \frac{l}{l_s} \leq 3.07$	$1.95 < \frac{l}{l_s} \leq 2.4$	$1.6 < \frac{l}{l_s} \leq 1.8$
9	$4.8 < \frac{l}{l_s} \leq 5.3$	$3.07 < \frac{l}{l_s} \leq 3.6$	$2.4 < \frac{l}{l_s} \leq 2.65$	$1.8 < \frac{l}{l_s} \leq 2.0$
10	$5.3 < \frac{l}{l_s} \leq 6.0$	$3.6 < \frac{l}{l_s} \leq 3.93$	$2.65 < \frac{l}{l_s} \leq 2.9$	$2.0 < \frac{l}{l_s} \leq 2.4$

Table 2.25.3.1(2) - Distance between Load Points in Ship Length Direction per Elementary Plate Panel of Inner Bottom

n_2	n_3			
	2	3	4	5
1	Actual breadth of dunnage			
2	$0.5l_s$	$0.33l_s$	$0.25l_s$	$0.2l_s$
3	$1.2l_s$	$0.67l_s$	$0.50l_s$	$0.4l_s$
4	$1.7l_s$	$1.20l_s$	$0.75l_s$	$0.6l_s$
5	$2.4l_s$	$1.53l_s$	$1.20l_s$	$0.8l_s$
6	$2.9l_s$	$1.87l_s$	$1.45l_s$	$1.2l_s$
7	$3.6l_s$	$2.40l_s$	$1.70l_s$	$1.4l_s$
8	$4.1l_s$	$2.73l_s$	$1.95l_s$	$1.6l_s$
9	$4.8l_s$	$3.07l_s$	$2.40l_s$	$1.8l_s$
10	$5.3l_s$	$3.60l_s$	$2.65l_s$	$2.0l_s$

2.25.4 Bilge hopper sloping plate and inner hull plate

2.25.4.1 The thickness of plating of longitudinally framed bilge hopper sloping plate and inner hull is not to be less than the value obtained, in mm, from the following formula:

$$t = K_1 \sqrt{\frac{a_{\text{hopper}} F_{SC}}{\lambda_p R_{eH}}} + t_c \quad \text{mm}$$

where: K_1 — coefficient, defined in 2.25.3;

t_c — corrosion addition, in mm, generally taken 2.5 mm, to be taken 3.5 mm for bilge hopper sloping plate and inner hull plate within 1.5 m height from the lowest point of inner bottom where the cargo holds are designed for loading/unloading by grabs;

R_{eH} — minimum yield stress of material, in N/mm²;

a_{hopper} — factor taken equal to:

$$a_{\text{hopper}} = -a_R \sin \left(\tan^{-1} \left| \frac{y_{G-SC}}{R} \right| - \theta_h \right) + g \cos(\theta_h - \varphi_m)$$

θ_h — angle, in degree, between inner bottom plate and bilge hopper sloping plate or inner hull plate, see Figure 2.25.1.2;

φ_m — in degree, see formula specified in 1.5.2 of Section 5, Chapter 1 of this PART;

a_R — tangential acceleration defined in 2.25.2;

g — acceleration due to gravity, $g = 9.81 \text{ m/s}^2$;

y_{G-SC} — centre of gravity in transverse direction, in m, defined in 2.25.2;

R — factor, defined in 2.25.2;

F_{SC} — equivalent mass of steel coils, in kg, taken equal to:

$$F_{SC} = C_k \cdot \frac{W_{SC} n_1}{n_2}$$

λ_p — permissible bending stress coefficient of plating, defined in 2.25.3;

C_k — coefficient, taken equal to:

$C_k = 3.2$, when steel coils are lined up two or more tier, or when steel coils are lined up one tier and key coil is located second or third from bilge hopper sloping plate or inner hull plate;

$C_k = 2.0$, in other cases.

2.25.5 Stiffeners of inner bottom

2.25.5.1 The section modulus W and the shear area A of single span stiffeners located on inner bottom plating are not to be less than the values obtained from the following formulae:

$$W = 1.1 K_3 \frac{(g + 0.5 a_v) F_{SC}}{8 \lambda_p R_{eH}} \quad \text{cm}^3$$

$$A = \frac{5(g + 0.5 a_v) F_{SC}}{0.9 \tau_{eH} \sin \phi} \times 10^{-3} \quad \text{cm}^2$$

where: K_3 — coefficient, defined in Table 2.25.5.1, to be taken as $2l_e/3$ for $n_2 > 10$;

- l_e — effective span of stiffeners, in m, see 1.2.3, Section 2, Chapter 1 of this PART;
 a_v — vertical acceleration, in m/s^2 , calculated according to the formula defined in 1.5.2, Section 5, Chapter 1 of this PART;
 g — acceleration due to gravity, $g = 9.81 m/s^2$;
 F_{SC} — equivalent mass of steel coils, in kg, defined in 2.25.3;
 R_{eH} — minimum yield stress of material, in N/mm^2 ;
 λ_s — permissible bending stress coefficient of stiffeners, see 2.25.5.1;
 τ_{eH} — shear yield stress of material, in N/mm^2 , see 2.25.5.1;

$$\tau_{eH} = \frac{R_{eH}}{\sqrt{3}}$$

- ϕ — angle between stiffener web and shell plating, in degree, to be taken at the middle of span of stiffener.

Table 2.25.5.1 - Coefficient K_3

n_2	1	2	3	4	6	7	8	9	10
K_3	l_e	$l_e - \frac{l^2}{l_e}$	$l_e - \frac{2l^2}{3l_e}$	$l_e - \frac{5l^2}{9l_e}$	$l_e - \frac{7l^2}{15l_e}$	$l_e - \frac{4l^2}{9l_e}$	$l_e - \frac{3l^2}{7l_e}$	$l_e - \frac{5l^2}{12l_e}$	$l_e - \frac{11l^2}{27l_e}$

2.25.6 Stiffeners located on bilge hopper sloping plate or inner hull plate

2.25.6.1 The section modulus W and the net shear area A of single span stiffeners located on bilge hopper sloping plate and inner hull plate are not to be less than the values obtained from the following formulae:

$$W = 1.1K_3 \frac{a_{hopper} F'_{SC}}{8\lambda_s R_{eH}} \text{ cm}^3$$

$$A = \frac{5a_{hopper} F'_{SC}}{0.9\tau_{eH} \sin \phi} \times 10^{-3} \text{ cm}^2$$

- where: K_3 — coefficient, defined in Table 2.25.5.1, to be taken as 2/3 for $n_2 > 10$;
 l_e — effective span of stiffeners, in m, see 1.2.3, Section 2, Chapter 1 of this PART;
 R_{eH} — minimum yield stress of material, in N/mm^2 ;
 a_{hopper} — coefficient, defined in 2.25.4.1;
 τ_{eH} — shear yield stress of material, in N/mm^2 , see 2.25.5.1;
 λ_s — permissible bending stress coefficient of stiffeners, see 2.25.5.1;
 F'_{SC} — equivalent mass of steel coils, in kg, defined in 2.25.4;
 ϕ — angle, in degree, defined in 2.25.5.

APPENDIX 1

LOADING INSTRUMENTS

1. General Requirements

1.1 Application

1.1.1 This Appendix applies to loading instruments consisting of the onboard computer system as required by 2.2.8 of this Chapter.

1.1.2 This Appendix applies to onboard computers which are, as required by 1.9.1.3 of Chapter 1 of this PART, capable of providing intact stability information, and to onboard computers having stability software, as stated in 1.9.1.4 of that Chapter.

1.1.3 The loading instruments covered by this Appendix are passive systems with manual data entry and active systems in the off-line operation mode only, excluding any active system with sensors reading and entering the contents of tanks, etc., and any integrated system which controls or initiates actions based on the sensor-supplied inputs.

The definitions of passive, active and integrated systems are given in paragraph 2 of Appendix 2.

1.2 Class notations

1.2.1 The class notation for a loading instrument consists of any combination of Loading Computer and the letters S, I, G and D, with each of these four letters indicating that the loading instrument is capable of calculating and checking one of the following items:

S: Hull strength in various loading conditions.

I: Intact stability.

G: Stability for the carriage of grain in bulk.

D: Damage stability.

For example, the class notation of Loading Computer S, I, D shows that the ship is provided with a loading instrument capable of calculating and checking the hull strength, intact stability and damage stability in various loading conditions.

1.3 Inspections of loading instruments

1.3.1 Inspections of loading instruments include hardware inspection, software approval, actual installation inspection and inspection after construction. Steps of implementation for inspections of loading instruments are shown in Figure 1.3.1.

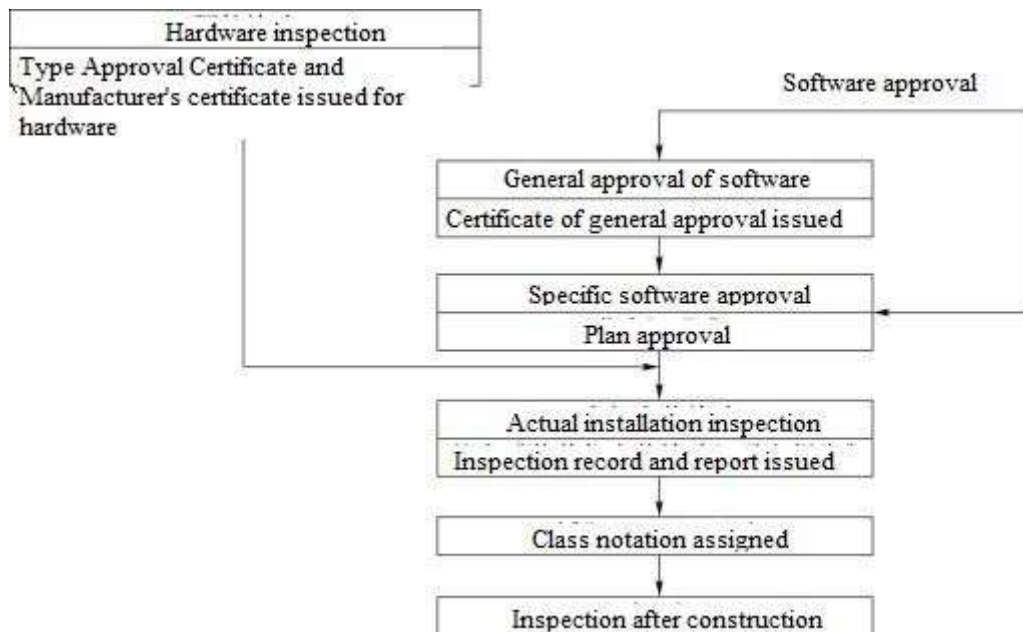


Figure 1.3.1 Steps of Implementation for Surveys of Loading Instruments

1.3.2 Software approval may be carried out by either one of the following two methods:

- (1) On completion of general approval of software, software approval is carried out for a specific ship;
- (2) Software approval is carried out directly to a specific ship.

1.3.3 Provision of loading instruments on board the ship may be made by either one of the following two methods:

- (1) a single loading instrument to be provided on board the ship;
- (2) two same loading instruments to be provided on board the ship, one for main use and the other as standby.

2. Hardware Inspections

2.1 General requirements

2.1.1 Loading instrument hardware inspections are to be carried out in accordance with the requirements for inspections of products in Chapter 3 of PART ONE of the Rules and this Section and, in general, consist of examination of plans and documents, type tests.

2.1.2 Hardware of loading instruments consists, in general, of computers and peripheral apparatus, where the printer is supplied as a separate unit from the computer, the type test of such a printer is not necessary.

2.1.3 Where two available loading instruments are installed onboard a ship, type approval certificate may be exempted, however, installation test is to be carried out.

2.2 Plans and documents

2.2.1 Where an application for hardware inspections is made, the following plans and documents should be submitted to ISC for approval:

- (1) Technical specifications of hardware and peripheral apparatus;
- (2) Fixing and installation of loading instruments;
- (3) Type test program.

2.3 Type tests

2.3.1 Type tests are to be carried out by a verification and test organization authorized by ISC and, in general, with the presence of the ISC Surveyor.

2.3.2 Type test items

- (1) Visual inspection;
- (2) Performance;
- (3) Electric power supply variations;
- (4) Dry heat;
- (5) Damp heat;
- (6) Vibration;
- (7) Inclination and rolling;
- (8) Protection by enclosure;
- (9) Low temperatures;
- (10) Electromagnetic compatibility.

2.3.3 Where the loading instruments, of which hardware is installed in an air-conditioned room, are used only for the purpose of calculation, and no input of external signals or output of control signals is made, the items of type tests may be suitably reduced.

2.3.4 Where one main computer together with a standby one are provided onboard the ship, the hardware may not be subject to the type tests.

2.3.5 For the methods used in type tests, reference may be made to ISC Guidelines for Type Approval Test of Electric and Electronic Products or the relevant requirements of standards acceptable to ISC.

3. Functional Requirements for Software

3.1 General requirements

3.1.1 The functions of loading instruments are to cover at least calculating and indicating still water bending moment and shear force at the specified hull positions in any loading condition or light ship condition quickly and easily. Where applicable, the maximum permissible value of a still water torsional moment resulted from the non-uniform loading of cargoes is to be indicated.

3.1.2 Single point loading instruments (i.e. with only one check point on board the ship) are not acceptable to ISC.

3.1.3 Loading instruments are not to be substituted for the approved or confirmed final loading manual or stability information (hereinafter referred to as the final loading manual), and the results of the calculations are only applicable to the ship for which it has been approved.

3.1.4 For a specific ship, the requirements for overall strength are mandatory. Where the installed loading instruments have the function of stability calculations and are assigned an appropriate class notation, however, the stability calculation software is to be capable of calculations for all stability requirements (including intact stability, grain-carrying stability and damage stability), either as mandatory or non-mandatory ones, applicable to the ship and is to contain relevant stability information, subject to the approval by ISC.

3.1.5 It is recommended that software be provided with an online help function, i.e. the software system may provide online help for input, output, calculation and printing.

3.1.6 The software is to be such that a common user can not alter the inputted data of the actual ship such as the geometrical characteristics, light ship weight, centre of gravity, capacity table, curve of allowable values.

3.1.7 The software is to be such that any user can not alter the inputted application programs.

3.1.8 The software is to, as far as possible, reduce significant or illogical input errors and alert the user to any input value exceeding the actual maximum capacity of a compartment or any negative value of the capacity.

3.1.9 The software is to be capable of clearly judging whether a loading condition complies with the relevant requirements, i.e. calculating for a certain loading condition. Where the calculation results exceed the permissible values, the user is to be alerted by distinct means such as prominent display, special markings or visible and audible alarms, screen display or printout.

3.1.10 The software is to be provided with passwords so that the computer will refuse to work and alert the user where any illegal password is input.

3.1.11 The software is to be at least capable of calculating the displacement and centre of gravity in any loading conditions and completing calculation and criteria of overall strength (and stability, if applicable) of the ship, displaying and printing out date and time of performing calculation and saving calculation results. All input data and calculation results displayed on the screen and printed out, including the fore and after draughts, are to be in definite and uniform measurement units and easily comparable with the approved final loading manual to avoid possible confusion and misunderstanding, with the identification marking and version number of the software being clearly indicated on each printed page.

3.1.12 The software interface is to be fully user-friendly and to alert the user to any operational error. Data loss or dead stop of the computer caused by the user's error is to be minimized.

3.2 Overall strength

3.2.1 The functional requirements for software in respect to overall strength are given in 2.2.8 of this Chapter.

3.3 Intact stability

3.3.1 The software is to use direct calculation to check intact stability and the following requirements are to be met:

- (1) The software is to be capable of calculating and displaying the height of the centre of gravity and initial metacentric height of the ship and correcting free surface effects and comparing such values with the permissible values, where applicable. If any permissible value is exceeded, an alarm is to be automatically initiated.
- (2) The software is to be at least capable of calculating and displaying GZ curves and correcting free surface effects.
- (3) The software is to be capable of calculating the intact stability in any loading conditions and achieving the criteria for intact stability according to the relevant requirements. The method for achieving the criteria is to be in conformity with the final loading manual and any other method used for this purpose is to be indicated in submissions and subject to agreement of ISC plan approval unit. The software is to be capable of automatically initiating an alarm in case of any permissible criterion being exceeded.

3.3.2 If damage stability is checked by the software according to the provisions of 3.5.2 of this Section, intact stability can be checked based on the same method.

3.4 Stability for carriage of grain in bulk

3.4.1 The software is to be in compliance with the relevant requirements in 3.3 of this Appendix.

3.4.2 The software is to be capable of inputting the permissible inclining moment curves.

3.4.3 The software is to be capable of calculating the stability for the carriage of grain in bulk and achieving the criteria for the stability according to the relevant requirements. The method for achieving the criteria is to be in conformity with the final loading manual. The software is at least to be able to calculate the inclining moment of actual shift of grain and the permissible inclining moment to which comparison is made. The software is to be capable of automatically initiating an alarm in case of any permissible value being exceeded.

3.5 Damage stability

3.5.1 If the software uses direct calculation to check damage stability, the following requirements are to be met:

- (1) The software is to indicate whether the calculation is performed by means of loss of buoyancy or increase of weight, and the former is recommended.
- (2) The software is to be capable of making corrections of free surface effects for GZ curves.
- (3) The software is to be capable of allowing for corrections for liquid loss of damaged tanks.
- (4) The software is to define the damaged compartment(s) and associated damage conditions in

advance for selection by the crew in calculation, and be capable of calculating and displaying the GZ curves after damage.

- (5) The software is to be capable of calculating the equilibrium position and stability in any damage condition, covering fore, after and mean draughts, trimming values, heeling angles, distance from equilibrium waterline to flooding openings, residual initial metacentric height, residual stability etc., and achieving the criteria for damage stability according to the relevant requirements. The method for achieving the criteria is to be in conformity with the final loading manual. The software is to be capable of automatically initiating an alarm in case of any permissible criterion being exceeded.

3.5.2 If damage stability is checked by the software on the basis of approved limit curves (the curve of permissible vertical position of the centre of gravity or the curve of permissible initial metacentric heights) or loading conditions, the following requirements are to be met:

- (1) The software is to be capable of calculating and displaying displacement, the position of the centre of gravity, buoyancy and initial metacentric height of the ship in any loading condition and correcting free surface effects as required and comparing such values with the approved data.
- (2) The software is to be capable of automatically initiating an alarm in case of any permissible criterion being exceeded (if limit curves are used) or any acceptable and safe tolerance being exceeded (compared with loading condition).

3.6 Additional requirements for bulk carriers, ore carriers and combination carriers

3.6.1 In addition to the above requirements, the loading instruments on board bulk carriers, ore carriers and combination carriers are to comply with the requirements of Section 7, Chapter 8 of this PART.

4. Software Approval

4.1 General requirements

4.1.1 Software approval consists of general approval and specific approval, covering:

- (1) verification that the data used are consistent with the current condition of the ship;
- (2) verification and approval of the test conditions;
- (3) verification that the software is appropriate for the required type of ship and corresponding calculations.

4.2 Requirements for general approval of software

4.2.1 The general approval of software of loading instruments means approval of design and calculation programs of the software, i.e. approval of the design methods, calculation functions and principles and relevant documents for programming and usage of the said software through actual tests on representative ships selected according to the submitted scope of application.

4.2.2 The general approval of software of loading instruments may specifically include the following:

- (1) Design methods, calculation functions and principles of the software are to be in conformity

with the classification/statutory requirements and comply with the relevant requirements in section 3 of this Appendix.

- (2) For ships of different types selected for tests, the calculation results for the typical loading conditions selected according 4.6 of this Appendix are, by comparison with those of the loading manual approved by ISC or ISC plan approval software, to comply with the accuracy requirements in 4.7 of this Appendix.
- (3) User's operation manual of loading instruments is to comply with the relevant requirements in 4.8 of this Appendix.

4.2.3 ISC will issue a Certificate of General Approval of Software of Loading Instruments to the software upon general approval by ISC.

4.2.4 The application and restrictions, e.g. applicable ship types and functional restrictions, are to be noted on the Certificate of General Approval of Software of Loading Instruments.

4.2.5 A Certificate of General Approval of Software of Loading Instruments remains valid for a period not exceeding 5 years. When the certificate expires and if the applicant confirms that no change has been made to the version of the said software, ISC will renew the Certificate of General Approval of Software of Loading Instruments. However, the plan approval unit responsible for the software approval is to carry out nonscheduled assessments of the software as necessary, e.g. in response to complaints from users.

4.2.6 Where the applicant has made any change to the software without re-approval by ISC, the Certificate of General Approval of Software of Loading Instruments issued by ISC is no longer valid.

4.2.7 Where the version of the loading instrument software, of which general approval is granted by ISC, is upgraded or changed, resubmission for approval is required. Submission of plans and documents which are the same as those for the approved version is unnecessary, but the applicant should indicate this in the application.

4.3 Steps of implementation for general approval of software

4.3.1 The general approval of software of loading instruments is to be carried out in accordance with the relevant ISC requirements for plan approval.

4.3.2 The applicant is to fill in an application for software approval of loading instruments. For the relevant contents of the application, refer to the relevant requirements of section 3 of this Appendix.

4.3.3 The test ships are to be so selected that all ship types and their functions as required in the application are covered. And the following are to be complied with:

- (1) for the strength calculation software, the applicant is to select the calculation results for at least one test ship, which may be either the sample ship provided by ISC or the one determined by

the applicant. Where the latter is selected, the prior agreement of the plan approval unit is necessary;

- (2) for the stability calculation software, test ships are to be selected in accordance with 6.1 of Appendix 2 of this Chapter.

4.3.4 The applicant is to submit the following plans and documents to ISC plan approval unit. After examination and approval, one set of their copies is to be returned to the applicant, one set sent to the Headquarters of ISC and one set filed by the plan approval unit (where application for specific approval of the software is made for the test ship at the same time, an additional copy of the user's operation manual and that of the calculation and test report are required for ISC survey unit):

- (1) Specification of the software system (for information), covering design method, calculation functions and principles, data structure as well as flowchart of the software, and explaining functional items as determined in the application and computational accuracy of the software such as methods used for numerical integration, interpolation, etc.
- (2) User's operation manual of loading instruments (for information).
- (3) Data of test ship(s) inputted in the software (for information), such as main dimensions, lightweight distribution and centre of gravity, Bonjean curves, hydrostatic data, tank capacity, permissible still water shear forces, permissible still water bending moments and, where applicable, correction factors of bulkhead shear forces and permissible still water torsional moments. Where the software has computation functions for intact stability, stability for the carriage of grain in bulk, damage stability, etc., corresponding data are also to be submitted for approval.
- (4) Test report (for approval) of loading calculations for conditions to be selected according to the requirements in 4.6 of this Appendix with the agreement of the plan approval unit, covering the input data and all output results.
- (5) General arrangement, lines, final loading manual of the test ship(s) and other additional plans or data required by ISC for information or use in check calculations.
- (6) A set of installation discs, including the executing software and internal testing data.

4.3.5 On satisfactory completion of examination of the above-mentioned plans and documents, the Certificate of Software Approval of Loading Instruments may be issued.

4.4 Requirements for specific approval of software

4.4.1 The specific approval of software means, for the purpose of a specific ship, the approval of loading instrument's software installed on board, i.e. the approval of the design method, calculation functions and principles, input data, user's operation manual, full-scale test report and other documents.

4.4.2 The specific approval of software may specifically include the following:

- (1) Design methods, calculation functions and principles of the software are to be in conformity with the classification requirements and comply with the relevant requirements in section 3 of this Appendix.

- (2) All input data of the software are to be consistent with those of the actual ship, i.e. being taken from the finished documents approved or confirmed by ISC, and in particular the lightweight and centre of gravity are to be taken from the inclining test report. Where the software is capable of stability calculation, the input data are to comply with paragraph 6.2 of Appendix 2.
- (3) The computation points along the ship's length and their number are to comply with ISC rules.
- (4) The permissible still water bending moments, permissible still water shear forces, and where applicable, permissible still water torsional moments and correction factors of bulkhead shear forces at the computation points along the ship's length are to be consistent with those in the final loading manual.
- (5) The calculation results for the typical loading conditions selected according to 4.6 of this Appendix are, by comparison with those of the final loading manual or ISC plan approval software, to comply with the accuracy requirements in 4.7 of this Appendix.
- (6) User's operation manual of the loading instrument is to comply with the requirements in 4.8 of this Appendix.

4.4.3 For software with a Certificate of General Approval of Software of Loading Instruments and in respect to the applicable ship types and functions stated in the Certificate, where application is made for specific approval of the software, submission of design methods, calculation functions and principles of the software is unnecessary.

4.4.4 For software without a Certificate of General Approval of Software of Loading Instruments, the applicant may directly apply to ISC for specific approval of loading instrument software.

4.5 Steps of implementation for specific approval of software

4.5.1 The specific approval of software is to be carried out in accordance with the relevant ISC requirements.

4.5.2 For the relevant contents of the application, refer to the relevant requirements of section 3 of this Appendix.

4.5.3 The applicant is to submit the following plans and documents to ISC:

- (1) For software without general approval by ISC, the applicable contents for the specific ship as required in (1), (2), (3), (4), (5) and (6) of 4.3.4 of this Appendix are to be submitted.
- (2) For software with general approval by ISC, the applicable contents for the specific ship as required in (2), (3), (4), (5) and (6) of 4.3.4 of this Appendix and a copy of the Certificate of General Approval of Software of Loading Instruments are to be submitted.

4.6 Test conditions

4.6.1 Test conditions are to be selected from the final loading manual.

4.6.2 Test conditions are at least to contain loading conditions for the following:

- (1) for minimum displacement, such as lightship condition or arrival condition with light ballast;

- (2) for maximum still water bending moment, such as ballast or partially loaded conditions;
- (3) for maximum displacement, such as fully loaded conditions;
- (4) any condition resulting in extremely large still water shear force, such as ore loaded in alternate holds, etc.;
- (5) where the software is capable of the stability calculation for carriage of grain in bulk, the test conditions are to include the one of a fully loaded hold with even filling at its ends, the one of a fully loaded hold with uneven filing at its ends and the one of a partly loaded hold;
- (6) where the software is capable of both intact stability calculation and damage stability calculation, the necessary typical conditions are to comply with paragraph 6.2 of Appendix 2.

4.6.3 The test conditions are to contain the arrival and departure conditions and cover all loaded holds and all functions of the software as far as possible.

4.6.4 The approved test conditions are to be stored as input data in such a way that no user can alter them. A copy of the approved test conditions is to be available on board.

4.7 Permissible values and error control

4.7.1 All selected permissible values and the calculation points along the ship's length are to be taken from the finished documents approved by ISC.

4.7.2 The curves of still water shear forces and still water bending moments are to be consistent with the corresponding curve tendency in the final loading manual. The peak value of still water bending moment is normally to occur at the position where the still water shear force is zero.

4.7.3 The maximum values of still water shear force, still water bending moment and still water torsional moment and their calculated values at the calculation points along the ship's length are, as compared with the calculation results of the final loading manual, to have their errors controlled within the ranges given in Table 4.7.3.

Table 4.7.3 - Error Control

Item	Error (in comparison to approved value, %)
Still water shear force	$\leq +5\%$
Still water bending moment	$\leq +5\%$
Still water torsional moment	$\leq +5\%$

4.7.4 The errors of the software in stability calculation are to comply with paragraph 5 of Appendix 2.

4.7.5 During examination, where the errors of the calculated values for individual calculation points of the loading instrument are significant as compared with the values of the final loading manual and no adequate evidence is available for wrong calculation of the loading instrument, check is to be made by using ISC plan approval software and the calculation results by this software

are to be accepted as standard ones. Where any principled error is found in the final loading manual, the unit which has approved the manual is to be informed of this matter together with the recommendation that the existing loading manual be revised.

4.8 Operation manual

4.8.1 At least one copy of operation manual of loading instrument of the ship is to be kept on board.

4.8.2 The operation manual of loading instrument is to be written in a language used by the users on board, and the language is to be the same as that used for screen display, printout and the approved final loading manual kept on board. Where the language is not English, an English translation is to be available.

4.8.3 The operation manual is to be written in a clear and unambiguous manner. The use of flowcharts is recommended for illustrating operational processes.

4.8.4 The operation manual is to contain the following:

- (1) particulars and version number of the software;
- (2) a copy of the Certificate of General Approval of Software of Loading Instruments (where applicable);
- (3) specification of hardware needed to run the software and guidance for software installation;
- (4) software running steps shown in menus and dialogues, description of error messages and warnings likely to be encountered and unambiguous instructions for subsequent actions to be taken by the user in each case;
- (5) lightweight and coordinates of centre of gravity;
- (6) full deadweight description of each test condition for loading calculation;
- (7) diagrams of the permissible still water shear forces and still water bending moments and where applicable, the permissible cargo torque;
- (8) where applicable, shear force correction factors;
- (9) operation procedure shown by calculation cases;
- (10) input and output data, calculation results shown by screen display, with necessary explanatory text;
- (11) explanation for function keys.

5. Actual Installation Inspections

5.1 General requirements

5.1.1 The Owner or the entrusting party is to submit application to ISC survey unit situated at the port of call of the ship.

5.1.2 The crew may master the operation and calculation of the loading instrument on board through learning or training. The installation inspection is to be carried out by the crew.

5.1.3 Actual installation inspection is to be carried out soon after the loading instrument has been installed on board the ship for verification of satisfactory operation and calculation and for check of strength and stability. Where by that time the final loading manual has not been approved, the installation inspection may be postponed until the manual is approved.

5.2 Inspections and tests

5.2.1 Where the loading instruments are provided as a main computer and a standby one on board a ship, installation inspections are to be carried out respectively and both computers are to be found satisfactory.

5.2.2 The installation inspections are to be carried out in the presence of ISC Surveyor. The following items are to be included in the installation inspections:

- (1) checking the certificate of hardware;
- (2) checking that the user's operation manual and test report of loading calculation are kept on board the ship;
- (3) examining the environment and position for installing the system: confirming that the position and method for installing the system are as required in the specification;
- (4) system stability testing: the computer system is to be capable of working normally after a continuous running period of one hour;
- (5) self-checking capability tests of hardware and peripheral apparatus: self-check tests to be carried out according to the specification for hardware and peripheral apparatus with self-check capability;
- (6) transient power failure test: re-starting the system after a period of 30 s of transient power failure, and confirming that:
 - ① it is still capable of working normally; and
 - ② its programs and data are not lost;
- (7) software security tests: where an illegal password is inputted (or in case of human maloperation), the system should refuse to work;
- (8) software safety tests: a common user is not to be capable of changing the application program and the input ship's data such as geometrical characteristics, tank capacity table, curve of permissible values;
- (9) system performance tests: the calculation results from the system operated by the crew of the ship based upon the loading conditions as stated in the approved test report of loading calculations are to be the same as those in the approved test report. Where the software is capable of stability calculation, tests are also to comply with paragraph 8 of Appendix 2.

5.2.3 The test report of loading calculations printed out by the loading instrument during installation inspection is to be confirmed and signed by the attending Surveyor. After satisfactory installation inspection, the attending Surveyor will issue a report and ISC will assign an appropriate class notation to the loading instrument.

5.3 Inspections of existing loading instruments on board ships

5.3.1 For ships provided with loading instruments approved by other member Societies of IACS, the operation manual, test report of loading calculations approved and related certificates of loading instrument hardware and software issued by these Societies may be reviewed, and installation inspections are to be carried out in accordance with 5.2.2 of this Appendix.

5.3.2 For ships provided with loading instruments not complying with the relevant requirements of ISC or approved by a party which is not member of IACS, installation inspections are to be carried out once again.

5.3.3 For ships assigned with class notation “Loading Computer”, the survey after construction is to be carried out in accordance with relevant requirements of 6.3.5 of Chapter 6, PART A of the Rules.

APPENDIX 2

IACS UR L5 COMPUTER SOFTWARE FOR ONBOARD STABILITY CALCULATIONS

(Rev.4, June 2020)

Application

This Unified Requirement is applicable to software which calculates the stability of actual loading conditions and which is installed on ships and on units subject to compliance with the 1966 Load Line Convention or the 1988 Protocol to the Load Line Convention, as amended, the IMO MODU Code and/or the 2008 IS Code.

The use of onboard computers for stability calculations is not a requirement of class.

Stability software installed onboard shall cover all mandatory class and statutory intact and damage stability requirements applicable to the ship. This UR, requires approval of software installed on onboard computers which is capable of performing stability calculations.

Active and passive systems are defined in paragraph 2. This UR covers passive systems and the off-line operation mode of active systems only.

The requirements in this UR apply to stability software on ships contracted for construction^① on or after 1 July 2005^{②③④}.

1 General

- The scope of a stability calculation software shall be in accordance with the stability information as approved by the Administration and shall at least include all information and perform all calculations or checks as necessary to ensure compliance with the applicable stability requirements.
- Approved stability software is not a substitute for the approved stability information, and is used as a supplement to the approved stability information to facilitate stability calculations.
- The input/output information shall be easily comparable with approved stability information so as to avoid confusion and possible misinterpretation by the operator relative to the approved stability information.
- An operation manual is to be provided for the onboard computer stability software.
- The language in which the stability information is displayed and printed out as well as the operation manual written shall be the same as used in the ship's approved stability information. The Society may require a translation into a language considered appropriate.
- The onboard computer software for stability calculations is to be ship specific and the results

① The "contracted for construction" date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of "contracted for construction", refer to IACS Procedural Requirement (PR) No.29.

② Changes introduced in Rev.2 of this UR are to be uniformly applied by IACS Societies on ships contracted for construction on or after 1 January 2007.

③ Changes introduced in Rev.3 of this UR are to be uniformly applied by IACS Societies on ships contracted for construction on or after 1 July 2018.

④ Changes introduced in Rev.4 of this UR are to be uniformly applied by IACS Societies on ships contracted for construction on or after 1 July 2021. of the calculations are to be only applicable to the ship for which it has been approved.

– In case of modifications implying changes in the main data or internal arrangement of the ship, the specific approval of any original stability calculation software is no longer valid. The software is to be modified accordingly and reaproved.

2 Calculation Systems

A passive system requires manual data entry;

an active system replaces the manual entry with sensors reading and entering the contents of tanks, etc.; and a third system, an integrated system, controls or initiates actions based on the sensor-supplied inputs and is not within the scope of this UR.

3 Types of Stability Software

Four types of calculations performed by stability software are acceptable depending upon a vessel's stability requirements:

Type 1: Software calculating intact stability only (for vessels not required to meet a damage stability criterion).

Type 2: Software calculating intact stability and checking damage stability on basis of a limit curve (e.g. for vessels applicable to SOLAS Part B-1 damage stability calculations, etc.) or checking all the stability requirements (intact and damage stability) on the basis of a limit curve.

Type 3: Software calculating intact stability and damage stability by direct application of preprogrammed damage cases based on the relevant Conventions or Codes for each loading condition (for some tankers, etc.).

Type 4: Software calculating damage stability associated with an actual loading condition and actual flooding case, using direct application of user defined damage, for the purpose of providing operational information for safe return to port .

Damage stability of both Type 3 and Type 4 stability software shall be based on a hull form model, that is, directly calculated from a full three-dimensional geometric model.

4 Functional Requirements

4.1 General requirements for any type of stability software

4.1.1 The calculation program shall present relevant parameters of each loading condition in order to assist the Master in his judgement on whether the ship is loaded within the approval limits. The following parameters shall be presented for a given loading condition:

- deadweight data;
- lightship data;
- trim;
- draft at the draft marks and perpendiculars;
- summary of loading condition displacement, VCG, LCG and, if applicable, TCG;
- downflooding angle and corresponding downflooding opening (not applicable for Type 2 software which uses limit curve for checking all the stability requirements. However, if intact stability criteria are given in addition to the limit curve, downflooding angle and the corresponding downflooding opening shall be indicated);
- compliance with stability criteria: Listing of all calculated stability criteria, the limit values, the obtained values and the conclusions (criteria fulfilled or not fulfilled) (not applicable for Type 2 software which uses limit curve for checking all the stability requirements. However, if intact stability criteria are given in addition to the limit curve, the limit values, the obtained values and

the conclusion shall be indicated).

4.1.2 A clear warning shall be given on screen and in hard copy printout if any of the loading limitations are not complied with.

Loading limitations shall include, but may not be limited to:

- Trim, draught, liquid densities, tank filling levels, initial heel;
- Use of limit KG/GM curves in conjunction with above for Type 2;
- Restrictions to the stowage height for timber where timber load lines are assigned.

4.1.3 Type 3 software is to include pre-defined relevant damage cases for both sides of the ship according to the applicable rules for automatic check of a given loading condition.

4.1.4 The date and time of a saved calculation shall be part of the screen display and hard copy printout.

4.1.5 Each hard copy printout shall contain identification of the calculation program including version number.

4.1.6 Units of measurement are to be clearly identified and used consistently within a loading calculation.

4.1.7 For Type 3 and Type 4 software, the system shall be pre-loaded with a detailed computer model of the complete hull, including appendages, all compartments, tanks and the relevant parts of the superstructure considered in the damage stability calculation, wind profile, down-flooding and up-flooding openings, cross-flooding arrangements, internal compartment connections and escape routes, as applicable and according to the type of stability software.

4.1.8 For Type 1 and Type 2 software, in case a full three-dimensional model is used for stability calculations, the requirements of the computer model are to be as per paragraph 4.1.7 above to the extent as applicable and according to the type of stability software.

4.2 Further requirements for Type 4 stability software

4.2.1 The normal (Type 1, 2 and 3) and (Type 4) software need not be “totally separated”. Where the normal and software are not totally separated:

- the function of switching between normal software and Type 4 software shall be provided.
- the actual intact loading condition is to be the same for both functions (normal operation and
- the module needs only to be activated in case of an incident. Approval of Type 4 software is for stability only.

4.2.2 In passenger ships which are subject to Type 4 software and have an onboard stability computer and shore-based support, such software need not be identical.

4.2.3 Each internal space shall be assigned its permeability as shown below, unless a more accurate permeability has been reflected in the approved stability information.

Space	Permeability			
Space Type	Default	Full	Partially Filled	Empty
Container Spaces	0.95	0.7	0.8	0.95
Dry Cargo Spaces	0.95	0.7	0.8	0.95
Ro-Ro Spaces	0.95	0.9	0.9	0.95
Cargo Liquids	0.95	0.7	0.8	0.95
Intended for Consumable Liquids	0.95	0.95	0.95	0.95
Stores	0.95	0.6	0.6	0.95
Occupied by Machinery	0.85			
Void Spaces	0.95			
Occupied by Accommodation	0.95			

4.2.4 The system shall be capable of accounting for applied moments such as wind, lifeboat launching, cargo shifts and passenger relocation.

4.2.5 The system shall account for the effect of wind by using the method in SOLAS regulation II-1/7-2.4.1.2 as the default, but allow for manual input of the wind speed/pressure if the on-scene pressure is significantly different ($P = 120 \text{ N/m}^2$ equates to Beaufort 6; approximately 13.8 m/s or 27 knots).

4.2.6 The system shall be capable of assessing the impact of open main watertight doors on stability (e.g. for each damage case provided for verification, additional damage stability calculation shall be done and presented, taking into account any watertight door located within the damaged compartment(s)).

4.2.7 The system shall utilize the latest approved lightship weight and centre of gravity information.

4.2.8 The output of the software is to be such that it provides the master with sufficient clear unambiguous information to enable quick and accurate assessment of the stability of the vessel for any actual damage, the impact of flooding on the means of escape and the controls of devices necessary for managing and/or controlling the stability of the ship. When the actual loading condition is input in the Type 4 software, the following output (intact stability) shall be available:

- deadweight data;
- lightship data;
- trim;
- heel;
- draft at the draft marks and perpendiculars;
- summary of loading condition displacement, VCG, LCG and, if applicable, TCG;
- downflooding angle and corresponding downflooding opening;
- free surfaces;

- GM value;
- GZ values relevant to an adequate range of heeling (not less than 60°) available indicatively at the following intervals: 0 5 10 15 20 25 30 40 50 60 deg;
- compliance with relevant intact stability criteria (i.e. 2008 IS Code): listing of all calculated intact stability criteria, the limiting values, the obtained values and the evaluation (criteria fulfilled or not fulfilled);
- GM/KG limiting curve according to SOLAS, Ch II-1, Regulation 5-1.

When the actual loading condition is associated to the actual damage case(s) due to the casualty, the following output (damage stability) shall be available:

- trim;
- heel;
- draft at the draft marks and perpendiculars;
- progressive flooding angle and corresponding progressive flooding openings;
- GM value;
- GZ values relevant to an adequate range of heeling (not less than 60°) available indicatively at the following intervals: 0 5 10 15 20 25 30 40 50 60 deg;
- compliance with stability criteria: listing of all calculated stability criteria, the limit values, the obtained values and the conclusions (criteria fulfilled or not fulfilled);
- the survivability criteria for Type 4 software are left to the discretion of the Administration;
- relevant flooding points (unprotected or weathertight) with the distance from the damage waterline to each point;
- list of all flooded compartments with the permeability considered;
- amount of water in each flooded compartment;
- escape route immersion angles;
- a profile view, deck views and cross-sections of the ship indicating the flooded waterplane and the damaged compartments.

4.2.9 For ro-ro passenger ships there shall be algorithms in the software for estimating the effect of water accumulation on deck (WOD) (e.g. 1. In addition to the predefined significant wave height taken from the approved stability document, there shall be possibility for the crew to input manually the significant wave height of the ship navigation area in the system, 2. In addition to the predefined significant wave height taken from the approved stability document, calculations with two additional significant wave heights shall be submitted for checking the correctness of the algorithms in the software for estimating the effect of WOD). ** This paragraph applies to Ro-Ro Passenger ships subject to the Stockholm Agreement (IMO Circular Letter No. 1891)

5 Acceptable Tolerances

Depending on the type and scope of programs, the acceptable tolerances are to be determined differently, according to 5.1 or 5.2. Deviation from these tolerances shall not be accepted unless the Society considers that there is a satisfactory explanation for the difference and that there will be no adverse effect on the safety of the ship.

Examples of pre-programmed input data include the following:

Hydrostatic data: Displacement, LCB, LCF, VCB, KM_t and MCT versus draught.

Stability data: KN or MS values at appropriate heel/trim angles versus displacement, stability limits.

Compartment data: Volume, LCG, VCG, TCG and FSM/Grain heeling moments vs level of the compartment's contents.

Examples of output data include the following:

Hydrostatic data: Displacement, LCB, LCF, VCB, KM_t and MCT versus draught as well as actual draughts, trim.

Stability data: FSC (free surface correction), GZ-values, KG, GM, KG/GM limits, allowable grain heeling moments, derived stability criteria, e.g. areas under the GZ curve, weather criteria.

Compartment data: Calculated Volume, LCG, VCG, TCG and FSM/Grain heeling moments vs level of the compartment's contents.

The computational accuracy of the calculation program results shall be within the acceptable tolerances, specified in 5.1 or 5.2, of the results using an independent program or the approved stability information with identical input.

5.1 Programs which use only pre-programmed data from the approved stability information as the basis for stability calculations, shall have zero tolerances for the printouts of input data. Output data tolerances are to be close to zero, however, small differences associated with calculation rounding or abridged input data are acceptable. Additionally differences associated with the use of hydrostatic and stability data for trims that differ from those in the approved stability information are acceptable, subject to review by the individual Society.

5.2 Programs which use hull form models as their basis for stability calculations, shall have tolerances for the printouts of basic calculated data established against either data from the approved stability information or data obtained using the approval authority's model. Acceptable tolerances shall be in accordance with Table 1.

Table 1

Hull Form Dependent	Tolerance
Displacement	± 2%
Longitudinal centre of buoyancy, from AP	± 1% / 50 cm
Vertical centre of buoyancy	± 1% / 5 cm
Transverse centre of buoyancy	± 0.5% of B / 5 cm
Longitudinal centre of flotation, from AP	± 1% / 50 cm
Moment to trim 1 cm	± 2%
Transverse metacentric height (GM _t)	± 1% / 5 cm
Longitudinal metacentric height (GM _l)	± 1% / 50 cm
Cross curves of stability	± 5 cm
Compartment dependent	
Volume or deadweight	± 2%

Longitudinal centre of gravity, from AP	± 1% / 50 cm
Vertical centre of gravity	± 1% / 5 cm
Transverse centre of gravity	± 0.5% of B / 5 cm
Free surface moment	± 2%
Shifting moment	± 5%
Level of contents	± 2%
Trim and stability	
Draughts (forward, aft, mean)	± 1% / 5 cm
GMt (solid and corrected for free surfaces)	± 1% / 5 cm
GZ values	± 5% / 5 cm
Downflooding angle	± 2°
Equilibrium angles	± 1°
Distance from WL to unprotected or weathertight openings, or other relevant point (if applicable)	± 5% / 5 cm
Areas under righting arm curve	± 5% / 0.0012 m·rad

Notes:

1. Deviation in % = [(base value – applicant's value)/base value] × 100 where the “base value” may be from the approved stability information or the society's computer model.
2. When applying the tolerances in Table 1 having two values, the allowable tolerance is the greater of the two values.
3. Where differences in calculation methodology exist between the programs used in the comparison, this may be a basis for accepting deviations greater than that specified in Table 1 provided a software examination is carried out in sufficient detail to clearly document that such differences are technically justifiable.
4. Deviation from these tolerances shall not be accepted unless the Society considers that there is a satisfactory explanation for the difference and that it is clearly evident from the Society's stability calculations that the deviation does not impact compliance with the required stability criteria for the ship under consideration.

6 Approval Procedure

Conditions of approval of the onboard software for stability calculations

The onboard software used for stability calculations is subject to approval, which is to include:

- verification of type approval, if any;
- verification that the data used are consistent with the current condition of the ship (refer to paragraph 6.2);
- verification and approval of the test conditions;
- verification that the software is appropriate for the type of ship and stability calculations required;
- verification of functional requirements under paragraph 4.1.2.

The satisfactory operation of the software with the onboard computer(s) for stability calculations is to be verified by testing upon installation (refer to paragraph 8). A copy of the approved test conditions and the operation manual for the computer/software are to be available on board.

6.1 General Approval (optional)

Upon application to the Society for general approval of the calculation program, the Society may provide the applicant with test data consisting of two or more design data sets, each of which is to include a ship's hull form data, compartmentation data, lightship characteristics and deadweight data, in sufficient detail to accurately define the ship and its loading condition. Acceptable hull form and compartmentation data may be in the form of surface coordinates for modeling the hull form and compartment boundaries, e.g: a table of offsets, or in the form of pre-calculated tabular data, e.g: hydrostatic tables, capacity tables, etc., depending upon the form of data used by the software being submitted for approval. Alternatively, the general approval may be given based on at least two test ships agreed upon between the Society and the applicant.

In general, the software is to be tested for two types of ships for which approval is requested, with at least one design data set for each of the two types. Where approval is requested for only one type of ship, a minimum of two data sets for different hull forms of that type of ship are required to be tested. For calculation software which is based on the input of hull form data, design data sets shall be provided for three types of ships for which the software is to be approved, or a minimum of three data sets for different hull forms if approval is requested for only one type of ship. Representative ship types which require different design data sets due to their hull forms, typical arrangements, and nature of cargo include: tanker, bulk carrier, container ship, and other dry cargo and passenger ships. The test data sets shall be used by the applicant to run the calculation program for the test ships. The results obtained (together with the hydrostatic data and cross-curve data developed by the program, if appropriate) shall be submitted to the Society for the assessment of the program's computational accuracy. The Society shall perform parallel calculations using the same data sets and a comparison of these results will be made against the applicant's submitted program's results.

6.2 Specific Approval

- The Society shall verify the accuracy of the computational results and actual ship data used by the calculation program for the particular ship on which the program will be installed.
- Upon application to the Society for data verification, the Society and the applicant shall agree on a minimum of four loading conditions, taken from the ship's approved stability information, which are to be used as the test conditions. For ships carrying liquids in bulk, at least one of the conditions shall include partially filled tanks. For ships carrying grain in bulk, one of the grain loading conditions shall include a partially filled grain compartment. Within the test conditions each compartment shall be loaded at least once. The test conditions normally are to cover the range of load draughts from the deepest envisaged loaded condition to the lightballast condition and shall include at least one departure and one arrival condition.
- For Type 4 stability software, the Society shall examine at least three damage cases, each of them associated with at least three loading conditions taken from the ship's approved stability information. Output of the software is to be compared with results of corresponding load / damage case in the approved damage stability booklet or an alternative independent software source.
- The Society is to verify that the following data, submitted by the applicant, is consistent with

arrangements and most recently approved lightship characteristics of the ship according to current plans and documentation on file with the Society, subject to possible further verification on board:

- Identification of the calculation program including version number;
- Main dimensions, hydrostatic particulars and, if applicable, the ship profile;
- The position of the forward and after perpendiculars, and if appropriate, the calculation method to derive the forward and after draughts at the actual position of the ship's draught marks;
- Ship lightweight and centre of gravity derived from the most recently approved inclining experiment or light weight check;
- Lines plan, offset tables or other suitable presentation of hull form data if necessary for the Society to model the ship;
- Compartment definitions, including frame spacing, and centres of volume, together with capacity tables (sounding/ullage tables), free surface corrections, if appropriate;
- Cargo and consumables distribution for each loading condition.

Verification by the Society does not absolve the applicant and shipowner of responsibility for ensuring that the information programmed into the onboard computer software is consistent with the current condition of the ship.

7 Operation Manual

A simple and straightforward operation manual is to be provided, containing descriptions and instructions, as appropriate, for at least the following:

- installation;
- function keys;
- menu displays;
- input and output data;
- required minimum hardware to operate the software;
- use of the test loading conditions;
- computer-guided dialogue steps;
- list of warnings.

8 Installation Testing

To ensure correct working of the computer after the final or updated software has been installed, it is the responsibility of the ship's Master to have test calculations carried out according to the following pattern in the presence of a Society surveyor:

From the approved test conditions at least one load case (other than light ship) shall be calculated.

Note: Actual loading condition results are not suitable for checking the correct working of the computer.

Normally, the test conditions are permanently stored in the computer. Steps to be performed:

- Retrieve the test load case and start a calculation run; compare the stability results with those in the documentation.

- Change several items of deadweight (tank weights and the cargo weight) sufficiently to change the draught or displacement by at least 10%. The results are to be reviewed to ensure that they differ in a logical way from those of the approved test condition.
- Revise the above modified load condition to restore the initial test condition and compare the results. Confirm that the relevant input and output data of the approved test condition have been replicated.
- Alternatively, one or more test conditions shall be selected and the test calculation performed by entering all deadweight data for each selected test condition into the program as if it were a proposed loading. The results shall be verified as identical to the results in the approved copy of the test conditions.

9 Periodical Testing

It is the responsibility of the ship's Master to check the accuracy of the onboard computer for stability calculations at each Annual Survey by applying at least one approved test condition. If a Society surveyor is not present for the computer check, a copy of the test condition results obtained by the computer check is to be retained on board as documentation of satisfactory testing for the surveyor's verification.

At each Special Survey this checking for all approved test loading conditions is to be done in presence of the surveyor.

The testing procedure shall be carried out in accordance with paragraph 8.

10 Other Requirements

Protection against unintentional or unauthorised modification of programs and data shall be provided.

The program shall monitor operation and activate an alarm when the program is incorrectly or abnormally used.

The program and any data stored in the system shall be protected from corruption by loss of power.

Error messages with regard to limitations such as filling a compartment beyond capacity, or exceeding the assigned load line, etc., shall be included.

APPENDIX 3

GUIDELINES FOR UR S11.2.1.3 FOR BALLAST LOADING CONDITIONS OF CARGO VESSELS INVOLVING PARTIALLY FILLED BALLAST TANKS

1 General guidance note regarding the use of UR S11.2.1.3

- 1.1 This document is intended for guidance and interpretation of UR S11.2.1.3 “Partially filled ballast tanks in ballast loading conditions”.
- 1.2 Case A and B are generally applicable for ballast loading conditions for any cargo vessel which might have one Ballast Water (BW) Tank (or one pair of BW Tanks) partially filled.
- 1.3 Case C is showing the conditions necessary for checking longitudinal strength for a conventional ore carrier with two pairs of large wing water ballast tanks partly filled during the ballast voyage.
- 1.4 Where applicable, similar considerations are to be given to other cargo vessels covered by UR S11 where ballast loading conditions involving partially filled ballast tanks may cause concerns for the longitudinal strength of the vessels.
- 1.5 This Appendix does not apply to CSR Bulk Carriers and Oil Tankers or to container ships to which UR S11A is applicable.
- 1.6 In the Figures, the conditions only intended for strength verification (not operational) are marked with a star (*), full tanks are marked with “Full”, empty tanks are marked with “Empty”, and consumables are marked with “cons.”.

2 Case A and B

2.1 Case A

Fig. 1 shows Case A, with a cargo vessel where partial filling of BW Tank no. 6 (P/S) is permitted and may take place at any time during the ballast voyage. Intermediate condition(s) should be specified as shown in the Figure, however filling/partial filling of BW Tank no. 6 (P/S) may be done at any step to keep acceptable trim and propeller immersion during the ballast voyage.

To obtain full operational flexibility regarding the filling level of BW Tank no. 6 (P/S), loading conditions A2 (full at departure)* and A8 (empty at arrival)* shall be added for strength verification. Additional conditions (full and empty BW Tank no. 6 (P/S)) related to the intermediate conditions A3-A6 are not necessary as A2* and A8* will be the most critical one.

2.2 Case B

Fig. 2 shows Case B, with a cargo vessel where partial filling of BW Tank no. 6 (P/S) to a given level (f6-int%) will be done after a specified % consumables is reached, see conditions B2 and B3. Before this % consumables (shown as 50% in this Figure) is reached, BW Tank no. 6 (P/S) shall be kept empty. When reaching a given level of consumables (shown as 20% in Figure 2), BW Tank no. 6 (P/S) shall be kept full, see conditions B5 and B6. Two additional intermediate conditions (B4* and B7*) shall be added for longitudinal strength verification.

In order to categorize a vessel according to Case B, clear operational guidance for partial filling of ballast tanks, in association with the consumption level as shown in Figure 2, is to be given in the

loading manual. If such operational guidance is not given, Case A is to be applied.

Case A has no limitation of consumables, whereas Case B has limitation of consumables.

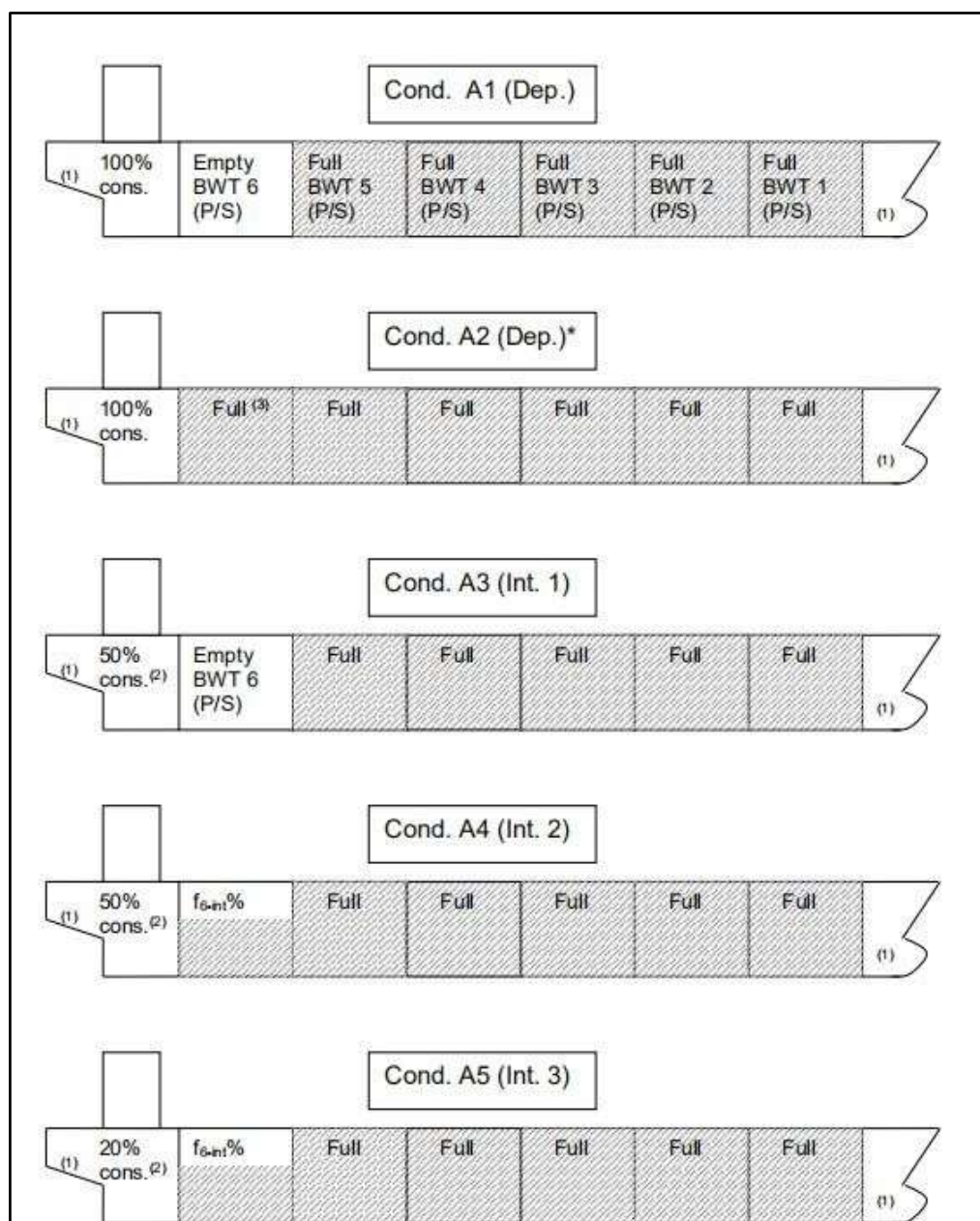


Figure 1 Case A, Partial filling of ballast tank no. 6 (P/S) is permitted at any stage during voyage. The intermediate conditions are specified, however other partial filling of BW Tank no. 6 (P/S) may be applied to keep acceptable trim and propeller immersion during the ballast voyage. Conditions only intended for strength verification (not operational) are marked: *

Notes

- (1) For peak tanks intended to be partially filled, all combinations of full or partially filled at intended level for those tanks are to be investigated.
- (2) The intermediate condition(s) to be specified incl. % consumables.
- (3) For bulk carriers carrying ore and with large wing water ballast tanks full/empty may be replaced with maximum/minimum filling levels according to trim limitations given in S11.2.1.3.

Case A, Partial filling of ballast tank no. 6 (P/S) is permitted at any stage during voyage. The intermediate condition is specified, however other partial filling of BW Tank no. 6 (P/S) may be applied to keep acceptable trim and propeller immersion during the ballast voyage. Conditions only intended for strength verification (not operational) are marked: *

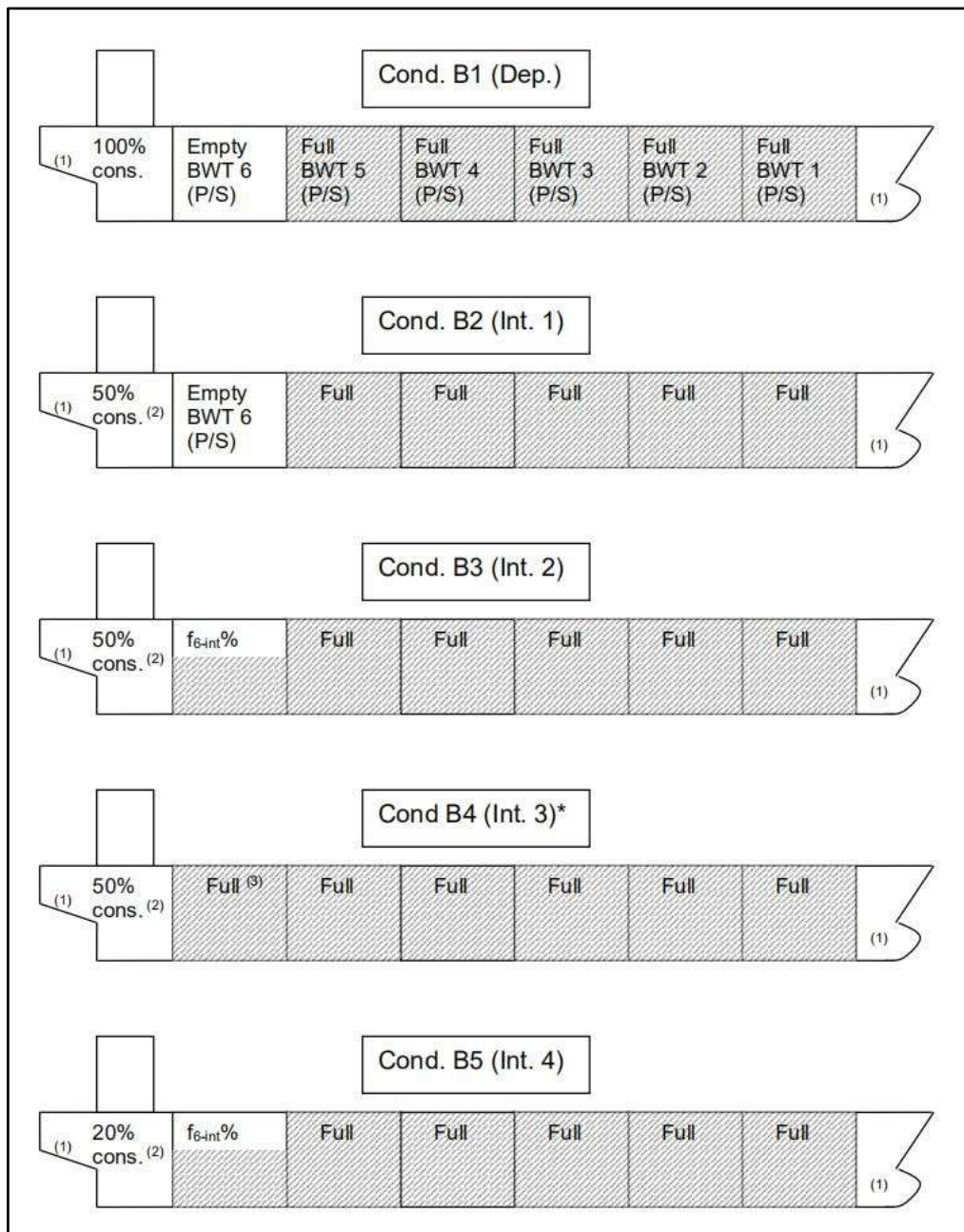
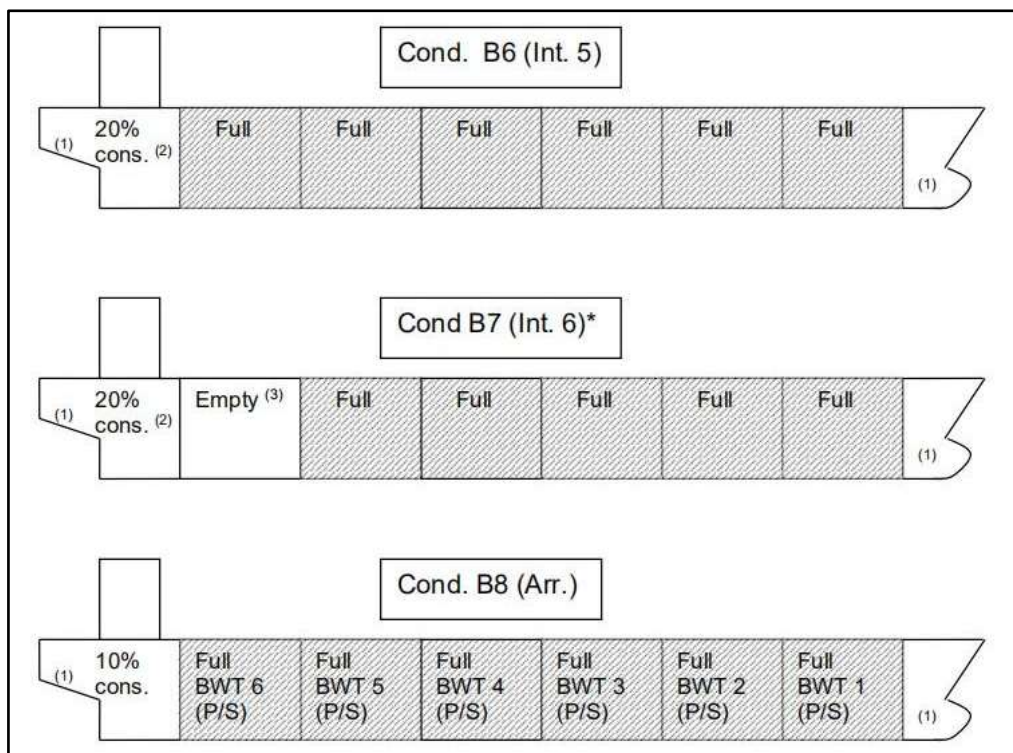


Figure 2 Case B, Partial filling of BW Tank no. 6 (P/S) only allowed during intermediate conditions, in this example between 50-20% consumables. Conditions only intended for strength verification (not operational) are marked: *



Notes

- (1) For peak tanks intended to be partially filled, all combinations of full or partially filled at intended level for those tanks are to be investigated.
- (2) The intermediate condition(s) to be specified incl. % consumables.
- (3) For bulk carriers carrying ore and with large wing water ballast tanks full/empty may be replaced with maximum/minimum filling levels according to trim limitations given in S11.2.1.3.

Case B, Partial filling of BW Tank no. 6 (P/S) only allowed during intermediate conditions, in this example between 50-20% consumables. Conditions only intended for strength verification (not operational) are marked: *

3 Case C – Conventional (with usual arrangement of WBT) ore carrier with two pairs of partially filled ballast water tanks

Fig. 3(a) show the operational loading conditions, departure condition (C1), four intermediate conditions (C2-C5) and arrival condition (C6), for a conventional (with usual arrangement of WBT) ore carrier with partial filling of both BW tank no.1 (P/S) and 7 (P/S) during voyage.

Filling level in partially filled BW tanks nos.1 (P/S) and 7 (P/S) for the operational conditions during ballast voyage is given in Table 1.

Table 1

Loading Condition	Consumables	Filling Level, WBT 1 (P/S)	Filling Level, WBT 7 (P/S)
C1 – Departure	100%	$f_{1dep}\%$	$f_{7dep}\%$
C2 – Intermediate 1	50% (1)	$f_{1dep}\%$	$f_{7dep}\%$
C3 – Intermediate 2	50% (1)	$f_{1int}\%$	$f_{7int}\%$
C4 – Intermediate 3	20% (1)	$f_{1int}\%$	$f_{7int}\%$
C5 – Intermediate 4	20% (1)	$f_{1arr}\%$	$f_{7arr}\%$
C6 – Arrival	10%	$f_{1arr}\%$	$f_{7arr}\%$

Note: (1) % consumables to be specified, indicated to 50% and 20 %.

Fig. 3(b) and Fig. 3(c)

- show the additional twelve loading conditions (C1-1 ~ C1-12) which shall be added for longitudinal strength verification of the departure condition (C1).

Fig. 3(d) and Fig. 3(i) s

- how the additional 32 loading conditions (C2-1 ~ C2-12, C3-1 ~ C3-4, C4-1 ~ C4-12 and C5-1 ~ C5-4) which shall be added for longitudinal strength verification of the intermediate conditions (C2 ~ C5).

Fig. 3(j) and Fig. 3(k)

- show the additional twelve loading conditions (C6-1 ~ C6-12) which shall be added for longitudinal strength verification of the arrival condition (C6).

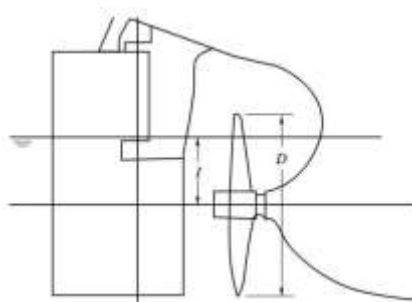
For the additional loading conditions, the maximum and the minimum filling level of BW tank are according to trim and propeller immersion limitations given in S11.2.1.3:

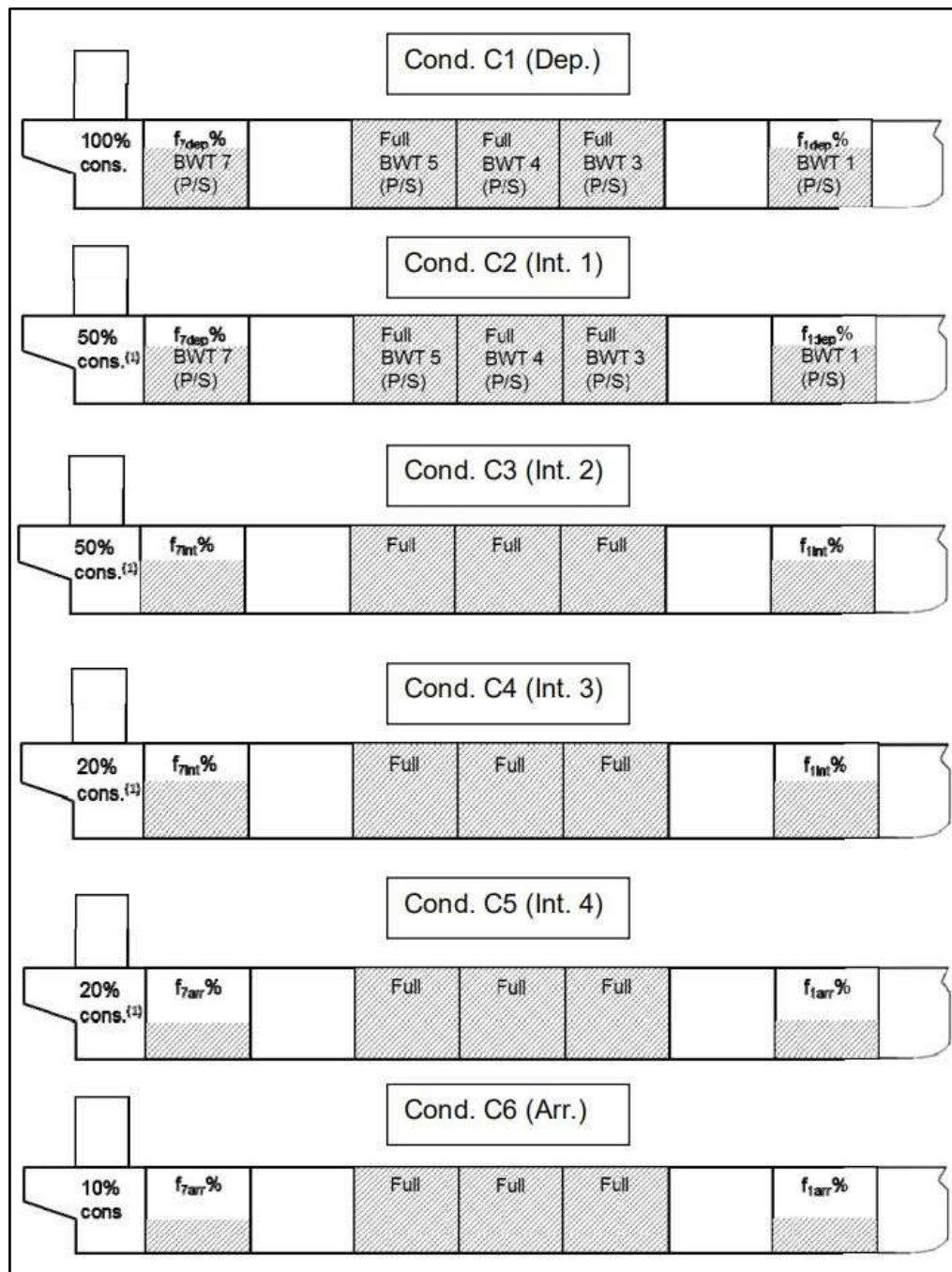
However, for conventional ore carriers with large wing water ballast tanks in cargo area, where empty or full ballast water filling levels of one or maximum two pairs of these tanks lead to the ship's trim exceeding one of the following conditions, it is sufficient to demonstrate compliance with maximum, minimum and intended partial filling levels of these one or maximum two pairs of ballast tanks such that the ship's condition does not exceed any of these trim limits. Filling levels of all other wing ballast tanks are to be considered between empty and full. The trim conditions mentioned above are:

- trim by stern of 3% of the ship's length, or
- trim by bow of 1.5% of ship's length, or
- any trim that cannot maintain propeller immersion (I/D) not less than 25%, where;

I = the distance from propeller centerline to the waterline

D = propeller diameter (see the following figure)





Notes

(1) The intermediate condition(s) to be specified incl. % consumables.

(2) Figures 3(b)-3(k): Maximum and minimum filling level of BW tank according to trim and propeller immersion limitations given in S11.2.1.3.

Figure 3(a) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 7 (P/S) during ballast voyage, operational conditions C1-C6.

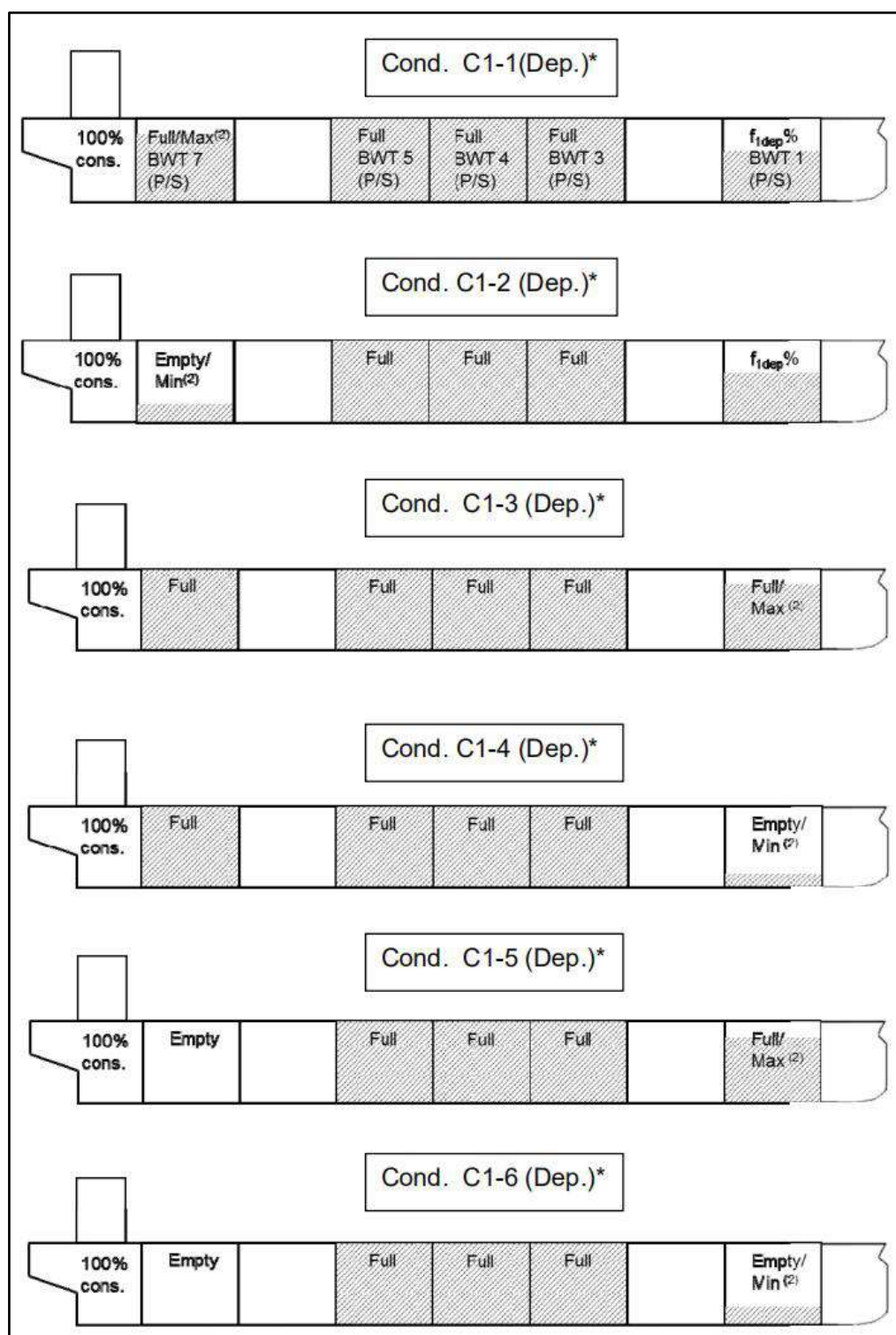


Figure 3(b) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 7 (P/S) during voyage. Departure conditions C1-1 to C1-6, only intended for strength verification (not operational) are marked: *

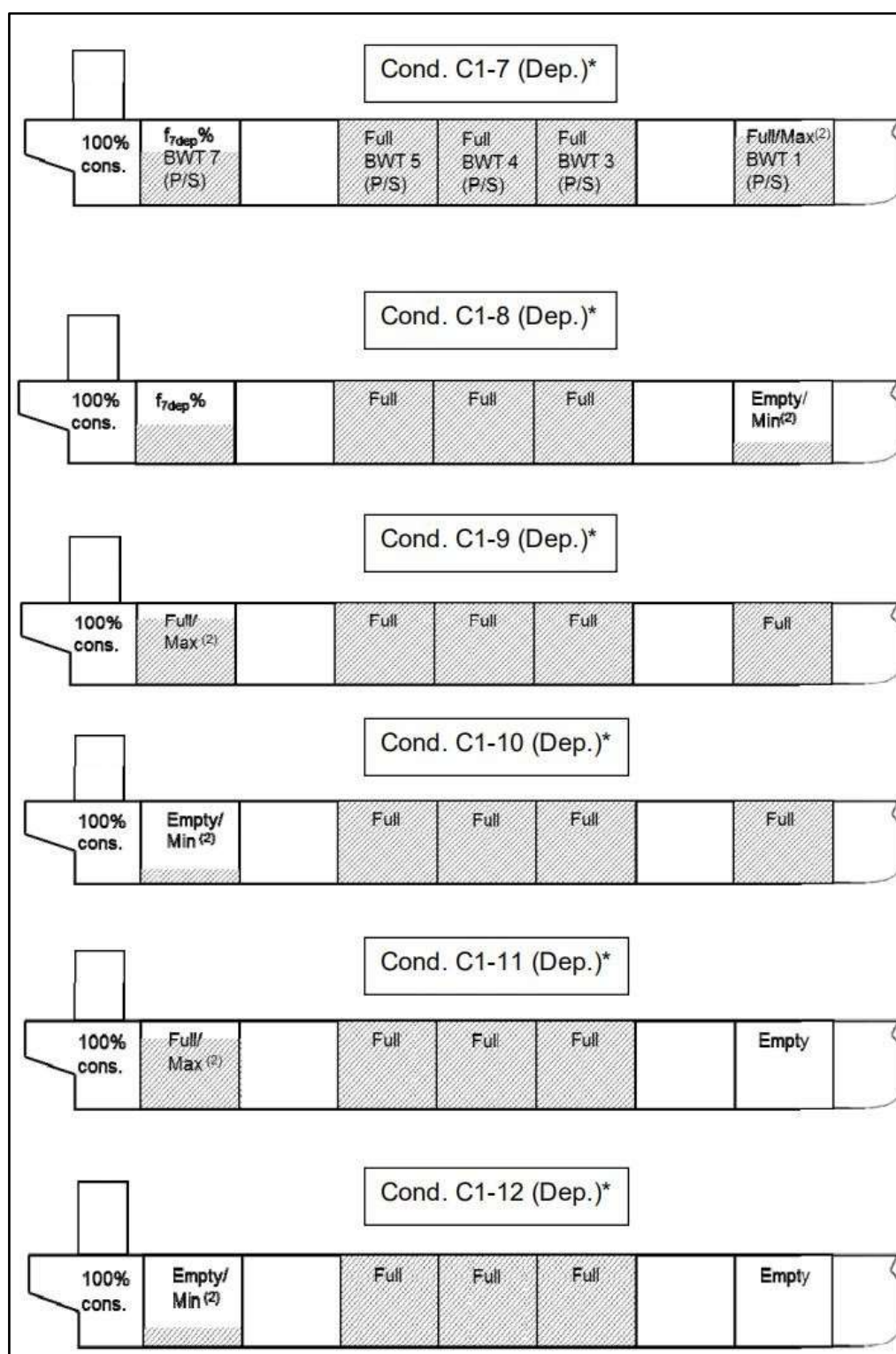


Figure 3(c) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 7 (P/S) during voyage. Departure conditions CD1-7 to C1-12, only intended for strength verification (not operational) are marked: *

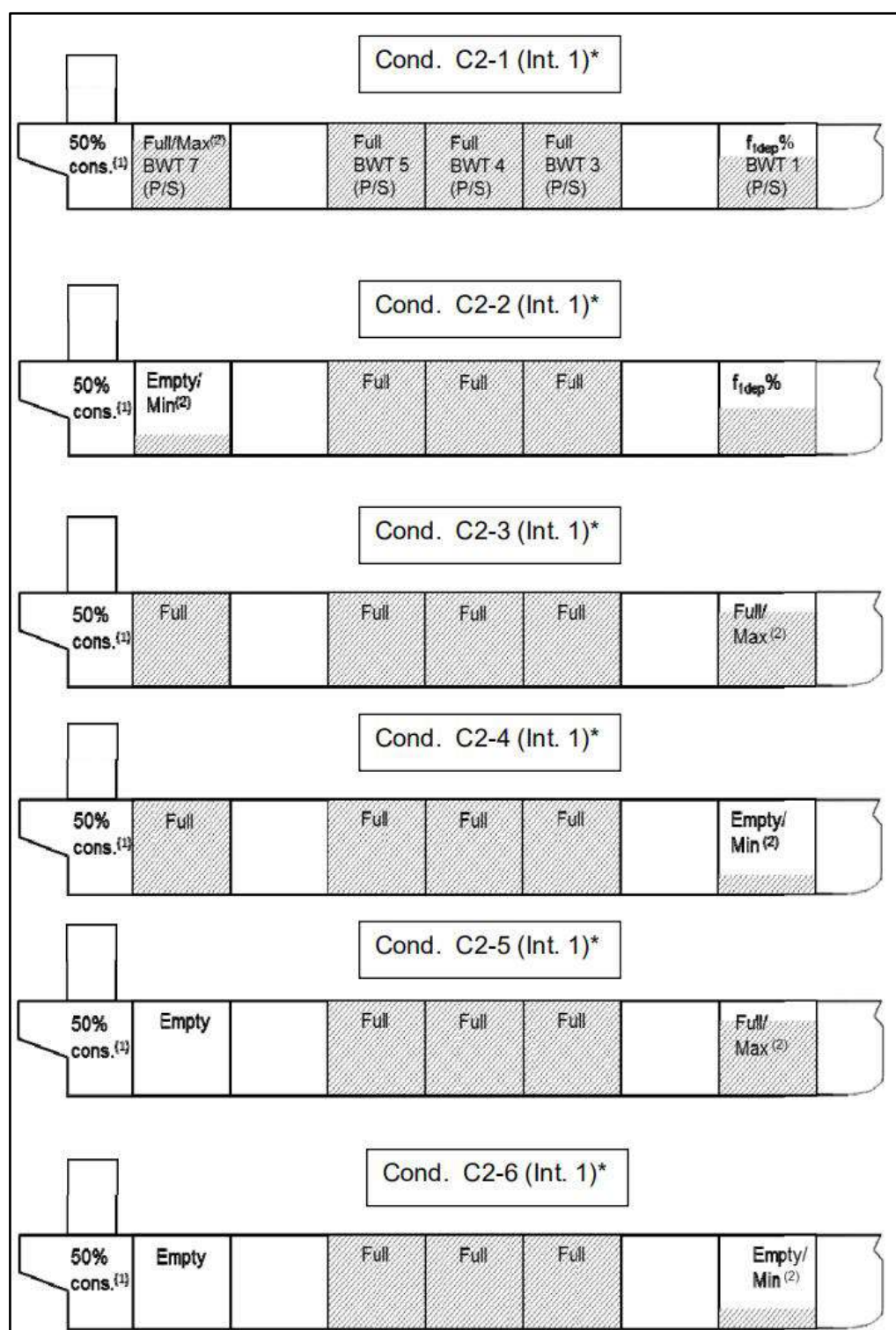


Figure 3(d) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 7 (P/S) during voyage. Intermediate conditions C2-1 to C2-6, only intended for strength verification (not operational) are marked: *

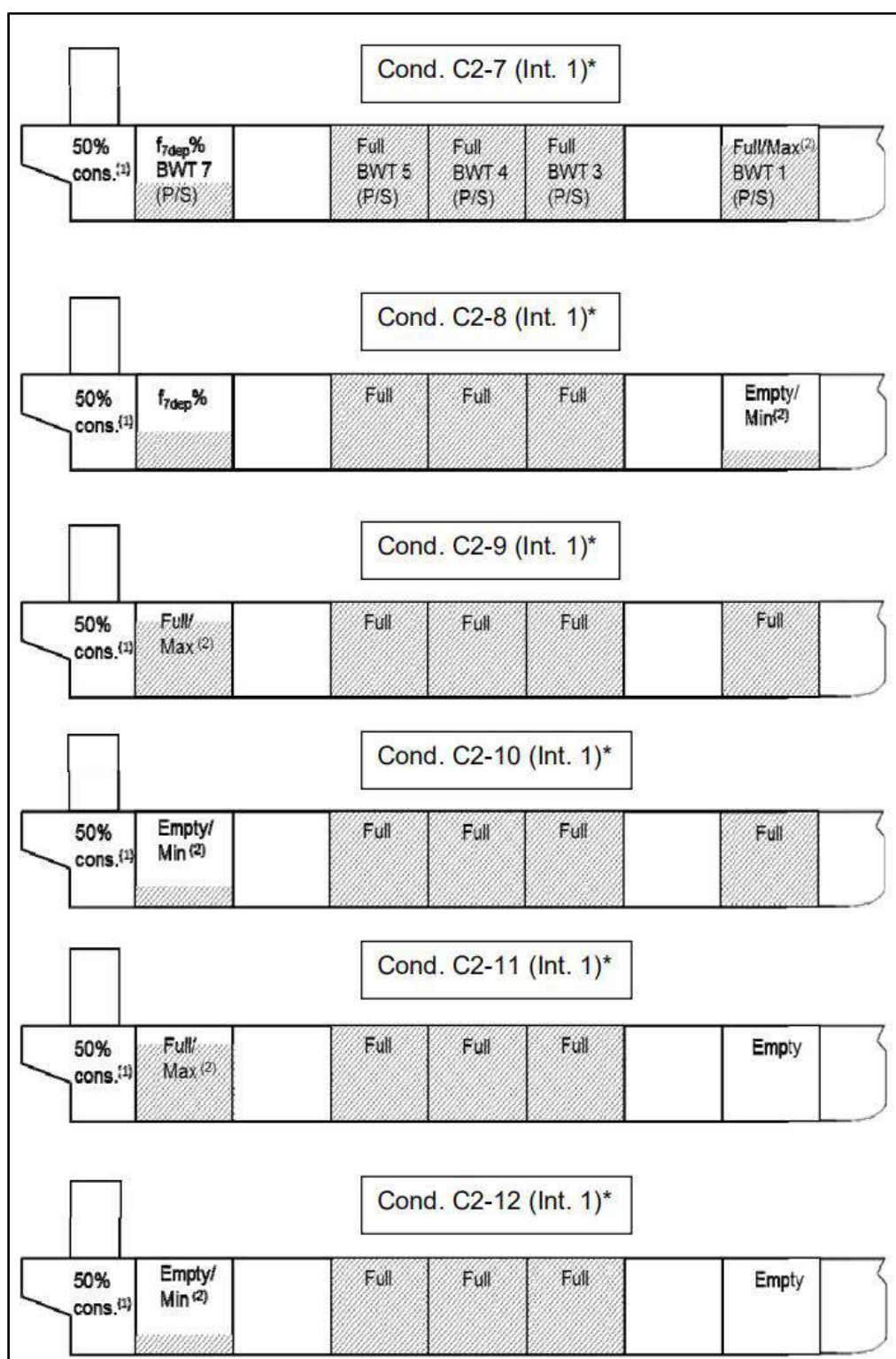


Figure 3(e) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 7 (P/S) during voyage. Intermediate conditions C2-7 to C2-12, only intended for strength verification (not operational) are marked: *

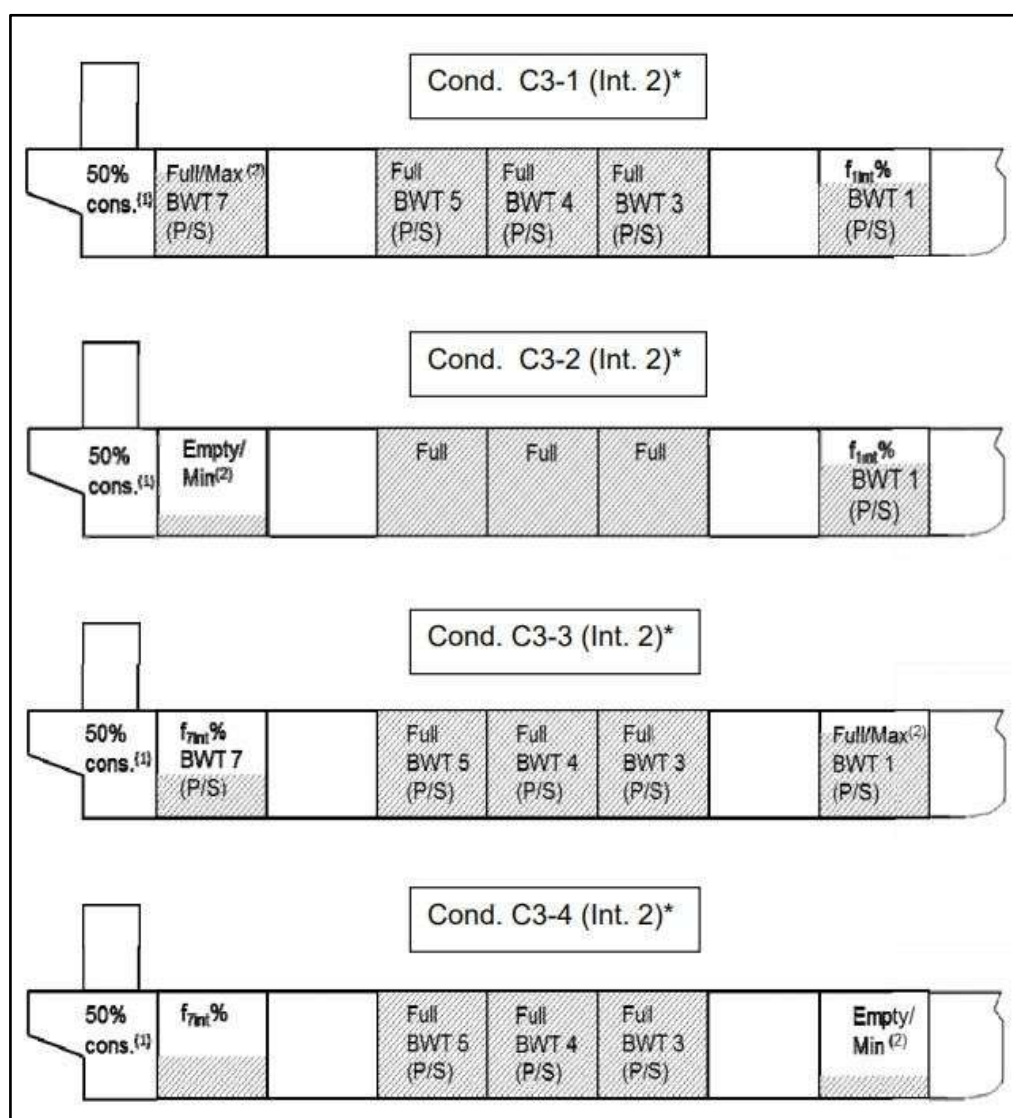


Figure 3(f) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 7 (P/S) during voyage. Intermediate conditions C3-1 to C3-4, only intended for strength verification (not operational) are marked: *

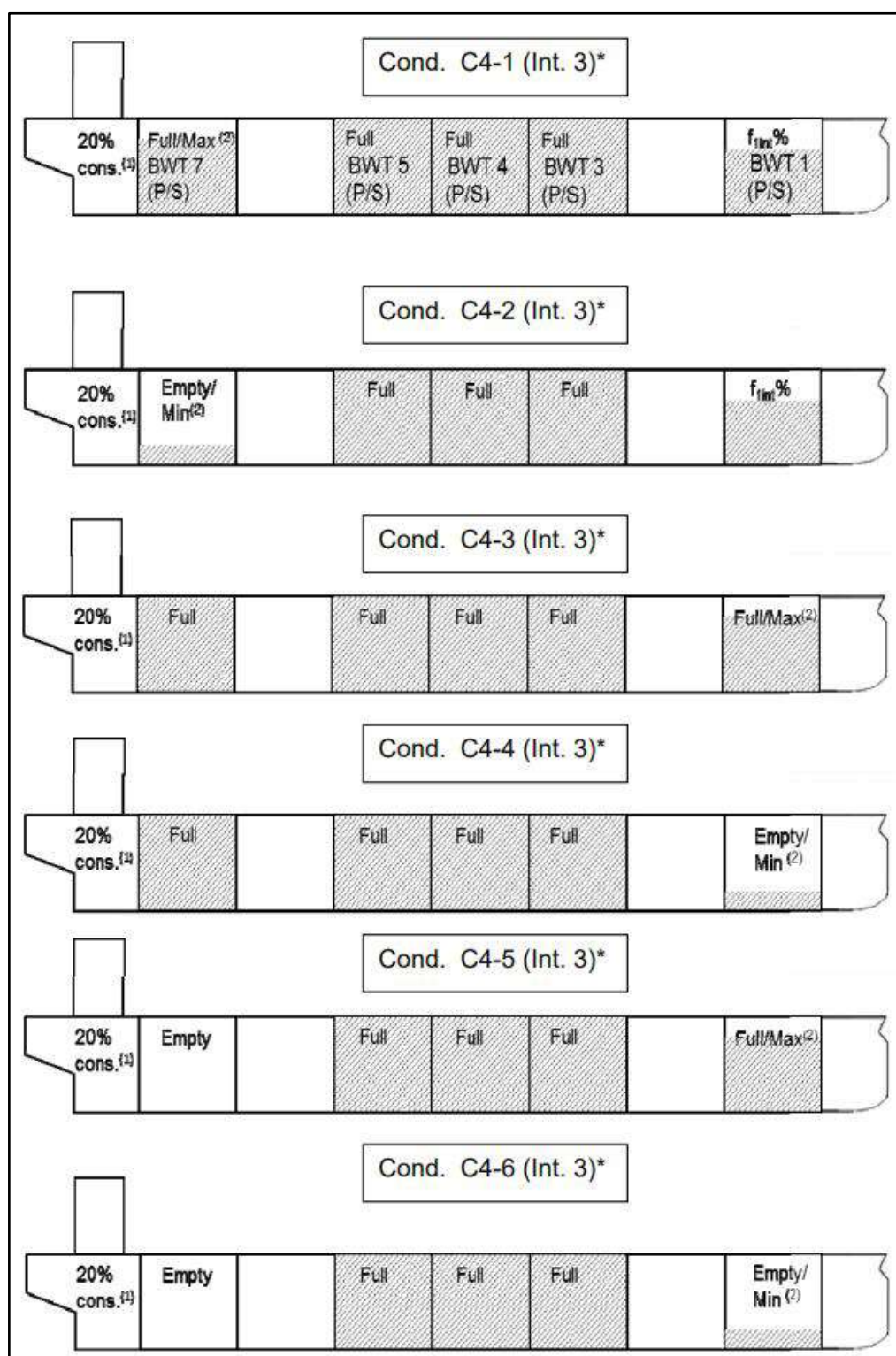


Figure 3(g) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 7 (P/S) during voyage. Intermediate conditions C4-1 to C4-6, only intended for strength verification (not operational) are marked: *

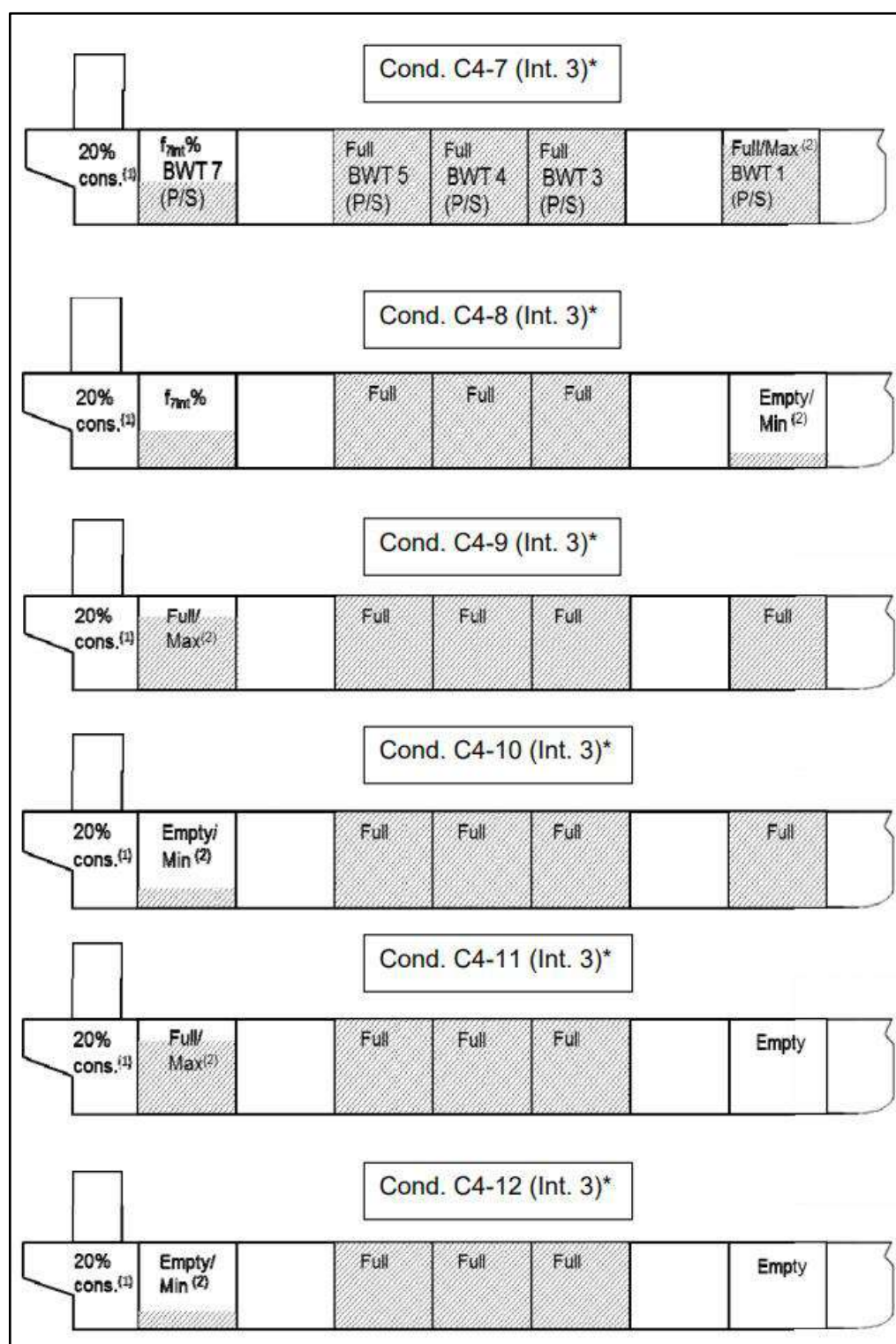


Figure 3(h) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 7 (P/S) during voyage. Intermediate conditions C4-7 to C4-12, only intended for strength verification (not operational) are marked: *

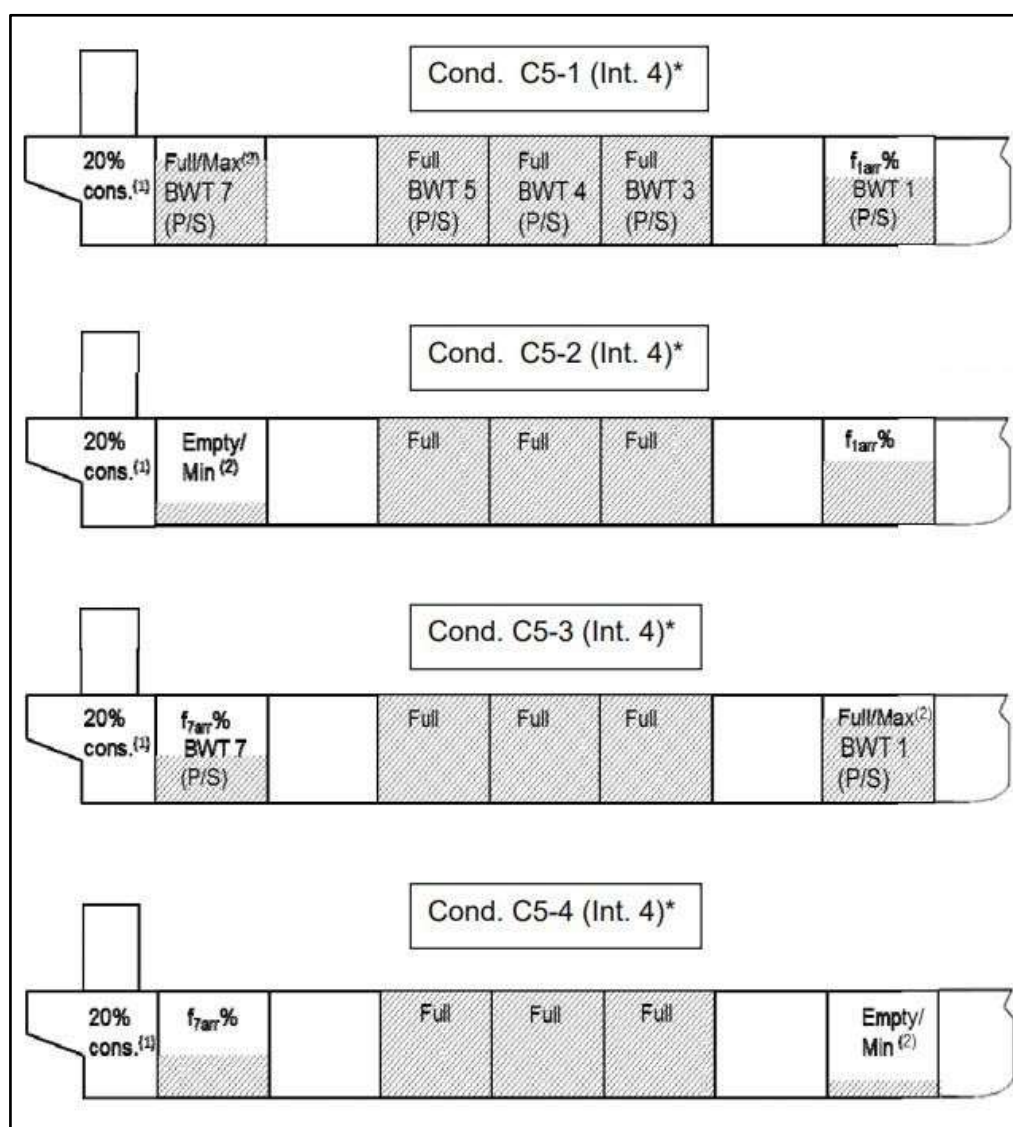


Figure 3(i) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 7 (P/S) during voyage. Intermediate conditions C5-1 to C5-4, only intended for strength verification (not operational) are marked: *

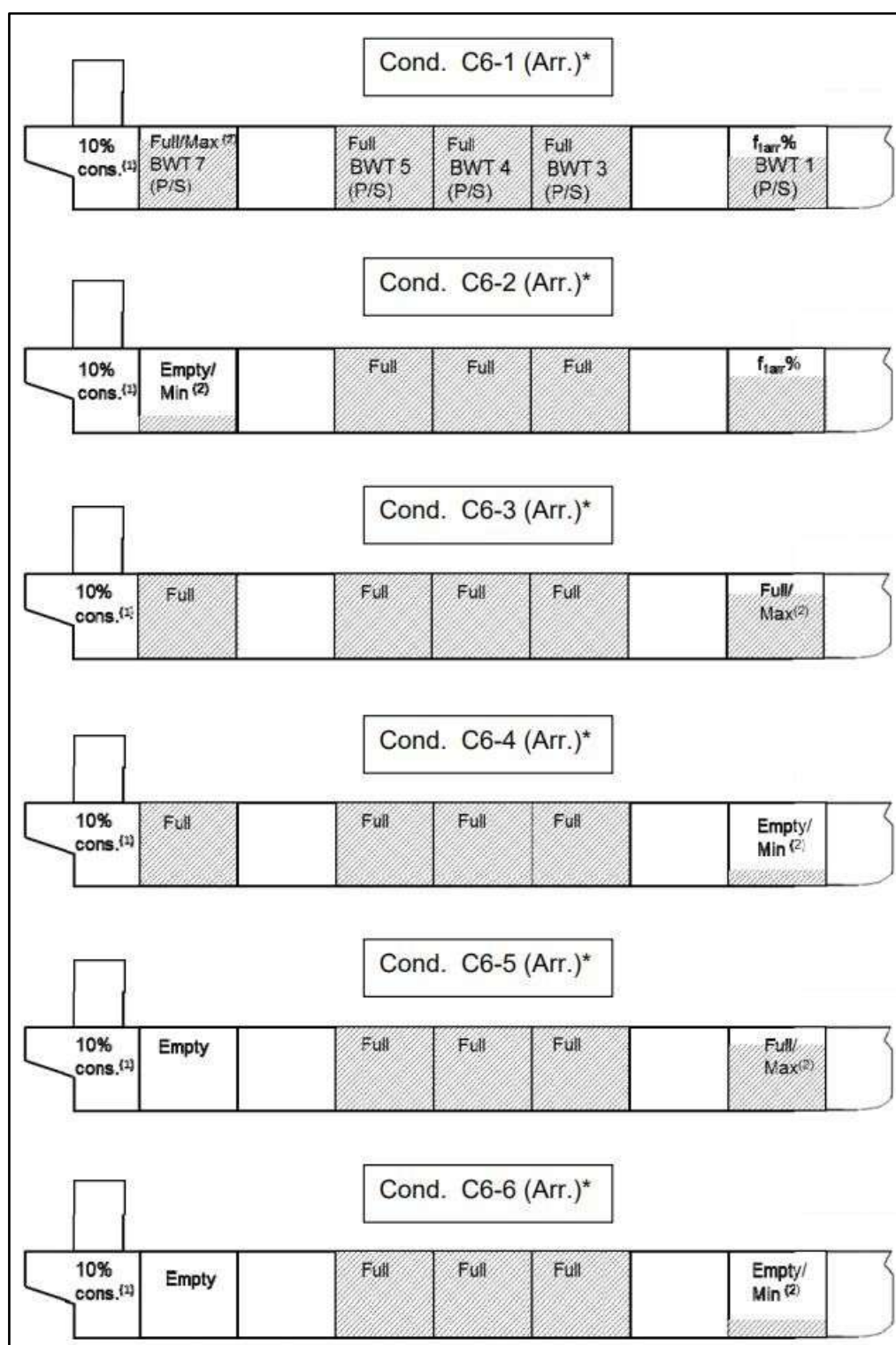


Figure 3(j) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 7 (P/S) during voyage. Arrival conditions C6-1-C6-6, only intended for strength verification (not operational) are marked: *

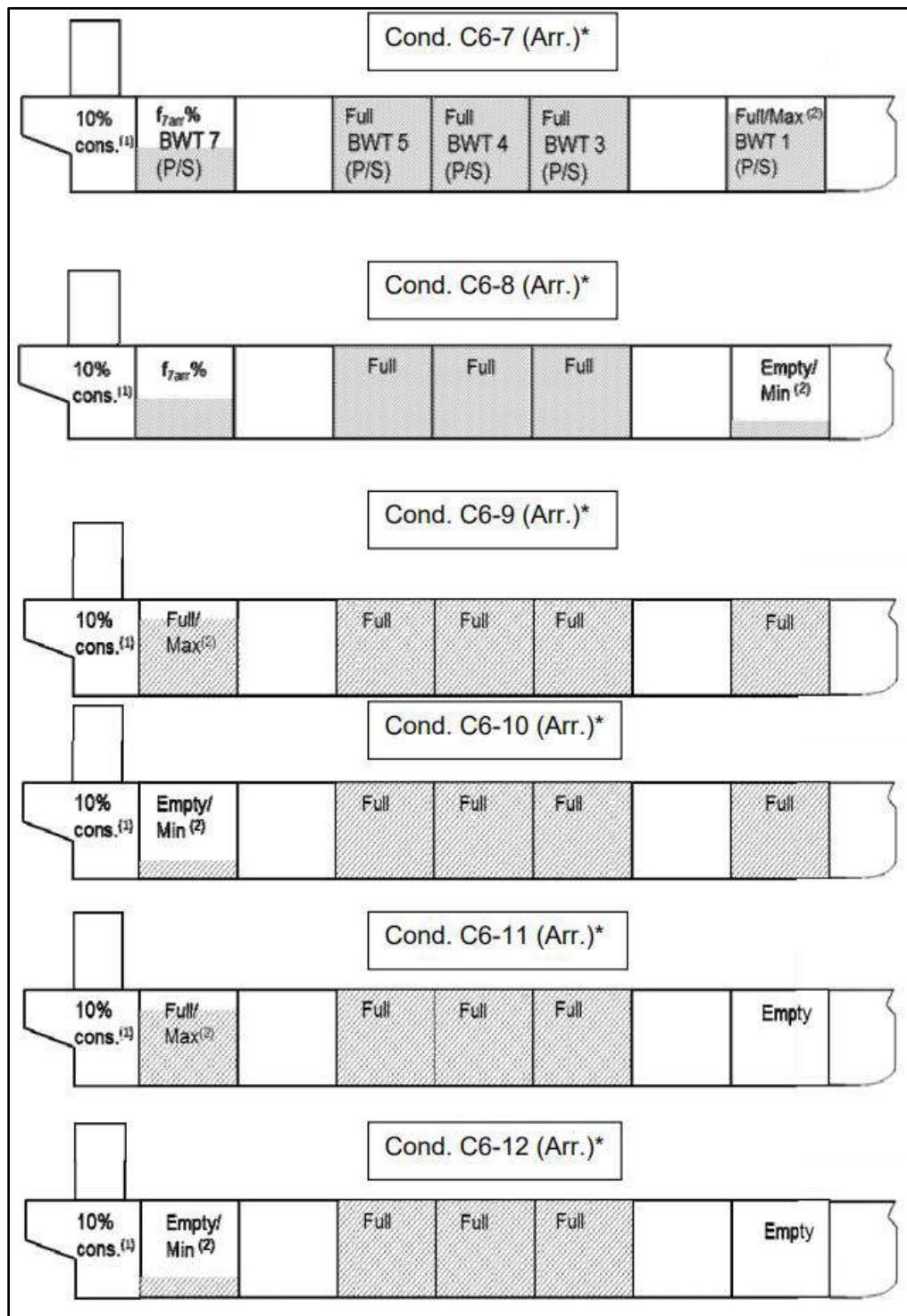


Figure 3(k) Case C, Ore Carrier. Partial filling of BW Tank no.1 (P/S) and 5 (P/S) during voyage. Arrival conditions C6-7 to C6-12, only intended for strength verification (not operational) are marked: *

APPENDIX 4

SLAMMING STRENGTH ASSESSMENT OF BOW BOTTOM STRUCTURES

1. General

1.1 General provisions

1.1.1 This Appendix applies to strength assessment of bow bottom structures against slamming for mono-hull ships.

1.2 The strength assessment against bottom slamming in this Appendix is based on Ochi-Mottor theory to predict the extreme value of slamming pressures and anti-plastic failure method to evaluate the slamming strength of shell plating, longitudinals and bottom grillage.

1.3 The longitudinal extent for the strength assessment of bow bottom slamming is to be consistent with that specified in 2.15.3 of Chapter 2 of this PART.

1.4 Where direct calculation is adopted, the relative motion results required by the procedure to calculate the slamming pressures are to be given by solving three-dimensional linear sea-keeping program.

2. Slamming Pressure

2.1 Calculation of slamming pressures

2.1.1 The slamming pressures P_B , in kPa, at each section is to be obtained from the following formula:

$$P_B = eP_S$$

where: e — correction coefficient, see 2.15.3.5 of this Chapter;

P_S — extreme value of slamming pressures, calculated in way of each transverse section when $e = 1$ and the maximum value is taken, in kPa, to be obtained by the following formula:

where: ρ — density of seawater, in t/m³, taken as 1.025;

$$P_S = \frac{1}{2} \rho k_1 C_{ps} \left\{ V_0^2 - 2E_v \ln \left[1 - (1 - \alpha)^{1/n} \right] \right\}$$

k_1 — slamming coefficient, obtained according to Table 2.1.1, the intermediate value may be obtained from interpolation:

Table 2.1.1 - Slamming Coefficient k_1

b_1 / d_1	1	2	4	6	8	10	12	14	16	18
For container ships, passenger ships and vehicle carriers	4.0	9.5	20.0	26.0	29.5	32.0	33.0	34.2	35.3	36.2
For other types of ships	4.0	9.5	20.0	26.0	28.5	29.6	30.0	29.6	28.8	28.0

- d_1 — $d/10$, in m, where d is the draught;
 b_1 — half breadth of the waterline for the transverse section concerned under draught d_1 , in m;
 C_{ps} — coefficient, taken as 0.44;
 V_0 — critical slamming speed, in m/s, obtained from the following formulae:

$$V_0 = \begin{cases} 0.0925\sqrt{L_s} & \text{for container ship passenger ship and vehicle carrier} \\ 0.07\sqrt{L_s} & \text{for other ship} \end{cases}$$

 E_v — variance of vertical relative velocities for the hull and wave surface of transverse section concerned, determined according to 2.1.2 of this Appendix;
 α — assurance rate, taken as 0.01;
 n — number of impacts, replaced by the mean number of impacts N within t_n , obtained from the following formula:

$$N = 3600 \frac{t_n}{2\pi} \sqrt{\frac{E_v}{E_r}} \exp \left\{ - \left(\frac{T_f^2}{E_r} + \frac{V_0^2}{E_v} \right) \right\}$$

- where: t_n — the calculated navigation time, in h, obtained according to Table 2.2.4;
 E_r — variance of vertical relative motions for the hull and wave surface of transverse section concerned, determined according to 2.1.2 of this Appendix;
 T_f — draught of transverse section concerned in assessment condition, in m.

2.1.2 Variance of vertical relative motions for the hull and wave surface of transverse section concerned E_r and variance of vertical relative velocities for the hull and wave surface of transverse section concerned E_v are obtained from the following formula:

$$E_r = 0.25(C_{pc}M_r)^2 / f_r$$

$$E_v = 0.25(\omega_e C_{pc} M_r)^2 / f_v$$

- where: C_{pc} — correction factor of vertical relative motion probability, taken as 1.2;
 ω_e — encounter frequency, in rad/s, obtained from the following formula:

$$\omega_e = \omega \left(1 + \frac{0.4\omega V_c}{g} \right)$$

 ω — effective wave frequency based on 80% length of the ship, in rad/s, obtained from the following formula:

$$\omega = \sqrt{\frac{2\pi g}{0.8L}}$$

 V_c — considered ship speed, in m/s, obtained from the following formula:

$$V_c = 0.5144V$$

 where: V — defined in 1.1.2.27 of Chapter 1;
 M_r — vertical relative motions for the hull and wave surface of the considered section, in m, obtained from the following formula:

$$M_r = H_{min} \left[1 + \frac{4.5}{(C_b + 0.2)} \left(\frac{x_a}{L} - x_m \right)^2 \right]$$

H_{min} — minimum wave height for calculation, in m, obtained from the following formula:

$$H_{min} = \frac{0.0545}{k_m} L (C_b + 0.2)^{0.33} \exp(-0.0044L)$$

x_a — longitudinal position from the considered section to the after perpendicular, in m;

x_m — coefficient, obtained from the following formula, to be taken not less than 0.2;

$$x_m = 0.45 - \frac{0.309V}{\sqrt{gL}}$$

k_m — coefficient, obtained from the following formula:

$$k_m = 1 + \frac{4.5(0.5 - x_m)^2}{(C_b + 0.2)}$$

f_v — coefficient along the length of ship, obtained from the following formula, the intermediate value may be obtained by linear interpolation:

$$f_r, f_v = \begin{cases} \text{obtained according to Table 2.1.2(1),} & \text{For } L \leq 200 \text{ m} \\ \text{take values for 200m and 300m and interpolation according to the length of ship,} & \text{For } 200 \text{ m} < L < 300 \text{ m} \\ \text{obtained according to Table 2.1.2(2),} & \text{For } L \geq 300 \text{ m} \end{cases}$$

Table 2.1.2 (1) - Coefficient f_r , f_v

x_a / L	0.8	0.85	0.9	0.95
f_r	7.3	5.03	3.86	3.21
f_v	4.08	3.39	3.01	2.7

Table 2.1.2 (2) – Coefficient f_r , f_v

x_a / L	0.8	0.85	0.9	0.95
f_r	3.15	2.52	2.21	2.08
f_v	1	1	1	1

2.2 Relative motion direct calculation

2.2.1 In calculation of the extreme value of slamming pressures, variance of vertical relative motions for the hull and wave surface of transverse section concerned E_r and vertical relative velocities E_v may be determined by direct calculation according to the requirements of this Section, namely the zero moment of motion response given respectively by spectrum analysis. In this case, the E_r and E_v of each section concerned are given by direct calculation, the slamming pressure P_B is replaced by the actual calculated value of extreme value of slamming pressures P_S .

2.2.2 For the direct strength assessment against bow bottom slamming, the loading condition with a minimum draught forward in navigation is to be identified from the Loading Manual.

2.2.3 Two-parameter P-M spectrum is adopted to model the wave power spectrum density function, which is given by the following formula:

$$S(\omega) = \frac{124H_s^2}{T_z^4} \omega^{-5} \exp\left(-\frac{496}{T_z^4} \omega^{-4}\right) f_0(\theta)$$

- where: H_s — significant wave height, in m;
 T_z — mean zero-crossing period, in s;
 ω — angular frequency of wave components, in rad/s;
 $f_0(\theta)$ — wave spreading function, obtained from the following formula:

$$f_0(\theta) = \begin{cases} \frac{2}{\pi} \cos^2(\theta - \theta_m), & |\theta - \theta_m| < 90 \\ 0, & \text{Other values} \end{cases}$$

- where: θ — extension wave direction, in degree;
 θ_m — main wave direction, in degree.

2.2.4 The extreme value of slamming pressures is to be determined by short-term prediction approach and the significant wave height H_s is obtained from the following formulae:

$$H_s = \begin{cases} 8 - 0.6 \left(\frac{300 - L}{100} \right)^{1.5} & \text{m, } L < 300\text{m} \\ 8 + 0.6 \left(\frac{L - 300}{100} \right)^{1.5} & \text{m, } L \geq 300\text{m} \end{cases}$$

The average zero up-crossing wave period T_z and calculated navigation time t_n are to be selected in accordance with Table 2.2.4 and the intermediate values are to be obtained by interpolation.

Table 2.2.4 - Selection of sea wave conditions

Parameter	6	7	8	9
Significant wave height H_s (m)	6	7	8	9
Average zero up-crossing wave period T_z (s)	8.703	9.4	9.99	10.503
Calculated navigation time t_n (h)	41	35	35	35

2.2.5 The speed is to be taken as 0.75V.

2.2.6 The head sea and head oblique sea are to be considered, and interval between wave heading angles is not to be greater than 30 degrees.

2.2.7 The range of wave frequencies is to include 0.2 rad/s to 1.8 rad/s in increments taken as 0.05 rad/s.

2.2.8 Linear rolling damping may be determined by test or empirical formula, if not applicable, 5% of the critical rolling damping value may be taken.

2.2.9 Where direct calculation is adopted for relative motion, the slamming coefficient k_1 in 2.1.1

of this Appendix is obtained from the following formula:

$$k_1 = \exp(1.377 + 2.419a_1 - 0.873a_3 + 9.624a_5)$$

where: a_1, a_2, a_3 — the coefficient of three-parameter conformal mapping for the transverse section under draught d_1 to unit circle as follows:

$$Z_0 = U(\zeta + a_1\zeta^{-1} + a_3\zeta^{-3} + a_5\zeta^{-5})$$

Z_0 — section coordinate;

ζ — circle coordinate;

U — scale ratio, $U = \frac{d_1}{1 - a_1 + a_3 - a_5}$.

3 Strength Assessment

3.1 Slamming strength of shell plating

3.1.1 The pressure P_{cp} related to the ultimate capacity of shell plating is to be obtained from the following formula:

$$P_{cp} = \frac{12R_{eH}t_1^2}{a^2 \left[3 - \frac{2}{\beta^2} (\sqrt{1 + 3\beta^2} - 1) \right]} \text{ MPa}$$

where: R_{eH} — yield stress of material, in N/mm²;

t_1 — net thickness of plate panel, in mm;

a — length of the shorter side of the plate panel, in mm;

b — length of the longer side of the plate panel, in mm;

β — ratio between the sides, $\beta = b/a$

3.1.2 When the relationship of the ultimate capacity P_{cp} and the extreme value of slamming pressures P_B is satisfied as below, the shell plating is considered to be with sufficient capacity against slamming:

$$1000 \frac{P_{cp}}{P_B} \geq 0.75$$

where: P_B — slamming pressures, in kPa, see 2.1 of this Appendix.

3.2 Slamming strength of shell longitudinals

3.2.1 The pressure P_{cl} related to the ultimate capacity of shell longitudinals is to be obtained from the following formula:

$$P_{cl} = \frac{16R_{eH}W_T}{al^2} \text{ MPa}$$

where: R_{eH} — yield stress of material, in N/mm²;

a — spacing of longitudinals, in mm;

l — span of longitudinals, in mm;

W_T — section modulus of longitudinals, including plate flange, in mm³.

3.2.2 When the relationship of the ultimate capacity pressure P_{cl} and the extreme value of slamming pressures P_B is satisfied as below, the shell longitudinals are considered to be with sufficient capacity against slamming:

$$1000 \frac{P_{cl}}{P_B} \geq 0.75$$

where: P_B —slamming pressures, in kPa, see 2.1 of this Appendix.

3.3 Slamming strength of bottom grillage

3.3.1 Structural FE model

- (1) The longitudinal extent of the model is to include the calculation range as specified in 1.3 of this Appendix and at least extend to one web frame distance forward and aft. The transverse extent is to be selected as possible as to reduce the effect of boundary constraints on the response of bottom grillage. For example, the scope between the knuckle to the mid-line of the inner bottom may be selected for oil tankers and similar selection is applicable for other ships.
- (2) Selection and meshing of elements are to comply with the requirements of Section 5, Chapter 1 of this PART.
- (3) Strength evaluation is to be carried out for all primary members within the extent of strengthening of bottom forward.
- (4) When the stress distribution or stiffness of members is affected by the openings on primary members, the methods may be adopted in accordance with the requirements of Section 5, Chapter 1 of this PART.

3.3.2 Boundary constraints

Floors and girders at the boundary of model are to be rigidly fixed.

3.3.3 Loads

According to the principle of slamming, the slamming pressure acts on the floor at the centre girder, the affected area is a square. The length of a side of this square S_1 is obtained from the following formula:

$$S_1 = \sqrt{1.1 C_B L B \times 10^{-3}} \quad \text{m}$$

The extreme value of slamming pressure at each station of bow bottom will not occur at the same time, therefore the extreme value acting at each station is to be calculated respectively and the maximum pressure of the bottom grillage is obtained. The distribution of slamming pressures on the floor is to be determined according to the following three situations:

- (1) $S_1 < S$: The slamming pressure only acts on one floor, see Figure 3.3.3(1), the force Q acting on the floor in per unit length is to be calculated by the following formula:

$$Q = C_D P_B S_1 \text{ kN/m}$$

where: S — spacing of floors, in m;

P_B —slamming pressures, in kPa, see 2.1 of this Appendix;

C_D —dynamic slamming coefficient, to be taken as 0.8.

- (2) $S < S_1 < 2S$: The slamming pressure acts on two floors, see Figure 3.3.3(2), the force Q acting on the floor in per unit length is to be calculated by the following formula:

$$Q_C = 0.5 C_D P_B S_1 \text{ kN/m}$$

- (3) $S_1 > 2S$: The slamming pressure acts on three floors, the force Q_C acting on the intermediate floor in per unit length is to be calculated by the following formula:

$$Q_C = C_D P_B S \text{ kN/m}$$

The force Q_S acting on the side floor in per unit length is to be calculated by the following formula: $Q_S = 0.5 C_D P_B (S_1 - S) \text{ kN/m}$

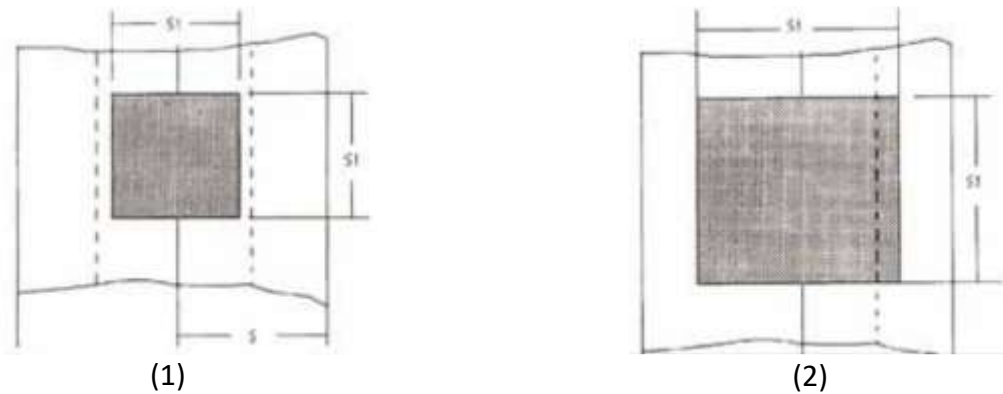


Figure 3.3.3

3.3.4 Acceptance criteria

Permissible stress of direct calculation of slamming strength for bow bottom grillage is to be determined in accordance with Table 3.3.4.

Table 3.3.4 - Permissible Stress

Member	Positive Stress of Inner Bottom Plating σ (N/mm ²)	Positive Stress of Outer Bottom Plating σ (N/mm ²)	Shear Stress (N/mm ²)	Equivalent Stress σ_e (N/mm ²)
Girder	122/K	112/K	108/K	180/K
Floor	132/K	132/K	98/K	196/K

Note: K — material factor.

CHAPTER 3

EQUIPMENT AND OUTFITS

SECTION 1 – RUDDERS

3.1.1 General requirements

3.1.1.1 Basic assumptions

- (1) This Section applies to ordinary profile rudders, and to some enhanced profile rudders with special arrangements for increasing the rudder force. Rudders not conforming to the profile types included in this Section will be subject to special consideration.
- (2) This section applies to rudders made of steel. Rudders made of material different from steel will be subject to special consideration.

3.1.1.2 Design considerations

- (1) Effective means are to be provided for supporting the weight of the rudder without excessive bearing pressure, e.g. by a rudder carrier attached to the upper part of the rudder stock. The hull structure in way of the rudder carrier is to be suitably strengthened.
- (2) Suitable arrangements are to be provided to prevent the rudder from lifting.
- (3) In rudder trunks which are open to the sea, a seal or stuffing box is to be fitted above the deepest load waterline, to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier. If the top of the rudder trunk is below the waterline at scantling draught (without trim), two separate watertight seals/stuffing boxes are to be provided.

3.1.1.3 Materials

- (1) Welded parts of rudders are to be made of materials complying with relevant requirements for hull structural steel in ISC Rules for Materials and Welding.
- (2) Material factor k for normal and high tensile steel plating may be taken into account when specified in each individual rule requirement. The material factor k is to be taken as defined in Section 3, Chapter 1 of this PART, unless otherwise specified.
- (3) Steel grade of plating materials for rudders and rudder horns are to be in accordance with Section 3, Chapter 1 of this PART.
- (4) Rudder stocks, pintles, coupling bolts, keys and cast parts of rudders are to be made of rolled, forged or cast carbon manganese steel in accordance with ISC Rules for Materials and Welding.
- (5) For rudder stocks, pintles, keys and bolts the minimum yield stress is not to be less than 200 N/mm². The requirements of this Section are based on a material's yield stress of 235 N/mm². If material is used having a yield stress differing from 235 N/mm² the material factor K is to be determined as follows:

$$K = \left(\frac{235}{R_{eH}} \right)^e$$

where: $e = 0.75$ for $R_{eH} > 235$ N/mm²;

$e = 1.00$ for $R_{eH} \leq 235 \text{ N/mm}^2$;

R_{eH} —specified minimum yield stress (N/mm^2) of material used, and is not to be taken greater than $0.7R_m$ or 450 N/mm^2 , whichever is the smaller value;

R_m — tensile strength (N/mm^2) of material used.

3.1.1.4 Welding and design details

- (1) Slot-welding is to be limited as far as possible. Slot welding is not to be used in areas with large in-plane stresses transversely to the slots or in way of cut-out areas of semi-spade rudders. When slot welding is applied, the length of slots is to be minimum 75 mm with breadth of $2t$, where t is the rudder plate thickness, in mm. The distance between ends of slots is not to be more than 125 mm. The fillet leg length is to comply with calculation requirements in 1.4.4, Chapter 1 of this PART, and welding is to be based on a weld factor of 0.44. The slots are to be fillet welded around the edges and filled with a suitable compound, e.g. epoxy putty. Slots are not to be filled with weld. Continuous slot welds are to be used in lieu of slot welds. When continuous slot welding is applied, the root gap is to be between 6-10 mm. The bevel angle is to be at least 15° .
- (2) In way of the rudder horn recess of semi-spade rudders, the radii in the rudder plating except in way of solid part in cast steel are not to be less than 5 times the plate thickness, but in no case less than 100 mm. Welding in side plate is to be avoided in or at the end of the radii. Edges of side plate and weld adjacent to radii are to be ground smooth.
- (3) Welds in the rudder side plating subjected to significant stresses from rudder bending and welds between plates and heavy pieces (solid parts in forged or cast steel or very thick plating) are to be made as full penetration welds. In way of highly stressed areas e.g. cut-out of semi-spade rudder and upper part of spade rudder, cast or welding on ribs is to be arranged. Two sided full penetration welding is normally to be arranged. Where back welding is impossible welding is to be performed against ceramic backing bars or equivalent. Steel backing bars may be used and are to be continuously welded on one side to the bevelled edge, see Figure 3.1.1.4(3). The bevel angle is to be at least 15° for one sided welding.

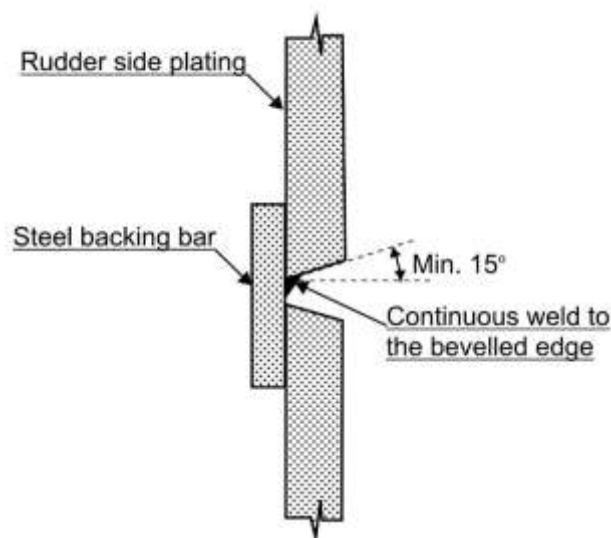


Figure 3.1.1.4(3) Use of steel backing bar in way of full penetration welding of rudder side plating

- (4) Requirements for welding and design details of rudder trunks are described in 3.1.9.2 of this Section.
- (5) Requirements for welding and design details when the rudder stock is connected to the rudder by horizontal flange coupling are described in 3.1.6.1(4) of this Section.
- (6) Requirements for welding and design details of rudder horns are described in 3.1.9.1(3).

3.1.1.5 Equivalence

- (1) ISC may accept alternatives to requirements given in this Section, provided they are deemed to be equivalent.
- (2) Direct analyses adopted to justify an alternative design are to take into consideration all relevant modes of failure, on a case by case basis. These failure modes may include, amongst others: yielding, fatigue, buckling and fracture. Possible damages caused by cavitation are also to be considered.
- (3) Where deemed necessary by ISC, lab tests, or full scale tests may be requested to validate the alternative design approach.

3.1.2 Rudder force and rudder torque

3.1.2.1 Rudder blades without cut-outs

- (1) The rudder force C_R upon which the rudder scantlings are to be based is to be determined from the following formula:

$$C_R = 132 K_1 K_2 K_3 A V^2 \text{ N}$$

where: C_R — rudder force, in N;

A — area of rudder blade, in m^2 ;

V — maximum service speed (knots). When the speed is less than 10 knots, V is to be replaced by the following:

$$V_{min} = (V + 20) / 3$$

For the astern condition the maximum astern speed V_{astern} (the greatest speed which the ship is designed to maintain in service at sea at the deepest sea-going draught) is to be used, however, in no case less than:

$$V_{astern} = 0.5 V;$$

K_1 — factor depending on the aspect ratio λ of the rudder area;

$K_1 = (\lambda + 2)/3$, with λ not to be taken greater than 2;

$$\lambda = b^2 / A_t;$$

b — mean height of the rudder area, in m. Mean breadth and mean height of rudder are calculated according to the coordinate system in Figure 3.1.2.1;

A_t — sum of rudder blade area A and area of rudder post or rudder horn, if any, within the height b , in m^2 ;

K_2 — coefficient depending on the type of the rudder and the rudder profile according to Table 3.1.2.1; data may be provided by tests with approval of ISC;

$K_3 = 0.8$ for rudders outside the propeller jet;
 $= 1.15$ for rudders behind a fixed propeller nozzle;
 $= 1.0$ otherwise.

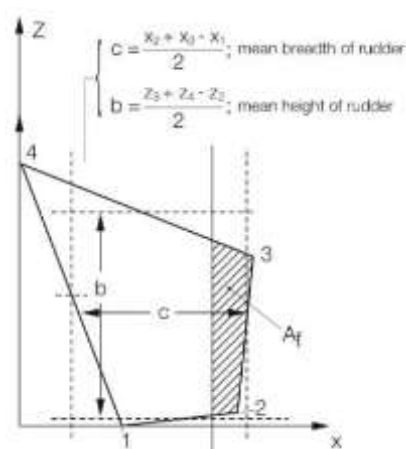
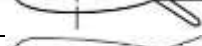
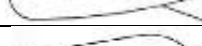
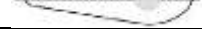


Figure 3.1.2.1

Table 3.1.2.1 - Factor K_2

Profile Type		K_2 (Ahead Condition)	K_2 (Astern Condition)
NACA-00 series / Göttingen		1.1	0.8
Flat side		1.1	0.9
Hollow		1.35	0.9
High lift rudders		1.7	1.3
Fish tail		1.4	0.8
Single plate		1	1
Mixed profiles (e.g. HSVA)		1.21	0.9

(2) The rudder torque is to be calculated for both the ahead and astern condition as follows:

$$Q_R = C_R r \text{ Nm}$$

where: $r = c (\alpha - k)$, in m;

c — mean breadth of rudder area, in m, see Figure 3.1.2.1;

α — coefficient, taken as 0.33 for ahead condition and 0.66 for astern condition; special consideration may be given for high lift rudders, and taken as 0.40 for ahead condition and 0.66 for astern condition if no test data may be provided;

$$k = \frac{A_f}{A};$$

A_f — portion of the rudder blade area situated ahead of the centre line of the rudder stock, in m^2 ;

$r_{min} = 0.1c$, in m, for ahead condition.

3.1.2.2 Rudder blades with cut-outs (semi-spade rudders)

The total rudder force C_R is to be calculated according to 3.1.2.1(1) of this Section. The pressure distribution over the rudder area, upon which the determination of rudder torque and rudder

blade strength is to be based, is to be derived as follows:

The rudder area may be divided into two rectangular or trapezoidal parts with areas A_1 and A_2 , so that $A = A_1 + A_2$ (see Figure 3.1.2.2).

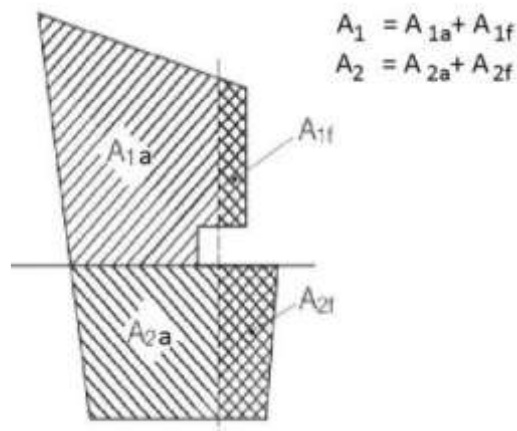


Figure 3.1.2.2 Areas A_1 and A_2

The levers r_1 and r_2 are to be determined as follows:

$$r_1 = c_1 (\alpha - k_1), \text{ m};$$

$$r_2 = c_2 (\alpha - k_2), \text{ m};$$

where: c_1, c_2 — mean breadth of partial areas A_1, A_2 determined, where applicable, in accordance with Figure 3.1.2.1;

$$k_1 = \frac{A_{1f}}{A_1};$$

$$k_2 = \frac{A_{2f}}{A_2};$$

A_{1a} — portion of A_1 situated aft of the centre line of the rudder stock, in m^2 ;

A_{1f} — portion of A_1 situated ahead of the centre line of the rudder stock, in m^2 ;

A_{2a} — portion of A_2 situated aft of the centre line of the rudder stock, in m^2 ;

A_{2f} — portion of A_2 situated ahead of the centre line of the rudder stock, in m^2 ;

$\alpha = 0.33$ for ahead condition;

$\alpha = 0.66$ for astern condition;

For parts of a rudder behind a fixed structure such as the rudder horn:

$\alpha = 0.25$ for ahead condition;

$\alpha = 0.55$ for astern condition;

The resulting force of each part may be taken as:

$$C_{R1} = C_R \frac{A_1}{A} \quad \text{N}$$

$$C_{R2} = C_R \frac{A_2}{A} \quad \text{N}$$

The resulting torque of each part may be taken as:

$$Q_{R1} = C_{R1} F_1 \quad \text{N} \cdot \text{m}$$

$$Q_{R2} = C_{R2} F_2 \quad \text{N} \cdot \text{m}$$

The total rudder torque is to be calculated for both the ahead and astern condition as follows:

$$Q_R = Q_{R1} + Q_{R2} \quad \text{N} \cdot \text{m}$$

For ahead condition Q_R is not to be taken less than:

$$Q_{Rmin} = 0.1 C_R \frac{A_1 c_1 + A_2 c_2}{A} \quad \text{N} \cdot \text{m}$$

3.1.3 Rudder strength calculation

3.1.3.1 The rudder force and resulting rudder torque as given in 3.1.2 of this Section causes bending moments and shear forces in the rudder body, bending moments and torques in the rudder stock, supporting forces in pintle bearings and rudder stock bearings and bending moments, shear forces and torques in rudder horns and heel pieces. The rudder body is to be stiffened by horizontal and vertical webs enabling it to act as a bending girder.

3.1.3.2 The bending moments, shear forces and torques as well as the reaction forces are to be determined by a direct calculation or by an approximate simplified method considered appropriate by ISC. For rudders supported by sole pieces or rudder horns these structures are to be included in the calculation model in order to account for the elastic support of the rudder body. Guidelines for calculation of bending moment and shear force distribution are given in Appendix 1 to this Chapter.

3.1.4 Rudder stock scantlings

3.1.4.1 The rudder stock diameter required for the transmission of the rudder torque is to be dimensioned such that the torsional stress τ_t is not exceeding the following value:

$$\tau_t = 68 / K \quad \text{N/mm}^2$$

The rudder stock diameter for the transmission of the rudder torque d_t is therefore not to be less than:

$$d_t = 4.2 \sqrt[3]{Q_R K} \quad \text{mm}$$

where: Q_R — total rudder torque [N·m] as calculated in 3.1.2.1(2) and 3.1.2.2 of this Section;

K — material factor for the rudder stock as given in 3.1.1.3(5) of this Section.

3.1.4.2 Rudder stock scantlings due to combined loads

If the rudder stock is subjected to combined torque and bending, the equivalent stress in the rudder stock is not to exceed $118 / K \text{ N/mm}^2$.

K — material factor for the rudder stock as given in 3.1.1.3(5).

The equivalent stress σ_e is to be determined by the formula:

$$\sigma_e = \sqrt{\sigma_b^2 + 3\tau_t^2} \quad \text{N/mm}^2$$

where: bending stress: $\sigma_b = \frac{10.2M}{d_c^3} \times 10^3 \quad \text{N/mm}^2;$

torsional stress: $\tau_t = \frac{5.1Q_R}{d_c^3} \times 10^3 \quad \text{N/mm}^2.$

The rudder stock diameter d_c is therefore not to be less than:

$$d_c = d_t \sqrt[3]{1 + \frac{4}{3} \left(\frac{M}{Q_R} \right)^2} \quad \text{mm}$$

where: M — bending moment, in N·m, at the station of the rudder stock considered.

For a spade rudder with trunk extending inside the rudder, the rudder stock scantlings are to be checked against the two cases defined in 2.2, Appendix 1 of this Chapter.

3.1.4.3 Before significant reductions in rudder stock diameter due to the application of steels with specified minimum yield stresses exceeding 235 N/mm² are granted, ISC may require the evaluation of the rudder stock deformations. Large deformations of the rudder stock are to be avoided in order to avoid excessive edge pressures in way of bearings.

3.1.5 Rudder blade

3.1.5.1 Permissible stresses

The section modulus and the web area of a horizontal section of the rudder blade are to be such that the following stresses will not be exceeded:

(1) In general, except in way of rudder recess sections where (2) applies :

- ① bending stress σ_b 110/k N/mm²
- ② shear stress, τ 50/k N/mm²
- ③ equivalent stress $\sigma = \sigma^2 + 3\tau^2 = 120/k$ N/mm²

K — material factor for the rudder plating as given in 3.1.1.3(2).

(2) In way of the recess for the rudder horn pintle on semi-spade rudders

- ① bending stress σ_b 75 N/mm²
- ② shear stress, τ 50 N/mm²
- ③ equivalent stress

Note: The stresses in (2) apply equally to high tensile and ordinary steels.

3.1.5.2 Rudder plating

The thickness t of the rudder side, top and bottom plating is not to be less than: $t = 5.5s\beta K$

$$t = 5.5s\beta \sqrt{K} \sqrt{d + C_R 10^{-4} / A + 2.5} \quad \text{mm}$$

where: d — scantling draught, in m;

C_R — rudder force, in N, according to 3.1.2.1 of this Section;

A — rudder area, in m²;

$$\beta = \sqrt{1.1 - 0.5\left(\frac{s}{b}\right)^2} \quad \text{max. } 1.00 \text{ if } \frac{b}{s} \geq 2.5;$$

s — smallest unsupported width of plating, in m;

b — greatest unsupported width of plating, in m;

K — material factor for the rudder plating as given in 3.1.1.3(2).

The thickness of the nose plate of rudder blades is not to be less than 1.2 times that of rudder side plating, but need not be greater than 22 mm. The thickness of web plates is not to be less than the greater of 70% of the rudder side plating thickness and 8 mm.

The rudder plating in way of the solid part is to be of increased thickness per 3.1.5.3(4).

3.1.5.3 Connections of rudder blade structure with solid parts

- (1) Solid parts in forged or cast steel, which house the rudder stock or the pintle, are to be provided with protrusions.

These protrusions are not required when the web plate thickness is less than:

- 10 mm for web plates welded to the solid part on which the lower pintle of a semi-spade rudder is housed and for vertical web plates welded to the solid part of the rudder stock coupling of spade rudders;
- 20 mm for other web plates.

- (2) The solid parts are in general to be connected to the rudder structure by means of two horizontal web plates and two vertical web plates.
- (3) Minimum section modulus of the connection with the rudder stock housing. The section modulus of the cross-section of the structure of the rudder blade W_s , in cm³, formed by vertical web plates and rudder plating, which is connected with the solid part where the rudder stock is housed is to be not less than:

$$W_s = c_s d_c^3 \left(\frac{H_E - H_X}{H_E} \right)^2 \frac{K}{K_s} 10^{-4} \text{ cm}^3$$

where: c_s — coefficient, to be taken equal to:

= 1.0 if there is no opening in the rudder plating or if such openings are closed by a full penetration welded plate;

= 1.5 if there is an opening in the considered cross-section of the rudder;

d_c — diameter of rudder stock in way of lower bearing, in mm, calculated according to 3.1.4 of this Section;

H_E — vertical distance between the lower edge of the rudder blade and the upper edge of the solid part, in m;

H_X — vertical distance between the considered cross-section and the upper edge of the solid part, in m;

K — material factor for the rudder blade plating as given in 3.1.1.3(2);

K_s — material factor for the rudder stock as given in 3.1.1.3(5).

The actual section modulus of the cross-section of the structure of the rudder blade is to be calculated with respect to the symmetrical axis of the rudder. The breadth of the rudder plating, in m, to be considered for the calculation of section modulus is to be not greater than:

$$b = s_v + 2H_x/3 \text{ m}$$

where: s_v — spacing between the two vertical webs, in m (see Figure 3.1.5.3).

Where openings for access to the rudder stock nut are not closed by a full penetration welded plate, they are to be deducted.

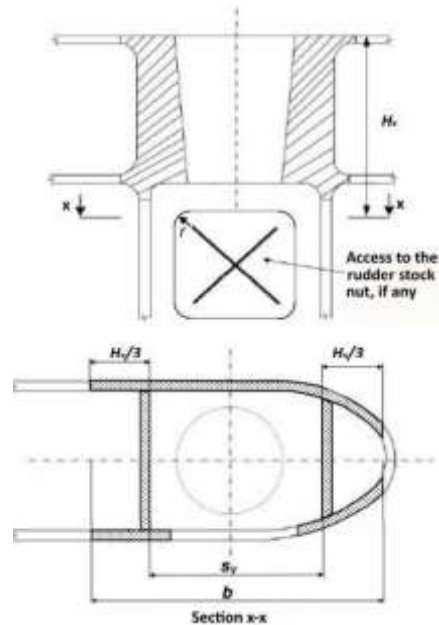


Figure 3.1.5.3 Cross-section of the connection between rudder blade structure and rudder stock housing, example with opening in only one side shown

- (4) The thickness of the horizontal web plates connected to the solid parts, in mm, as well as that of the rudder blade plating between these webs, is to be not less than the greater of the following values:

$$t_H = 1.2t \text{ mm}$$

$$t_H = 0.045d_s^2 / S_H \text{ mm}$$

where: t — defined in 3.1.5.2 of this Section;

d_s — diameter, in mm, to be taken equal to:

= d_c , as per 3.1.4.2 of this Section, for the solid part housing the rudder stock;

= d_p , as per 3.1.7.1 of this Section, for the solid part housing the pintle;

S_H — spacing between the two horizontal web plates, in mm.

The increased thickness of the horizontal webs is to extend fore and aft of the solid part at least to the next vertical web.

- (5) The thickness of the vertical web plates welded to the solid part where the rudder stock is housed as well as the thickness of the rudder side plating under this solid part is to be not less than the values obtained, in mm, from Table 3.1.5.3.

Table 3.1.5.3 - Thickness of side plating and vertical web plates

Type of Rudder	Thickness of Vertical Web Plates (mm)		Thickness of Rudder Plating (mm)	
	Rudder Blade without Opening	Rudder Blade with Opening	Rudder Blade without Opening	Area with Opening
Rudder supported by sole piece	1.2 t	1.6 t	1.2 t	1.4 t
Semi-spade and spade rudders	1.4 t	2.0 t	1.3 t	1.6 t

where: t = thickness of the rudder plating, in mm, as defined in 3.1.5.2 of this Section.

The vertical web plates and rudder plating the thickness of which has been increased are to extend below the solid piece at least to the next horizontal web.

3.1.5.4 Single plate rudders

(1) Mainpiece diameter

The mainpiece diameter is calculated according to 3.1.4.1 and 3.1.4.2 of this Section respectively. For spade rudders the lower third may taper down to 0.75 times stock diameter.

(2) Blade thickness

The blade thickness t is not to be less than:

$$t_b = 1.5sV\sqrt{K+2.5} \quad \text{mm}$$

where: s — spacing of stiffening arms, in m not to exceed 1 m;

V — speed in knots, see 3.1.2.1(1) of this Section;

K — material factor for the rudder plating as given in 3.1.1.3(2) of this Section.

(3) Arms

The thickness of the arms t_a is not to be less than the blade thickness:

$$t_a = t_b \text{ mm}$$

The section modulus W is not to be less than:

$$W = 0.5 s C_1^2 V^2 K \text{ cm}^3$$

where: C_1 — horizontal distance from the aft edge of the rudder to the centreline of the rudder stock, in m;

K — material factor as given in 3.1.1.3(2) or 3.1.1.3 (5) of this Section respectively.

3.1.6 Rudder stock couplings

3.1.6.1 Horizontal flange couplings

(1) The diameter of the coupling bolts d_b is not to be less than:

$$d_b = 0.62 \sqrt{d_s^3 K_b / n e_m K_s} \quad \text{mm}$$

where: d_s — stock diameter, taken equal to the greater of the diameters d_t or d_c according to 3.1.4.1 and 3.1.4.2, in mm;

n — total number of bolts, which is not to be less than 6;

e_m — mean distance, in mm, of the bolt axes from the centre of the bolt system;

K_s — material factor for the stock as given in 3.1.1.3(5) of this Section;

K_b — material factor for the bolts as given in 3.1.1.3(5) of this Section.

- (2) The thickness of the coupling flanges t_f , in mm, is not to be less than the greater of the following formulae:

$$t_f = d_b \sqrt{K_f / K_b} \quad \text{mm}$$

$$t_f = 0.9 d_b \quad \text{mm}$$

where: K_f — material factor for flange as given in 3.1.1.3(5) of this Section;

K_b — material factor for the bolts as given in 3.1.1.3(5) of this Section;

d_b — bolt diameter, in mm, calculated for a number of bolts not exceeding 8.

- (3) The width of material between the perimeter of the bolt holes and the perimeter of the flange is not to be less than $0.67 d_b$.
- (4) The welded joint between the rudder stock and the flange is to be made in accordance with Figure 3.1.6.1 or equivalent.

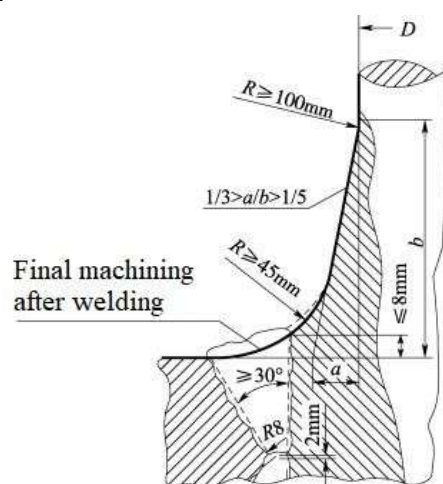


Figure 3.1.6.1 Welded joint between rudder stock and coupling flange

- (5) Coupling bolts are to be fitted bolts and their nuts are to be locked effectively.

3.1.6.2 Vertical flange couplings of rudder stock and rudder blades

- (1) The diameter of the coupling bolts d_b , in mm, is not to be less than:

$$d_b = 0.81 d_s / \sqrt{n \times \sqrt{K_b / K_s}} \quad \text{mm}$$

where: d_s — stock diameter [in mm] in way of coupling flange;

n — total number of bolts, which is not to be less than 8;

K_b — material factor for bolts as given in 3.1.1.3(5) of this Section;

K_s — material factor for stock as given in 3.1.1.3(5) of this Section.

- (2) The first moment of area of the bolts about the centre of the coupling, m , is to be not less than:

$$m = 0.00043 d_s^3 \quad \text{cm}^3$$

- (3) The thickness of the coupling flanges is to be not less than the bolt diameter, and the width of

the flange material between the perimeter of the bolt holes and the perimeter of the flange is to be not less than 0.67 db.

- (4) Coupling bolts are to be fitted bolts and their nuts are to be locked effectively.

3.1.6.3 Cone couplings with key

(1) Tapering and coupling length

Cone couplings without hydraulic arrangements for mounting and dismounting the coupling are to have a taper c on diameter of 1:8 – 1:12.

Where $c = (d_0 - d_u) / l_c$, see Figure 3.1.6.3(a) and Figure 3.1.6.3(c).

The diameters d_0 and d_u are shown in Figure 3.1.6.3(a) and the cone length, l_c , is defined in Figure 3.1.6.3(c).

The cone coupling is to be secured by a slugging nut. The nut is to be secured, e.g. by a securing plate as shown in Figure 3.1.6.3(a).

The cone shapes are to fit exactly. The coupling length l is to be, in general, not less than $1.5d_0$.

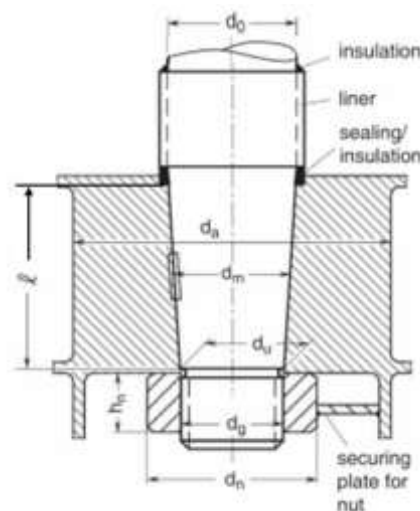


Figure 3.1.6.3(a) Cone coupling with key

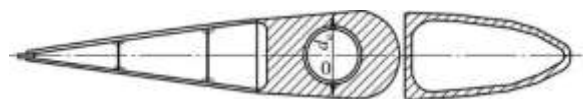


Figure 3.1.6.3(b) Gudgeon outer diameter d_g

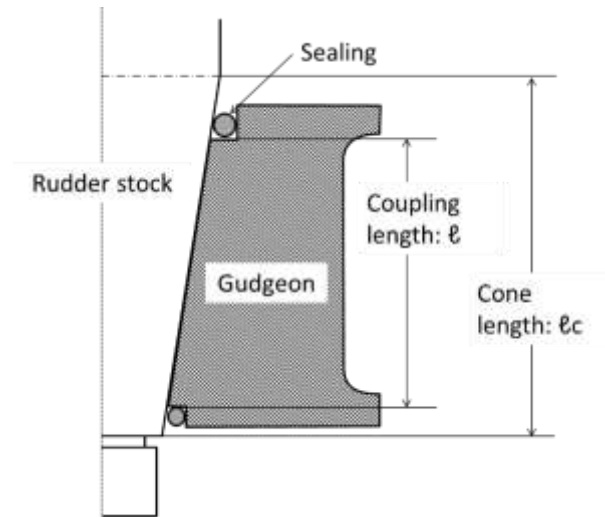


Figure 3.1.6.3(c) Cone length and coupling length

(2) Dimensions of key

For couplings between stock and rudder a key is to be provided, the shear area a_s of which, in cm^2 , is not to be less than:

$$a_s = \frac{17.55 Q_F}{d_k R_{eH1}} \quad \text{cm}^2$$

where:

Q_F — design yield moment of rudder stock, in $\text{N}\cdot\text{m}$;

$$Q_F = 0.02664 d^3 / K \quad \text{N}\cdot\text{m}$$

Where the actual diameter d_{ta} is greater than the calculated diameter d_t , the diameter d_{ta} is to be used. However, d_{ta} applied to the above formula need not be taken greater than $1.145 d_t$.

d_t — stock diameter, in mm, according to 3.1.4.1 of this Section;

K — material factor for stock as given in 3.1.1.3(5) of this Section;

d_k — mean diameter of the conical part of the rudder stock, in mm, at the key;

R_{eH1} — specified minimum yield stress of the key material, in N/mm^2 .

The effective surface area a_k , in cm^2 , of the key (without rounded edges) between key and rudder stock or cone coupling is not to be less than:

$$a_k = \frac{5 Q_F}{d_k R_{eH2}}$$

where: R_{eH2} — specified minimum yield stress of the key, stock or coupling material, in N/mm^2 .

(3) The dimensions of the slugging nut are to be as follows (see Figure 3.1.6.3(a)):

external thread diameter: $dg \geq 0.65 d_o$, height: $h_n \geq 0.6 dg$,

outer diameter: $dn \geq 1.2 du$ or $1.5 dg$, whichever is the greater.

(4) It is to be proved that 50% of the design yield moment is solely transmitted by friction in the cone couplings. This can be done by calculating the required push-up pressure and push-up length according to 3.1.6.4(2) and 3.1.6.4(3) for a torsional moment $Q'F = 0.5QF$.

(5) Notwithstanding the requirements of 3.1.6.3(2) and 3.1.6.3(4), where a key is fitted to the

coupling between stock and rudder and it is considered that the entire rudder torque is transmitted by the key at the couplings, the scantlings of the key as well as the push-up force and push-up length are to be calculated according to the torque transmitted (not to be greater than the design yielding torque of the rudder stock).

3.1.6.4 Cone couplings with special arrangements for mounting and dismounting the couplings

- (1) Where the stock diameter exceeds 200 mm, the press fit is recommended to be effected by a hydraulic pressure connection. In such cases the cone is to be more slender, $c \approx 1:12$ to $\approx 1:20$. In case of hydraulic pressure connections the nut is to be effectively secured against the rudder stock or the pintle. For the safe transmission of the torsional moment by the coupling between rudder stock and rudder body the push-up pressure and the push-up length are to be determined according to 3.1.6.4(2) and 3.1.6.4(3) respectively.

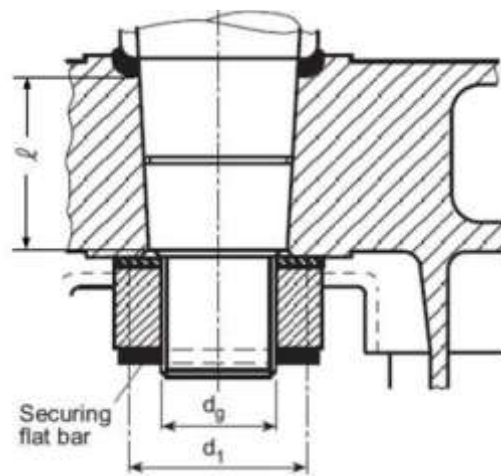


Figure 3.1.6.4 Cone couplings without key

(2) Push-up pressure

The push-up pressure is not to be less than the greater of the two following values:

$$P_{req1} = \frac{2Q_F \times 10^3}{d_m^2 l \pi \mu_0} \quad \text{N/mm}^2$$

$$P_{req2} = \frac{6M_c \times 10^3}{l^2 d_m} \quad \text{N/mm}^2$$

where: Q_F — design yield moment of rudder stock, as defined in 3.1.6.3(2) of this Section, in N·m;

d_m — mean cone diameter, in mm, see Figure 3.1.6.3(a);

l — coupling length, in mm;

μ_0 — frictional coefficient, equal to 0.15;

M_c — bending moment in rudder stock at the top of the cone coupling (e.g. in case of spade rudders), in N·m.

For spade rudder with trunk extending inside the rudder, the coupling is to be checked against the two cases defined in 2.2, Appendix 1 of this Chapter.

It has to be proved by the designer that the push-up pressure does not exceed the permissible surface pressure in the cone. The permissible surface pressure, in N/mm², is to be determined by the following formula:

$$P_{perm} = \frac{0.95 R_{eH} (1 - \alpha^2)}{\sqrt{3 + \alpha^4}} - p_b \quad \text{N/mm}^2$$

where :

$$p_b = \frac{3.5 M_e \times 10^3}{d_m l^2} \quad \text{N/mm}^2$$

R_{eH} — specified minimum yield stress of the material of the gudgeon, in N/mm²;

$$\alpha = \frac{d_m}{d_a};$$

d_m — diameter, in mm, see Figure 3.1.6.3(a);

d_a — outer diameter of the gudgeon to be not less than 1.25 d_0 , in mm, see Figure 3.1.6.3 (a) and 3.1.6.3(b). (The least diameter is to be considered).

(3) Push-up length

The push-up length Δl , in mm, is to comply with the following formula:

$$\Delta l_1 \leq \Delta l \leq \Delta l_2$$

where :

$$\Delta l_1 = \frac{P_{req} d_m}{E \left(\frac{1 - \alpha^2}{2} \right) c} + \frac{0.8 R_{tm}}{c} \quad \text{mm}$$

$$\Delta l_2 = \frac{P_{perm} d_m}{E \left(\frac{1 - \alpha^2}{2} \right) c} + \frac{0.8 R_{tm}}{c} \quad \text{mm}$$

R_{tm} — mean roughness, in mm, taken equal to 0.01;

c — taper on diameter according to 3.1.6.4(1) of this Section, in mm;

Note: In case of hydraulic pressure connections the required push-up force P_e , in N, for the cone may be determined by the following formula:

$$P_e = p_{req} d_m \pi l \left(\frac{c}{2} + 0.02 \right)$$

The value 0.02 is a reference for the friction coefficient using oil pressure. It varies and depends on the mechanical treatment and roughness of the details to be fixed. Where due to the fitting procedure a partial push-up effect caused by the rudder weight is given, this may be taken into account when fixing the required push-up length, subject to approval by ISC.

3.1.7 Pintles

3.1.7.1 Scantlings

The pintle diameter d_p , in mm, is not to be less than:

$$d_p = 0.35 \sqrt{BK_p} \quad \text{mm}$$

where : B — relevant bearing force, in N;

k_p — material factor for pintle as given in 3.1.1.3(5) of this Section.

3.1.7.2 Couplings

(1) Tapering

Pintles are to have a conical attachment to the gudgeons with a taper on diameter not greater than:

1:8 to 1:12 for keyed and other manually assembled pintles applying locking by slugging nut, 1:12 to 1:20 on diameter for pintles mounted with oil injection and hydraulic nut.

(2) Push-up pressure for pintle

The required push-up pressure for pintle in case of oil injection fitting, in N/mm², is to be determined by the maximum pressure of P_{req1} and P_{req2} as given below:

The pintle diameter d_p , in mm, is not to be less than:

$$P_{req1} = 0.4 \frac{Bd_0}{d_m^2 l} \quad \text{N/mm}^2$$

$$P_{req2} = \frac{6M_{bp}}{l^2 d_m} \times 10^3 \quad \text{N/mm}^2$$

where : B — Supporting force in the pintle, in N;

d_0 — Pintle diameter, in mm, see Figure 3.1.6.3(a);

M_{bp} — bending moment in the pintle cone coupling to be determined by:

$$M_{bp} = Bl_a \quad \text{N·m}$$

l_a — length between middle of pintle-bearing and top of contact surface between cone coupling and pintle, see Figure 3.1.7.2.

The push up length Δl_1 is to be calculated similarly as in 3.1.6.4(3) of this Section, using required push-up pressure and properties for the pintle.

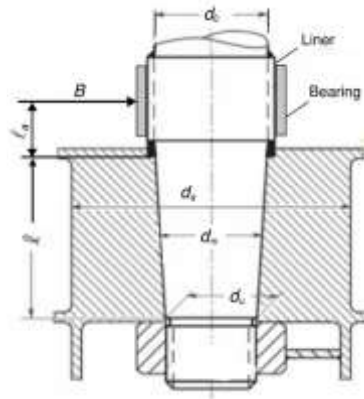


Figure 3.1.7.2 Pintle cone coupling indicating l_a

3.1.7.3 The minimum dimensions of threads and nuts are to be determined according to 3.1.6.3(3).

3.1.7.4 Pintle housing. The length of the pintle housing in the gudgeon is not to be less than the pintle diameter d_p . d_p is to be measured on the outside of shaft sleeves. The thickness of the pintle housing is not to be less than $0.25 d_p$.

3.1.8 Rudder stock bearing, rudder shaft bearing and pintle bearing

3.1.8.1 Liners and bushes

(1) Rudder stock bearing

Liners and bushes are to be fitted in way of bearings. For rudder stocks and pintles having diameter less than 200 mm, liners in way of bushes may be provided optionally. The minimum thickness of liners and bushes t_{min} is to be equal to:

- $t_{min} = 8$ mm for metallic materials and synthetic material;
- $t_{min} = 22$ mm for lignum material.

(2) Pintle bearing

The thickness of any liner or bush t , in mm, is not to be less than the minimum thickness defined in 3.1.8.1(1) and the following value:

$$t = 0.01\sqrt{B}$$

where: B — relevant bearing force, in N.

3.1.8.2 Minimum bearing surface

An adequate lubrication is to be provided.

The bearing surface A_b (defined as the projected area: length $\times$ outer diameter of liner) is not to be less than:

$$A_b = \frac{P}{q_a} \text{ mm}^2$$

where : P — reaction force, in N, in bearing as determined in 3.1.3.2 of this Section;
 q_a — allowable surface pressure according to Table 3.1.8.2.

The allowable surface pressure q_a for the various combinations is to be taken as reported in the

table below. Higher values than given in Table 3.1.8.2 may be taken in accordance with makers' specifications if they are verified by tests:

Table 3.1.8.2 - Allowable surface pressure q_a

Bush Material	q_a (N/mm ²)
Lignum vitae	2.5
White metal, oil lubricated	4.5
Synthetic material with hardness greater than 60 Shore D ^①	5.5 ^②
Steel ^③ , bronze, and hot-pressed bronze-graphite materials	7

Notes:

- ① Indentation hardness test at 23 °C and with 50% moisture, are to be carried out according to a recognized standard. Synthetic bearing materials are to be of an approved type.
- ② Surface pressures exceeding 5.5 N/mm² may be accepted in accordance with bearing manufacturer's specification and tests, but in no case more than 10 N/mm².
- ③ Stainless and wear-resistant steel in an approved combination with stock liner.

3.1.8.3 Bearing dimensions

The length/diameter ratio of the bearing surface is not to be greater than 1.2. The bearing length L_p of the pintle is to be such that $D_p \leq L_p \leq 1.2 D_p$

where: D_p — Actual pintle diameter measured on the outside of liners, in mm.

3.1.8.4 Bearing clearances

With metal bearings, clearances should not be less than $d / 1000 + 1.0$ mm (where d is the outer diameter of rudder stock or pintle) on the diameter. If non-metallic bearing material is applied, the bearing clearance is to be specially determined considering the material's swelling and thermal expansion properties. This clearance is not to be taken less than 1.5 mm on bearing diameter unless a smaller clearance is supported by the manufacturer's recommendation and there is documented evidence of satisfactory service history with a reduced clearance.

3.1.9 Strength of rudder horns and rudder trunk

3.1.9.1 Rudder horns

The bending moments and shear forces are to be determined by a direct calculation or in line with the guidelines given in 2.4 and 2.5 of Appendix 1 for semi spade rudder with one elastic support and semi spade rudder with 2-conjugate elastic support respectively.

The section modulus around the horizontal x-axis W is not to be less than:

$$W = M_b K / 67 \text{ cm}^3$$

where: M_b — bending moment at the section considered, in N·m.

The shear stress τ is not to be larger than:

$$\tau \leq 18 / K \text{ N/mm}^2$$

where: K — material factor as given in 3.1.1.3(2) or 3.1.1.3(5) of this Section.

(1) Equivalent stress

At no section within the height of the rudder horn is the equivalent stress to exceed $120/K$ N/mm². The equivalent stress σ_v is to be calculated by the following formula

$$\sigma_v = \sqrt{\sigma_b^2 + 3(\tau^2 + \tau_T^2)} \quad \text{N/mm}^2$$

where : $\sigma_b = Mb / Z_x$, in N/mm²;

Z_x — section modulus of rudder horn at the section considered, in cm³;

B_1 — supporting force in the pintle bearing, in N;

A_h — effective shear area of rudder horn in y-direction, in mm²;

$$\tau_T = M_T 10^3 / 2 A_T t_h, \text{ in N/mm}^2;$$

M_T — torsional moment, in N·m;

A_T — area in the horizontal section enclosed by the rudder horn (including the area of inner hollow area), in mm²;

t_h — plate thickness of rudder horn, in mm;

(2) Rudder horn plating

The thickness of the rudder horn side plating t is not to be less than:

$$t = 2.4 \sqrt{LK} \quad \text{mm}$$

where : L — length of the ship, in m;

K — material factor, as given in 3.1.1.3(2) or 3.1.1.3(5) of this Section respectively.

(3) Welding and connection to hull structure

The rudder horn plating is to be effectively connected to the aft ship structure, e.g. by connecting the plating to side shell and transverse/ longitudinal girders, in order to achieve a proper transmission of forces, see Figure 3.1.9.1.

If the connection of rudder horn and hull structure is so designed that the rudder horn is transited to hull plating in the curved way, particular attention is to be made to the effectiveness of the bending of rudder horn and the stress of transverse webs.

Brackets or stringer are to be fitted internally in horn, in line with outside shell plate, as shown in Figure 3.1.9.1.

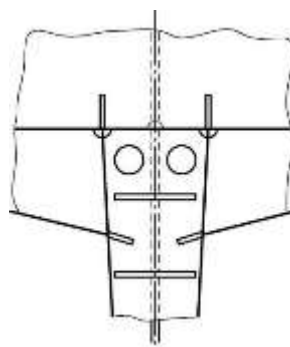


Figure 3.1.9.1 Connection of rudder horn to aft ship structure

Transverse webs of the rudder horn are to be led into the hull up to the next platform deck in a sufficient number.

Strengthened plate floors are to be fitted in line with the transverse webs in order to achieve a

sufficient connection with the hull.

The centre line bulkhead (wash-bulkhead) in the after peak is to be connected to the rudder horn. Scallops are to be avoided in way of the connection between transverse webs and shell plating. The weld at the connection between the rudder horn plating and the side shell is to be full penetration. The welding radius is to be as large as practicable and may be obtained by grinding.

3.1.9.2 Rudder trunk

The requirements in this paragraph apply to trunk configurations which are extended below stern frame and arranged in such a way that the trunk is stressed by forces due to rudder action.

(1) Materials, welding and connection to hull

The steel used for the rudder trunk is to be of weldable quality, with a carbon content not exceeding 0.23% on ladle analysis or a carbon equivalent *CEQ* not exceeding 0.41%.

Plating materials for rudder trunks are in general not to be of lower grades than corresponding to class II as defined in Section 3, Chapter 1 of this PART.

The weld at the connection between the rudder trunk and the shell or the bottom of the skeg is to be full penetration.

For rudder trunks extending below shell or skeg, the fillet shoulder radius *r*, in mm (see Figure 3.1.9.2) is to be as large as practicable and to comply with the following formulae:

$$r = 0.1d_c / K, \text{ without being less than:}$$

$$r = 60 \text{ mm} \quad \text{when } \sigma = 40 / K \text{ N/mm}^2$$

$$r = 30 \text{ mm} \quad \text{when } \sigma < 40 / K \text{ N/mm}^2$$

where: *d_c* — rudder stock diameter axis as defined in 3.1.4.2;

σ — bending stress in the rudder trunk, in N/mm²;

K — material factor for the rudder trunk as given in 3.1.1.3(2) or 3.1.1.3(5) of this Section.

The radius may be obtained by grinding. If disk grinding is carried out, score marks are to be avoided in the direction of the weld. The radius is to be checked with a template for accuracy.

Four profiles at least are to be checked. A report is to be submitted to the Surveyor.

Rudder trunks comprising of materials other than steel are to be specially considered by ISC.

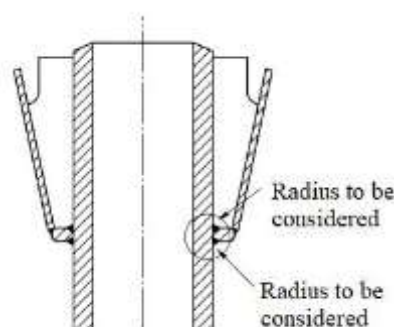


Figure 3.1.9.2

(2) Scantlings

The scantlings of the trunk are to be such that: the equivalent stress due to bending and shear does not exceed $0.35 R_{eH}$.

The bending stress on welded rudder trunk σ is to be in compliance with the following formula:

$$\sigma \leq 80 / K \text{ N/mm}^2$$

where: σ — bending stress in the rudder trunk, as defined in 3.1.9.2(1);

K — material factor for the rudder trunk as given in 3.1.1.3(2) or 3.1.1.3(5) of this Section, not to be taken as less than 0.7;

R_{eH} — specified minimum yield stress, in N/mm^2 , of the material used.

For calculation of bending stress, the span to be considered is the distance between the mid-height of the lower rudder stock bearing and the point where the trunk is clamped into the shell or the bottom of the skeg.

3.1.10 Others**3.1.10.1 Quadrants and tillers**

(1) The section modulus W of the tiller at any section from the centre of the rudder stock about the vertical axis is not to be less than that obtained from the following formula:

$$W = 0.14 \left(1 - \frac{D_s}{R}\right) D_t^3 (K_t / K_s) \text{ mm}^3$$

where: D_s — distance from the section under consideration to the centerline of the stock on the tiller, not greater than the bore diameter of the pin, in mm, see Figure 3.1.10.1;

D_t — stock diameter, in mm, at the tiller, taken not greater than 1.145 times the value calculated according to 3.1.4.1 of this Section;

R — radius of quadrant or length of tiller, in mm;

K_t — material factor of tiller, see 3.1.1.3(5) of this Section;

K_s — material factor of stock, see 3.1.1.3(5) of this Section.

For quadrants having more than one arm, the combined section modulus of the arms is not to be less than that required in the above formula.

For tillers of rectangular section, the breadth to depth ratio is not to be more than 2.

(2) Depth of boss of the quadrant or tiller $h \geq 1.0D_t$, and its outside diameter $D_0 \geq 1.8D_t$, see Figure 3.1.10.1. Where the depth of boss of the tiller h is greater than D_t , the required outer diameter D_0 may be reduced accordingly. It is to ensure that $h \times D_0^2 \geq 3.24D_t^3$, and D_0 is not to be less than $1.6D_t$ in any case. D_t is defined in (1) above.

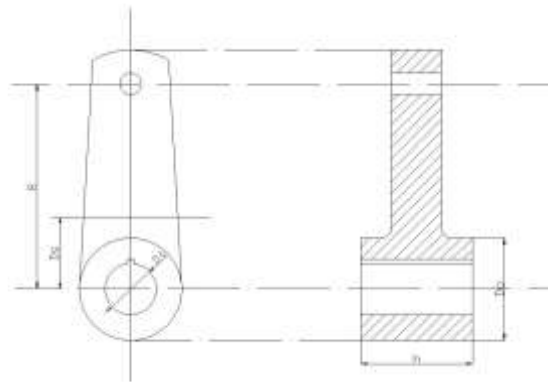


Figure 3.1.10.1

(3) Where the boss of a tiller (quadrant) is composed of two half pieces, at least one key is to be fitted and each end of the key is to be secured by at least 2 bolts. The bolts are to be pretightened and the prestressing force on each bolt is to correspond to 70% of the permissible stress of bolt material. Where double keys are used, the prestressing force may be reduced appropriately. The total cross-sectional area A_b of all bolts is not to be less than that obtained from the following formula:

$$A_b = 0.2 \times \frac{D_t^3}{b} (K_b / K_s) \quad \text{mm}^2$$

where: D_t — stock diameter, in mm, at the tiller, taken not greater than 1.145 times the value calculated according to 3.1.4.1 of this Section;
 b — distance between centerlines of bolt at both ends, in mm;
 K_b — material factor of bolt, see 3.1.1.3(5) of this Section;
 K_s — material factor of stock, see 3.1.1.3(5) of this Section.

(4) The cross-sectional area A_r and moment of inertia I_r of the rod connecting the tiller (quadrant) to the tiller are not to be less than those obtained from the following formulas:

$$A_r = 0.12 \times \frac{D_t^3}{R} (K_r / K_s) \quad \text{mm}^2$$

$$I_r = 6.6 \times \frac{D_t^3 l^2}{R} \times 10^{-6} (K_r / K_s) \quad \text{mm}^4$$

where: D_t — diameter of the rudder stock, at the tiller of a passive rudder, taken not greater than 1.145 times the value calculated according to 3.1.4.1 of this Section;
 l — length of the connecting rod, in mm;
 R — length of the tiller of the passive rudder, in mm;
 K_r — material factor of connecting rod, see 3.1.1.3(5) of this Section;
 K_s — material factor of stock, see 3.1.1.3(5) of this Section.

(5) For a rotary vane type steering gear, the rotor and blades of the gear are to comply with the requirements of 3.1.10.1(1) and 3.1.10.1(2) for boss of the tiller and the tiller.

3.10.1.2 Connection of rudder tiller to stock

(1) The connection of the rudder tiller to stock is to be such that mechanical forces are transmitted from the steering gear to the rudder stock in any operational condition. The torque T_d transmitted

by such connection is not to be less than twice the design torque of the steering gear, but need not be greater than the design yield torque QF of the stock calculated according to 3.1.6.3(2) of this Section. The design torque of the steering gear is corresponding to the design pressure in 13.1.6.5 of Chapter 13, PART THREE of the Rules.

(2) For torque transmission by friction, the average surface pressure p_r for the connection of tiller to stock is not to be less than that obtained from the following formula:

$$p_r \geq \frac{2T_{fr}}{\pi D_m^2 l f} \times 10^3 \quad \text{N/mm}^2$$

where: T_{fr} — torque transmitted by friction, in N·m;

= T_d , for keyless connection;

= $0.5T_d$, for keyed connection

T_d — torque transmitted through connection of tiller to stock, in N·m, determined according to 3.1.10.2(1) of this Section;

D_m — diameter of the rudder stock or mean diameter of the taper, in mm;

l — length of the effectively connected portion of the tiller, in mm;

f — coefficient of friction, taken as 0.15 for hydraulic fit or 0.18 for dry fit.

(3) For conical connection, nuts are to be used for securing against axial displacement. It is to be ensured that the size of nuts is to sustain the weight of rudder and rudder stock without considering the force of friction between rudder tiller and rudder stock, and reference may be made to the requirements of 3.1.6.3(3) of this Section.

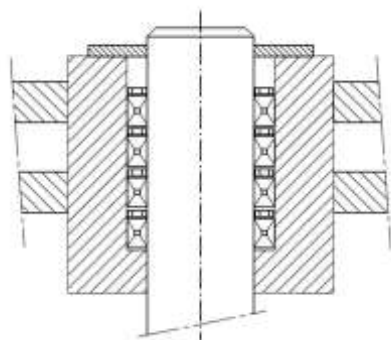
(4) Where the tiller is connected to the stock by means of several expansion sleeves or conical sleeves, as indicated in Figure 3.1.10.2, the influence of axial forces is also to be taken into account. In this case, the torque T_{d1} transmitted by the connection of tiller to stock is not to be less than that obtained from the following formula:

$$T_{d1} = \sqrt{T_d^2 + (2W \cdot D_m)^2 \cdot 10^{-4}} \quad \text{N·m}$$

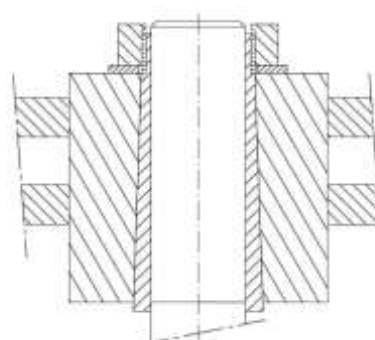
where: T_d — torque, in N·m, determined according to 3.1.10.2(1) of this Section;

W — weight of rudder and rudder stock, in kg;

D_m — diameter of rudder stock, in mm.



(a) Expansion sleeve



(b) Conical sleeve

Figure 3.1.10.2

(5) The taper of cone on diameter is to be not greater than 1:15 for keyless conical connection and not greater than 1:10 for keyed conical connection.

(6) For keyed connection, the shear area A_s of the key is not to be less than that obtained from the following formula:

$$A_s = \frac{70(T_d - k_{key} T_{fr})}{D_k R_{eH}} \quad \text{cm}^2$$

where: T_d — torque transmitted through connection of tiller to stock, in N·m, calculated according to 3.1.10.2 of this Section;

k_{key} — coefficient, determined as follows:

= 0.7 where boss of tiller is composed of two half pieces and secured by bolts;

= 0.9 for hydraulic fitting of tiller to stock;

= 1.0 in other cases.

T_{fr} — torque transmitted by friction, in N·m, calculated according to the following formula:

$$T_{fr} = \frac{\pi p_r D_m^2 l f}{2} \times 10^{-3}$$

where: p_r — average surface pressure for the connection of tiller to stock, in N/mm², determined according to 3.1.10.2(2) of this Section. Where hydraulic fitting or shrinkage fit is adopted for the conical connection, the average push-up surface pressure is to be taken;

D_m, l, f — same as in 3.1.10.2(2) of this Section;

D_k — mean diameter, in mm, of rudder stock cone in way of the position where the key is fitted;

R_{eH} — yield stress, in N/mm², of key material.

(7) For keyed connections, the compressed area A_k of keys (round edge portion not included) is not to be less than that obtained from the following formula

$$A_k = \frac{22(T_d - k_{key} T_{fr})}{D_k R_{eH}} \quad \text{cm}^2$$

where: $T_d, k_{key}, T_{fr}, D_k$ — same as in (6) above;

R_{eH} — yield stress, in N/mm², of key material.

(8) Where two keys are fitted, the shear area A_s and compressed area A_k of each key may be taken as 2/3 of the value obtained for one key.

(9) The keyway is to have an adequately rounded end. The radius of curvature is usually not to be less than 5% of the thickness of the key. The compressive stress on the stock/tiller keyway is not to exceed 90% of the yield stress of the material used.

(10) Where the hydraulic fitting or shrinkage fit is adopted for the conical connection, the push-up length and the average push-up surface pressure are to be determined in accordance with the following requirements:

① The push-up length S is to meet the following:

$$S_1 \leq S \leq S_2$$

The minimum push-up length

$$S_1 = \frac{1}{k_1} \left[\frac{2p_r D_m k_2^2}{E(k_2^2 - 1)} + 0.02 \right] \text{ mm}$$

The maximum push-up length

$$S_2 = \frac{1}{k_1} \left[1.6 R_{eH} D_m \frac{k_2^2}{E \sqrt{3k_2^4 + 1}} + 0.02 \right] \text{ mm}$$

where: p_r — average surface pressure for the connection of tiller to stock, in N/mm^2 , determined according to 3.1.10.2(2) of this Section;

k_1 — taper of cone on diameter;

$k_2 = (D_m + 2t_a) / D_m$;

D_m — mean diameter of cone, in mm;

t_a — mean thickness of boss of tiller, in mm;

R_{eH} — yield stress of material of boss of tiller or rudder stock, whichever is less, in N/mm^2 ;

E — elastic modulus, to be taken as 2.06×10^5 , in N/mm^2 .

② The average push-up surface pressure P is to be calculated by the following formula:

$$P = \frac{SE(k_2^2 - 1)k_1}{2D_m k_2^2} \text{ N/mm}^2$$

where: k_1, k_2, D_m and E — same as in ① above;

S — the push-up length to be determined in accordance with ① above, in mm.

3.1.10.3 Strengthening for navigation in ice

(1) For ships with Ice Class notations the scantlings and arrangement of the rudder structures are to comply with the relevant requirements of Chapter 4 of this PART.

SECTION 2 - ANCHORING AND MOORING EQUIPMENT

3.2.1 Equipment number

3.2.1.1 The anchoring equipment for sea-going ships are to be provided in accordance with Tables 3.2.1.1(1) and 3.2.1.1(2), based on the ship type and service area as well as the equipment number derived from 3.2.1.2 of this Section. Requirements of this Section for the number, length and breaking loads of towlines and mooring lines are only as guidance.

For non-self-propelled ships engaged in special work, of which an increased mass of anchors is required by the owner and anchoring operations are carried out by means of other appliances, chain cables may be provided in accordance with the rule requirements for the mass of anchors only. The requirement for the anchoring equipment in this Section is intended for temporary mooring of a vessel within a harbour or sheltered area when the vessel is awaiting berth, tide, etc. The equipment is therefore not designed to hold a ship off fully exposed coasts in rough weather or to stop a ship which is moving or drifting. In this condition the loads on the anchoring equipment increase to such a degree that its components may be damaged or lost owing to the high energy forces generated, particularly in large ships.

The anchoring equipment presently required in this Section is designed to hold a ship in good holding ground in conditions such as to avoid dragging of the anchor. In poor holding ground the holding power of the anchors will be significantly reduced.

The Equipment Numeral (EN) formula for anchoring equipment required in this Section is based on an assumed maximum current speed of 2.5 m/sec, maximum wind speed of 25 m/sec and a minimum scope of chain cable between 6 and 10, the scope being the ratio between length of chain paid out and water depth. For ships with an equipment length greater than 135 m, alternatively the required anchoring equipment can be considered applicable to a maximum current speed of 1.54 m/s, a maximum wind speed of 11 m/s and waves with maximum significant height of 2 m. It is assumed that under normal circumstances a ship will use only one bow anchor and chain cable at a time.

Manufacture of anchors and anchor chain cables is to be in accordance with the relevant requirements of ISC Rules for Materials and Welding.

The bower anchor is to be connected with its chain cable, arranged onboard the ship and ready for use. In addition to planned anchoring for normal operations, anchoring equipment is also important for ship safety in emergency situations such as loss of maneuverability, unscheduled repairs and other unexpected situations.

Table 3.2.1.1(1) - Equipment Required

Ship Type	Required Equipment
Cargo ships, bulk carriers, oil tankers, trailing suction dredgers, ferries, etc.	Using N
Tugs	Using N

Offshore supply ships	Using N, but the chain cables are to be selected two grades above N
Manned barges	Using N
Unmanned barges	Using N, but only one bower anchor is required, and 0.5 times the length of chain cables required for N may be provided
Floating cranes, floating pile drivers, or other similar workboats	Using N, but side projections of the crane, pile driver, etc., are to be considered for N. If the anchors used comply with the requirements of this Table, they may be used in lieu of bower anchors .

3.2.1.2 The equipment number N is to be obtained from the following formula:

$$N = \Delta^{\frac{2}{3}} + 2(Bh + S_{fun}) + \frac{A}{10}$$

where: Δ — moulded displacement, in t, to the summer load waterline;
 B — moulded breadth, in m;
 h — effective height, in m, from the summer load waterline to the top of the uppermost house, i.e.:

$$h = a + \sum h_i$$

where: a — vertical distance at hull side, in m, measured from the summer load waterline amidships to the upper deck;
 h_i — height at the centreline, in m, of each tier of houses having a breadth greater than $B/4$; for the lowest tier h_1 is to be measured at centreline from the upper deck or from a notional deck line where there is local discontinuity in the upper deck, see Figure 3.2.1.1(1);
 A — area, in m^2 , in profile view of the hull, within the length of the vessel, and of superstructures and deckhouses and funnels above the summer load waterline, which are within the length of the vessel, and also having a breadth greater than $B/4$. The side projected area of the funnel is considered in A when AFS is greater than zero. In this case, the side projected area of the funnel should be calculated between the upper deck, or notional deck line where there is local discontinuity in the upper deck, and the effective height h_F ;
 S_{fun} — effective front projected area of the funnel, in m^2 , defined as:

$$S_{fun} = AFS - S_{shield}$$

where: AFS — front projected area of the funnel, in m^2 , calculated between the upper deck at centreline, or notional deck line where there is local discontinuity in the upper deck, and the effective height h_F . AFS is taken equal to zero if the funnel breadth is less than or equal to $B/4$ at all elevations along the funnel height;
 h_F — effective height of the funnel, in m, measured from the upper deck at centreline, or notional deck line where there is local discontinuity in the upper deck, and the

top of the funnel. The top of the funnel may be taken at the level where the funnel breadth reaches $B/4$;

Sshield — the section of front projected area AFS , in m^2 , which is shielded by all deck houses having breadth greater than $B/4$. If there are more than one shielded section, the individual shielded sections i.e. *Sshield1*, *Sshield 2* etc as shown in Figure 3.2.1.2(3) to be added together. To determine *Sshield*, the deckhouse breadth is assumed B for all deck houses having breadth greater than $B/4$ as shown for *Sshield1*, *Sshield2* in Figure 3.2.1.2(3). When several funnels are fitted on the ship, the above parameters are taken as follows:

h_F — effective height of the funnel, in m , measured from the upper deck, or notional deck line where there is local discontinuity in the upper deck, and the top of the highest funnel. The top of the highest funnel may be taken at the level where the sum of each funnel breadth reaches $B/4$;

AFS — sum of the front projected area of each funnel, in m^2 , calculated between the upper deck, or notional deck line where there is local discontinuity in the upper deck, and the effective height h_F . AFS is to be taken equal to zero if the sum of each funnel breadth is less than or equal to $B/4$ at all elevations along the funnels height;

A — Side projected area, in m^2 , of the hull, superstructures, houses and funnels above the Summer Load waterline which are within the length of the ship. The total side projected area of the funnels is to be considered in the side projected area of the ship, A , when AFS is greater than zero. The shielding effect of funnels in transverse direction may be considered in the total side projected area, i.e., when the side projected areas of two or more funnels fully or partially overlap, the overlapped area needs only to be counted once.

The equipment number of tugs is to be determined by the following formula:

$$N = \Delta^{\frac{2}{3}} + 2(aB + \sum b_i h_i) + \frac{A}{10}$$

where: b_i — breadth, in m , of superstructures or of deckhouses of each tier having a breadth greater than $B/4$.

a , B and h_i — same as defined above;

For tugs under 45 m in length intended for towing service only, one anchor may be used onboard provided that the second anchor and its relevant chain cable holds readily available to be installed. In case of loss of anchor, the tug is to remain in port until replace anchor equipment is installed onboard. In the calculation of h and A , sheer and trim are to be ignored, i.e. h is the sum of freeboard amidships plus the height (at centreline) of each tier of houses having a breadth greater than $B/4$. Screens and bulwarks more than 1.5 m in height are to be regarded as parts of superstructures or deckhouses.

Screens and bulwarks more than 1.5 m in height are to be regarded as parts of superstructures or deckhouses. If a house having a breadth greater than $B/4$ is above a house with a breadth of $B/4$ or less then the wide house is to be included but the narrow house ignored.

The height of the hatch coamings and that of any deck cargo, such as containers, may be disregarded when determining h and A . With regard to determining A , when a bulwark is more than 1.5 m high, the area shown as A_2 in Figure 3.2.1.2(2) is to be included in A . The total length of chain given in Table 3.2.1.1(2) is to be divided in approximately equal parts between the two bower anchors.

For ships of length less than 90 m, alternative methodology using direct force calculation for anchoring equipment described in appendix 3 of this Chapter may be used.

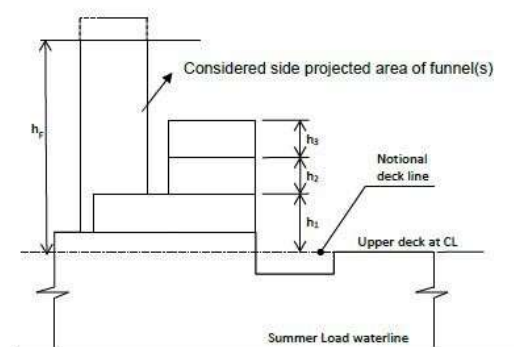


Figure 3.2.1.2(1)

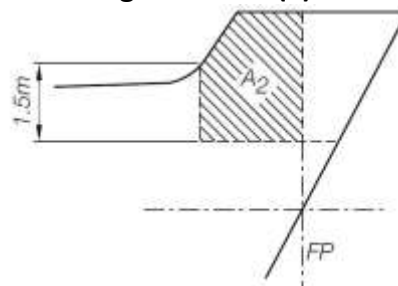


Figure 3.2.1.2(2)

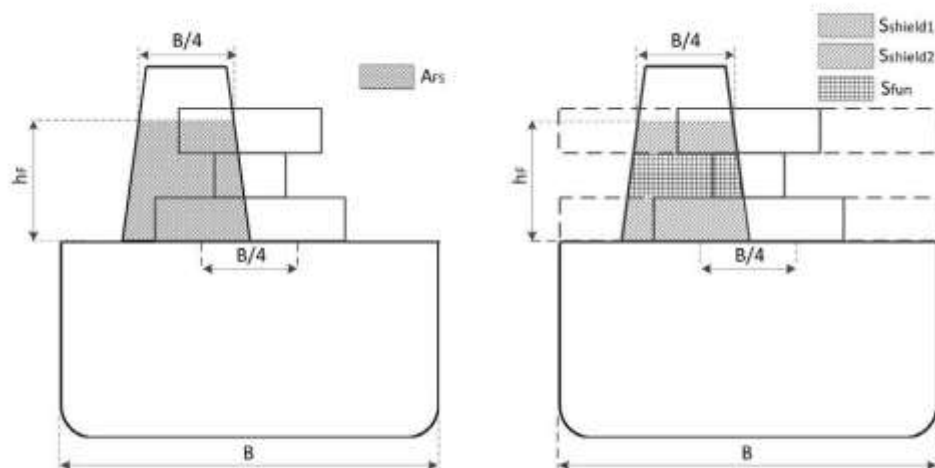


Figure 3.2.1.2(3)

3.2.2 Anchors

3.2.2.1 The mass of individual bower anchors may vary within -7% to +7% of the mass given in Table 3.2.1.1(2) of this Section, provided that the total mass of the bower anchors is not to be less than that would have been required for anchors of equal mass.

3.2.2.2 The mass of the head, including pins and swivels, of an ordinary stockless anchor is not to be less than 60% of the total mass of the anchor.

3.2.2.3 Stocked bower anchors may be used, but the mass excluding the stock is not to be less than 80% of the mass given in Table 3.2.1.1(2) of this Section for ordinary stockless bower anchors.

3.2.2.4 When high holding power anchors are used as bower anchors, the mass of each such anchor may be 75% of the mass given in Table 3.2.1.1(2) of this Section for ordinary stockless bower anchors. When super high holding power anchors of the proven holding power are used as bower anchors, the mass of each such anchor may be reduced to not less than 50% of the mass required for ordinary stockless anchors in Table 3.2.1.1(2) of this Section. See specific requirements of Section 1, Chapter 10 of PART ONE of ISC Rules for Materials and Welding. Where high holding power anchors or very high holding power anchors are used as bower anchors, leading to the reduction in the mass of anchors, the notation RWA may be assigned.

Table 3.2.1.1(2) - Anchoring and Towing Equipment

Serial No.	Equipment No., N		Bower anchors		Stud link chain cable for bower anchors				Towlines		Mooring lines		
	Exceeding	Not exceeding	Number	Mass of each anchor (kg)	Total length (m)	Diameter			Min. length (m)	Ship design Min. breaking load (kN)	Number	Min. length each (m)	Ship design Min. breaking load (kN)
						ISC grade 1	ISC grade 2	ISC grade 3					
1	50	70	2	180	220	14	12.5		180	98	3	80	37
2	70	90	2	240	220	16	14		180	98	3	100	40
3	90	110	2	300	247.5	17.5	16		180	98	3	110	42
4	110	130	2	360	247.5	19	17.5		180	98	3	110	48
5	130	150	2	420	275	20.5	17.5		180	98	3	120	53
6	150	175	2	480	275	22	19		180	98	3	120	59
7	175	205	2	570	302.5	24	20.5		180	112	3	120	64
8	205	240	2	660	302.5	26	22	20.5	180	129	4	120	69
9	240	280	2	780	330	28	24	22	180	150	4	120	75
10	280	320	2	900	357.5	30	26	24	180	174	4	140	80
11	320	360	2	1020	357.5	32	28	24	180	207	4	140	85
12	360	400	2	1140	385	34	30	26	180	224	4	140	96
13	400	450	2	1290	385	36	32	28	180	250	4	140	107
14	450	500	2	1440	412.5	38	34	30	180	277	4	140	117
15	500	550	2	1590	412.5	40	34	30	190	306	4	160	134
16	550	600	2	1740	440	42	36	32	190	338	4	160	143

17	600	660	2	1920	440	44	38	34	190	370	4	160	160
18	660	720	2	2100	440	46	40	36	190	406	4	160	171
19	720	780	2	2280	467.5	48	42	36	190	441	4	170	187
20	780	840	2	2460	467.5	50	44	38	190	479	4	170	202
21	840	910	2	2640	467.5	52	46	40	190	518	4	170	218
22	910	980	2	2850	495	54	48	42	190	559	4	170	235
23	980	1060	2	3060	495	56	50	44	200	603	4	180	250
24	1060	1140	2	3300	495	58	50	46	200	647	4	180	272
25	1140	1220	2	3540	522.5	60	52	46	200	691	4	180	293
26	1220	1300	2	3780	522.5	62	54	48	200	738	4	180	309
27	1300	1390	2	4050	522.5	64	56	50	200	786	4	180	336
28	1390	1480	2	4320	550	66	58	50	200	836	4	180	352
29	1480	1570	2	4590	550	68	60	52	220	888	5	190	352
30	1570	1670	2	4890	550	70	62	54	220	941	5	190	362
31	1670	1790	2	5250	577.5	73	64	56	220	1024	5	190	384
32	1790	1930	2	5610	577.5	76	66	58	220	1109	5	190	411
33	1930	2000	2	6000	577.5	78	68	60	220	1168	5	190	437
34	2000	2080	2	6000	577.5	78	68	60	220	1168			
35	2080	2230	2	6450	605	81	70	62	240	1259			
36	2230	2380	2	6900	605	84	73	64	240	1356			
37	2380	2530	2	7350	605	87	76	66	240	1453			
38	2530	2700	2	7800	632.5	90	78	68	260	1471			
39	2700	2870	2	8300	632.5	92	81	70	260	1471			
40	2870	3040	2	8700	632.5	95	84	73	260	1471			
41	3040	3210	2	9300	660	97	84	76	280	1471			
42	3210	3400	2	9900	660	100	87	78	280	1471			
43	3400	3600	2	10500	660	102	90	78	280	1471			
44	3600	3800	2	11100	687.5	105	92	81	300	1471			
45	3800	4000	2	11700	687.5	107	95	84	300	1471			
46	4000	4200	2	12300	687.5	111	97	87	300	1471			
47	4200	4400	2	12900	715	114	100	87	300	1471			
48	4400	4600	2	13500	715	117	102	90	300	1471			
49	4600	4800	2	14100	715	120	105	92	300	1471			
50	4800	5000	2	14700	742.5	122	107	95	300	1471			
51	5000	5200	2	15400	742.5	124	111	97	300	1471			
52	5200	5500	2	16100	742.5	127	111	97	300	1471			
53	5500	5800	2	16900	742.5	130	114	100	300	1471			
54	5800	6100	2	17800	742.5	132	117	102	300	1471			
55	6100	6500	2	18800	742.5		120	107					
56	6500	6900	2	20000	770		124	111					
57	6900	7400	2	21500	770		127	114					
58	7400	7900	2	23000	770		132	117					
59	7900	8400	2	24500	770		137	122					
60	8400	8900	2	26000	770		142	127					
61	8900	9400	2	27500	770		147	132					
62	9400	10000	2	29000	770		152	132					
63	10000	10700	2	31000	770			137					

64	10700	11500	2	33000	770			142					
65	11500	12400	2	35500	770			147					
66	12400	13400	2	38500	770			152					
67	13400	14600	2	42000	770			157					
68	14600	16000	2	46000	770			162					

3.2.3 Chain cables

3.2.3.1 For ships with N less than 90, chain cables may be substituted by studless chains of equivalent proof-load.

3.2.3.2 Wire rope may be used in place of chain cable on ships subject to the following conditions:

- (1) with less than 90 m in length and which will need an anchor for emergency purposes, i.e., not intended to use their anchor in normal temporary anchoring operation, or
- (2) with the anchoring equipment used for positioning with a minimum of 4 points anchoring, e.g., for cable or pipe laying.
- (3) for anchors used for operation of floating cranes, floating pile drivers or other similar workboats as specified in Table 3.2.1.1(1).

3.2.3.3 Use of wire rope is subject to the following conditions:

- (1) The wire ropes are to have a total length equal to 1.5 times the corresponding length of stud link chain cables required in Table 3.2.1.1(2), and a minimum breaking load equal to that given for the corresponding stud link chain cable of Grade ISC 1.
- (2) The anchor weight shall be increased by 25 % compared to anchor associated with chain cable according to Table 3.2.1.1(2).
- (3) A short length of chain cable is to be fitted between the wire rope and the anchor, having a length equal to 12.5 m or the distance from the anchor in the stowed position to the winch, whichever is the lesser.
- (4) All surfaces being in contact with the wire need to be rounded with a radius of not less than 10 times the wire rope diameter (including stem).
- (5) Steel wire shall be selected to fit for purpose based on the manufacturer recommendation and shall be provided with guidance for maintenance and inspection.

3.2.3.4 A swivel is to be provided to the chain cables at the outboard end to which the anchor is connected.

3.2.3.5 The inboard end of the chain cable is to be connected to the structure by fasteners and so arranged that they will be capable of being immediately released from a position easily accessible outside the chain locker. Fasteners and their hull support structures are to be able to withstand breaking load which is not less than 15% and not greater than 30% of the anchor chain fitted.

3.2.3.6 Grade ISC 1 material having a tensile stress of less than 400 N/mm² is not to be used in association with high holding power anchors. Grade ISC 3 material is to be used only for chains of 20.5 mm or more in diameter.

3.2.3.7 The total length of chain given in Table 3.2.1.1(2) is to be divided in approximately equal parts between the two bower anchors.

3.2.4 Towlines and mooring lines

3.2.4.1 The number, length and breaking loads of mooring lines are to be marked on the mooring arrangement plan of the ship. The towlines listed in Table 3.2.1.1(2) are provided on board for the tug or for the use by other ships towing the ship. The lateral projected area of deck cargoes as given by the ship nominal capacity condition is to be taken into account during the calculation of equipment number for selection of towing lines. As an alternative method to 3.2.4, the number and strength of mooring lines may be determined by means of direct mooring analysis of Appendix 2 of this Chapter.

3.2.4.2 Mooring lines for ships with $EN \leq 2000$ are to be determined according to Table 3.2.1.1(2). For ships having the ratio $A/N > 0.9$, number of lines given in Table 3.2.1.1(2) is to be added to the number of mooring lines according to the following formulae:

One line where	$0.9 < \frac{A}{N} \leq 1.1$
two lines where	$1.1 < \frac{A}{N} \leq 1.2$
three lines where	$1.2 < \frac{A}{N}$

3.2.4.3 The strength of mooring lines and the number of head, stern, and breast lines (see Figure 3.2.4.2) for ships with an Equipment Number $EN > 2000$ are based on the side-projected area A_1 . Side projected area A_1 is to be calculated similar to the side-projected area A according to 3.2.1.2 but considering the following conditions:

Ballast draft is to be considered for the calculation of the side-projected area A_1 . For ship types with small change of draft, e.g. passenger ships and ro-ro ships, the summer load waterline may be used for the calculation of the side-projected area A_1 .

Wind shielding of the pier can be considered for the calculation of the side-projected area A_1 unless the ship is intended to be regularly moored to jetty type piers. A height of the pier surface of 3 m over waterline may be assumed, i.e. the lower part of the side projected area with a height of 3 m above the waterline for the considered loading condition may be disregarded for the calculation of the side-projected area A_1 .

Deck cargo as given by the nominal capacity condition (as defined in 3.6.2.10 of this Chapter) is to be included for the determination of side-projected area A_1 . The summer load waterline may be used for the calculation of condition with deck cargo. Deck cargo may not need to be considered if a ballast draft condition generates a larger side-projected area A_1 than the full load condition

with cargo on deck. The larger of both side-projected areas is to be chosen as side-projected area A_1 .

(1) The mooring lines as given here under are based on a maximum current speed of 1.0 m/s and the following maximum wind speed, in m/s:

$V_w = 25 - 0.002(A_1 - 2000)$	for passenger ships, ferries, and car carriers with $2000 \text{ m}^2 < A_1 \leq 4000 \text{ m}^2$
$= 21$	for passenger ships, ferries, and car carriers with $A_1 > 4000 \text{ m}^2$
$= 25$	for other ships

The wind speed is considered representative of a 30 second mean speed from any direction and at a height of 10 m above the ground. The current speed is considered representative of the maximum current speed acting on bow or stern ($\pm 10^\circ$) and at a depth of one-half of the mean draft. Furthermore, it is considered that ships are moored to solid piers that provide shielding against cross current. Additional loads caused by, e.g., higher wind or current speeds, cross currents, additional wave loads, or reduced shielding from non-solid piers may need to be particularly considered. Furthermore, it is to be observed that unbeneficial mooring layouts can considerably increase the loads on single mooring lines.

Breast line: A mooring line that is deployed perpendicular to the ship, restraining the ship in the off-berth direction.

Spring line: A mooring line that is deployed almost parallel to the ship, restraining the ship in fore or aft direction.

Head/Stern line: A mooring line that is oriented between longitudinal and transverse direction, restraining the ship in the off-berth and in fore or aft direction. The amount of restraint in fore or aft and off-berth direction depends on the line angle relative to these directions.

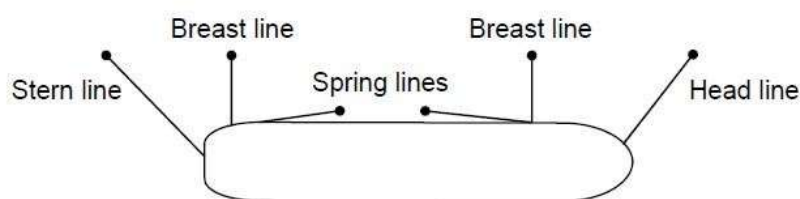


Figure 3.2.4.2 Breast line, spring line, head/stern line

(2) The ship design minimum breaking strength, in kN, of the mooring lines for ships with $EN > 2000$ is not to be less than the value obtained from the following formula and to be limited to 1275 kN:

$$MBL_{SD} = 0.1A_1 + 350 \text{ kN}$$

However, in this case the mooring lines are to be considered as not sufficient for the wind speed given in (1), the acceptable wind speed V_w^* , in m/s, can be estimated as follows:

$$V_w^* = V_w \sqrt{\frac{MBL_{SD}^*}{MBL_{SD}}}$$

where: V_w is the wind speed as per (1);

MBL_{SD} is the ship design breaking strength of the mooring lines intended to be supplied, to be taken less than corresponding to an acceptable wind speed of 21 m/s:

$$MBL_{SD}^* \geq \left(\frac{21}{V_w} \right)^2 \cdot MBL_{SD}$$

MBL_{SD} — the breaking strength as recommended according to the formula in (2).

If lines are intended to be supplied for an acceptable wind speed V_w design minimum breaking strength is to be taken as: higher than V_w as per (1), the ship

$$MBL_{SD}^* = \left(\frac{V_w^*}{V_w} \right)^2 \cdot MBL_{SD}$$

(3) The total number of head, stern and breast lines for ships with $EN > 2000$ is not to be less than:

$$n = 8.3 \cdot 10^{-4} A_1 + 6$$

For oil tankers, chemical tankers, bulk carriers, and ore carriers the total number of head, stern and breast lines is to be taken as:

$$n = 8.3 \cdot 10^{-4} A_1 + 4$$

The total number of head, stern and breast lines is to be rounded to the nearest whole number.

(4) The number of head, stern and breast lines may be increased or decreased in conjunction with an adjustment to the strength of the lines. The adjusted strength, MBL^{**} , is to be taken as:

$$MBL_{SD}^{**} = 1.2 \cdot MBL_{SD} \cdot n / n^{**} \leq MBL_{SD} \quad \text{for increased number of lines,}$$

$$MBL_{SD}^{**} = MBL_{SD} \cdot n / n^{**} \quad \text{for reduced number of lines.}$$

where: MBL_{SD} is MBL_{SD} or MBL'_{SD} specified in (1) and (2) of this paragraph;

n^{**} is the increased or decreased total number of head, stern and breast lines;

n the number of lines for the considered ship type as calculated by the above formulas without rounding.

(5) The total number of spring lines is to be taken not less than:

Two lines where $EN < 5000$,

Four lines where $EN \geq 5000$.

The ship design minimum breaking strength of spring lines is to be the same as that of the head, stern and breast lines. If the number of head, stern and breast lines is increased in conjunction with an adjustment to the ship design minimum breaking strength of the lines, the number of spring lines is to be increased in accordance with the following formula, but rounded up to the nearest even number.

$$n_s^* = MBL_{SD} / MBL_{SD}^{**} \cdot n_s$$

where: MBL_{SD} is MBL_{SD} or MBL'_{SD} specified in (1) and (2) of this paragraph;

n_s is the number of spring lines;

n_s^* is the increased number of spring lines.

3.2.4.4 The length of mooring lines for ships with EN of less than or equal to 2000 may be taken from Table 3.2.1.1(2). For ships with EN > 2000 the length of mooring lines may be taken as 200 m. The lengths of individual mooring lines may be reduced by up to 7% of the above given lengths, but the total length of mooring lines is not to be less than would have resulted had all lines been of equal length.

3.2.4.5 The wire ropes for towlines listed in Table 3.2.1.1(2) of this Section are to be of a flexible, galvanized construction having a breaking strength of not less than 1.37 kN/mm^2 per wire. The construction type of the wire ropes is to be referred to the provisions in Section 4, Chapter 10, PART A of ISC Rules for Materials and Welding.

3.2.4.6 Towlines and mooring lines may be of natural fibre, synthetic fibre material or a mixture of wire and natural fibre. In no case is the circumference of the ropes made of natural fibre or synthetic fibre to be less than 63 mm (20 mm in diameter).

3.2.4.7 All ropes having a breaking strength in excess of 736 kN are to be handled by specially designed winches.

3.2.4.8 In engineering ships, service winches may be used in lieu of windlasses, provided that these winches can efficiently handle chain cables.

3.2.5 Strength requirements for securing of windlasses on fore decks

3.2.5.1 Paragraph 3.2.5 of this Section provides strength requirements for the securing of windlasses located on the exposed deck over the forward $0.25L$ of all ships of 80 m or over in length, where the height of the exposed deck in way of the windlasses is less than $0.1L$ or 22 m above the summer load waterline, whichever is the lesser.

3.2.5.2 Where mooring winches are integral with the anchor windlass, they are to be considered as part of the windlass.

3.2.5.3 The following pressures and associated areas are to be applied (see Figure 3.2.5.3):

- (1) Force $P_x = 200 \text{ kN/m}^2$ normal to the shaft axis and away from the forward perpendicular, over the projected area in this direction.
- (2) Force $P_y = 150 \text{ kN/m}^2$ parallel to the shaft axis and acting both inboard and outboard separately, over the multiple of f times the projected area in this direction, where f is defined as:

$$f = 1 + \frac{B}{H}, \text{ but not greater than } 2.5$$

where: B — width of windlass measured parallel to the shaft axis, in m;

H — overall height of windlass, in m.

3.2.5.4 Forces in the bolts, chocks and stoppers securing the windlass to the deck are to be calculated. The windlass is supported by N bolt groups, each containing one or more bolts, see Figure 3.2.5.3.

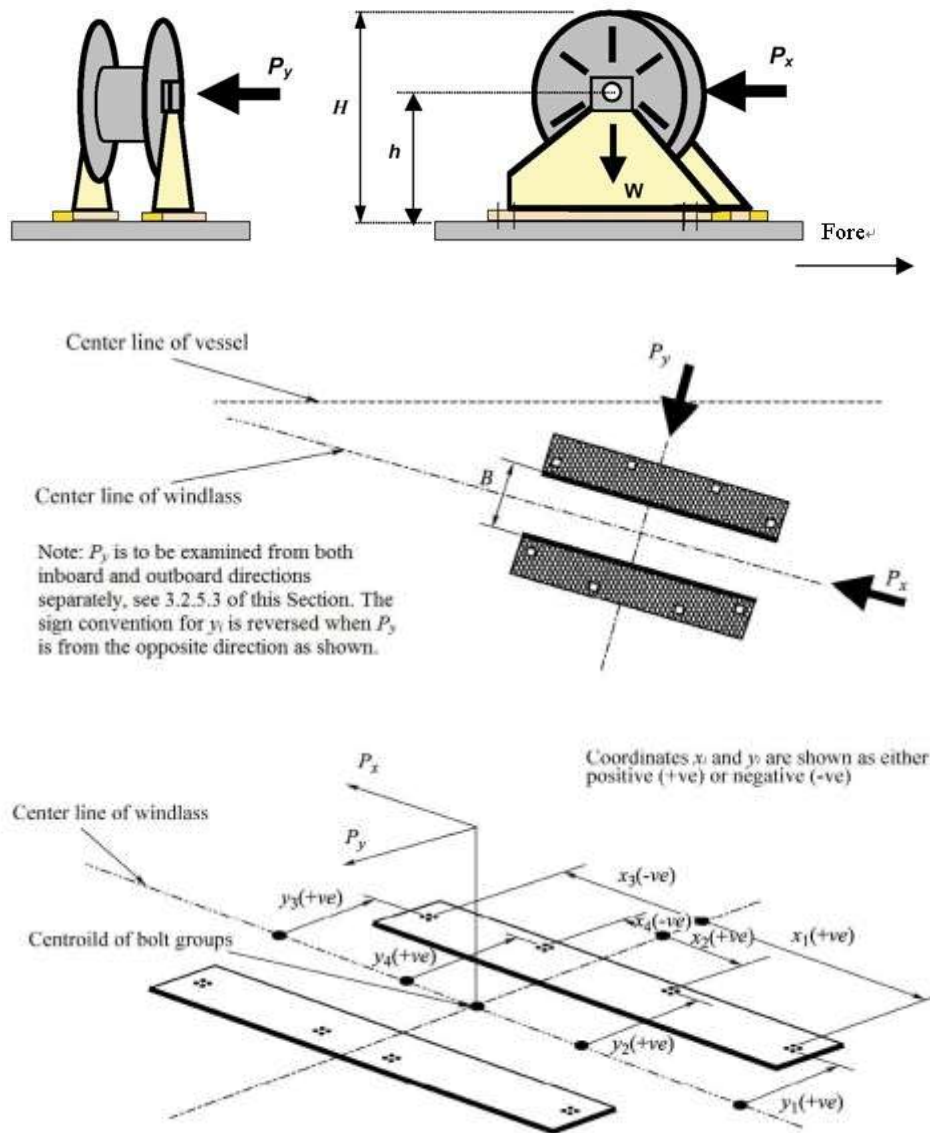


Figure 3.2.5.3

3.2.5.5 The axial force R_i in bolt group (or bolt) i , may be calculated from:

$$R_{xi} = \frac{P_x h x_i A_i}{I_x} \quad \text{kN}$$

$$R_{yi} = \frac{P_y h y_i A_i}{I_y} \quad \text{kN}$$

$$R_i = R_{xi} + R_{yi} - R_{zi} \quad \text{kN}$$

where: P_x — force acting normal to the shaft axis, in kN;
 P_y — force acting parallel to the shaft axis, in kN, either inboard or outboard, whichever gives the greater force in bolt group i ;
 h — shaft height above the windlass mounting, in cm;
 x_i, y_i — x and y coordinates of bolt group i from the centroid of all N bolt groups, positive in the direction opposite to that of the applied force, in cm
 A_i — cross sectional area of all bolts in group i , in cm^2 ;

$I_x = \sum A_i x_i^2$, in cm^4 , sum of moments of inertia for N bolt groups about y -axis;

$I_y = \sum A y_i^2$, in cm^4 , sum of moments of inertia for N bolt groups about x-axis;
 R_{sj} — static reaction at bolt group i , due to weight of windlass, in kN.

3.2.5.6 Shear forces F_{xi} , F_{yi} applied to the bolt group i , and the resultant combined force F_i may be calculated from:

$$\begin{aligned} F_{xi} &= \frac{P_x - \alpha g W}{N} \quad \text{kN} \\ F_{yi} &= \frac{P_y - \alpha g W}{N} \quad \text{kN} \\ F_i &= \sqrt{F_{xi}^2 + F_{yi}^2} \quad \text{kN} \end{aligned}$$

where: α — coefficient of friction, taken as 0.5;
 W — mass of windlass, in t;
 g — gravity acceleration, taken as 9.81 m/s^2 ;
 N — number of bolt groups.

3.2.5.7 Axial tensile and compressive forces in 3.2.5.5 of this Section and lateral forces in 3.2.5.6 of this Section are to be considered in the design of the supporting structure.

3.2.5.8 Tensile axial stresses in the individual bolts in each bolt group are to be calculated. The horizontal forces F_{xi} and F_{yi} are normally to be reacted by shear chocks. Where “fitted” bolts are designed to support these shear forces in one or both directions, the equivalent stresses in the individual bolts are to be calculated, and compared to the stress under proof load. The safety factor against bolt proof strength is not to be less than 2.0. Where pourable resins are incorporated in the holding down arrangements, due account is to be taken in the calculations.

3.2.5.9 Direct calculation is to be performed for the strength of the deck framing supporting the windlass and its securing bolt loads as defined in 3.2.5.3 to 3.2.5.7 of this Section.

SECTION 3 - CEILINGS AND CARGO BATTENS

3.3.1 Ceiling

3.3.1.1 Wood ceiling is to be laid from the floors to the upper part of the bilge in single bottom ships, and over the bilges in ships having double bottoms. The ceiling is to be arranged so as to be readily removable for inspection.

3.3.1.2 Where ceiling is to be laid on the inner bottom under hatchways, battens are to be laid underneath the ceiling, and the thickness of the battens is to be at least 30 mm. Where the double bottom tank is not intended to carry oil fuel, ceiling may be laid directly on the inner bottom plating embedded in a suitable bituminous solution or other effective coverings.

3.3.1.3 Either in single or double bottom ships, the thickness of the ceiling in cargo holds is to be

determined according to the ship's length L as follows:

- for $L \leq 60$ m, not less than 50 mm;
- for $60 \text{ m} < L \leq 90$ m, not less than 55 mm;
- for $L > 90$ m, not less than 60 mm.

3.3.1.4 Bottom ceiling or shaft tunnel ceiling under hatchways may be omitted provided that the thickness of the inner bottom plating or shaft tunnel top plating is increased by 2 mm.

3.3.1.5 If cargo is handled by grabs or similar mechanical appliances, double layers of ceiling are to be fitted on the inner bottom under hatchways (the thickness of each ceiling layer is to be in compliance with 3.3.1.3 of this Section); if the thickness of the inner bottom plating is increased by 5 mm, the wood ceiling may be omitted.

3.3.1.6 If cargo is carried in a hold adjacent to a deep oil tank with heating appliances, the hold side of the bulkhead is to be fitted with wood ceiling or insulation. If wood ceiling is fitted, the thickness is to comply with the requirements of 3.3.1.3 of this Section.

3.3.1.7 The covers or fittings of the manholes in cargo holds are, so far as practicable, not to project above the inner bottom plating or bottom ceiling; but if impracticable, they are to be protected by a steel coaming around each manhole, and such coamings together with wood ceiling or steel covers thereon are to be gradually sloped down to the flush surface of the inner bottom plating or bottom ceiling.

3.3.1.8 The external surface of tank top plating or shaft tunnel top plating covered by wood ceiling is to be coated with bituminous solution or other effective coating. Tank top plating and shaft tunnel top plating not covered by wood ceiling are to be coated with paints.

3.3.2 Cargo battens

3.3.2.1 Wood cargo battens are to be fitted at ship sides in cargo holds intended for the carriage of general cargoes. The clear space between adjacent rows of the cargo battens is not to exceed 300 mm, and the thickness and breadth of the cargo battens are to be determined in relation to the ship's length L as follows:

- for $L \leq 60$ m, breadth not less than 100 mm, and thickness not less than 30 mm;
- for $60 \text{ m} < L \leq 90$ m, breadth not less than 120 mm, and thickness not less than 40 mm;
- for $L > 90$ m, breadth not less than 150 mm, and thickness not less than 50 mm.

Cargo battens may be made of steel.

SECTION 4 - MASTS OR DERRICK POSTS

3.4.1 General requirements

3.4.1.1 Masts or derrick posts intended to support light derricks are to have at least two points of effective support. The superstructure deck with sufficient strength or the top of a substantial house may be used as one of the points of effective support.

3.4.1.2 Masts or derrick posts are to be effectively attached to the deck plating (at the point of support) where they pass through the deck, and the openings in the deck plating are to be effectively strengthened and compensated.

3.4.2 Wall thickness

3.4.2.1 The relative values between the outside diameter D and wall thickness t of the masts or derrick posts are to be in compliance with those given in the following formulae:

$$D \leq \frac{1000t}{25-t} \quad \text{mm for } t \leq 15 \text{ mm}$$

$$D \leq 100t \quad \text{mm for } t > 15 \text{ mm}$$

3.4.2.2 The minimum wall thickness of masts or derrick posts is to be 6 mm; if the masts or derrick posts are used as ventilator pipes, the minimum wall thickness is not to be less than 7 mm.

3.4.3 Local strengthening

3.4.3.1 Masts or derrick posts intended to support light derricks are to be increased in thickness or doubled in plating, as appropriate, in way of the lower end, crosstrees, derrick seatings, and fixed eye plates for topping lifts or stays where concentrated loads may be expected to occur. Where strengthening is made by doubling plates, the depth and breadth of the doubling plates are to be slightly greater than those of the above fittings or the outside diameter of the masts or derrick posts in way, as appropriate.

3.4.3.2 The conditions and the factor of safety for strength calculations of masts or derrick posts are to comply with the requirements of the flag State Administration.

SECTION 5 - EMERGENCY TOWING ARRANGEMENTS

3.5.1 Application

3.5.1.1 This Section applies to liquid cargo carriers of 20,000 tons deadweight and over, including oil tankers, chemical tankers and liquefied gas carriers, for being towed out of dangerous areas in emergency cases with the arrangements needed.

3.5.2 Class notations

3.5.2.1 Liquid cargo carriers fitted with emergency towing arrangements complying with this Section will be assigned the class notation of Emergency Towing Arrangements.

3.5.3 Plans and documents

3.5.3.1 The following plans and documents are to be submitted for approval:

- (1) Details of emergency towing arrangements;
- (2) Details of strongpoints and fairleads of emergency towing arrangements (related calculations are also to be submitted for information);
- (3) Local structures supporting strongpoints and fairleads;
- (4) Operation manual for emergency towing arrangements.

3.5.4 General requirements

3.5.4.1 The emergency towing arrangements are to be so designed that they are capable of easy operation and rapid connection to the towing vessel in the absence of main power of the ship.

3.5.4.2 The emergency towing arrangements are to be subject to approval by ISC and in accordance with the following requirements:

- (1) The aft emergency towing arrangement is to be pre-rigged and capable of being deployed in harbour conditions in not more than 15 min.
- (2) The pick-up gear for the aft towing pennant is to be designed at least for manual operation by one person taking into account the absence of power and the potential for adverse environmental conditions. The pick-up gear is to be protected against the weather and other adverse conditions.
- (3) The forward emergency towing arrangement is to be designed at least with a means of securing a towline to the chafing gear using a suitably positioned pedestal roller to facilitate connection of the towing pennant.
- (4) The forward emergency towing arrangement is to be capable of being deployed in harbour conditions in not more than 1 h.
- (5) Forward emergency towing arrangements that comply with the requirements for aft emergency towing arrangements may be accepted.
- (6) All emergency towing arrangements are to be clearly marked to facilitate safe and effective use even in darkness and poor visibility.

3.5.5 Arrangement and strength

3.5.5.1 typical details of emergency towing arrangements, see Figure 3.5.5.1.

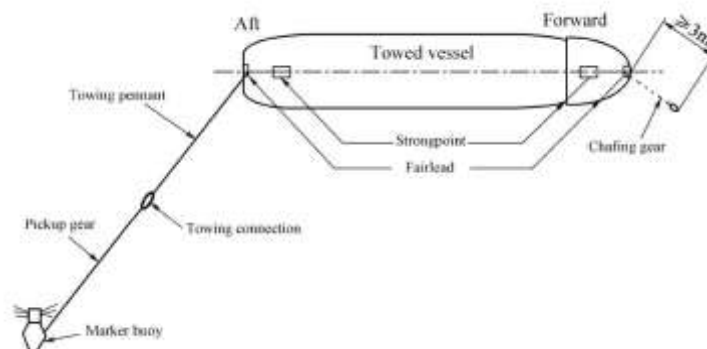


Figure 3.5.5.1 Typical Details of Emergency Towing Arrangements

The bow and stern strongpoint and fairleads are to be located so as to facilitate towing from either side of the bow or stern and minimize the stress on the towing system. Main components of towing arrangements are as shown in Table 3.5.5.1.

Table 3.5.5.1 - Major Components of Towing Arrangements

Major Components	Location		Strength Requirements
	Forward of Ship	Aft of Ship	
Pick-up gear	Optional	Yes	–
Towing pennant	Optional	Yes	Yes
Chafing gear	Yes	Depending on design	Yes
Fairlead	Yes	Yes	Yes
Strongpoint	Yes	Yes	Yes
Roller pedestal	Yes	Depending on design	–

3.5.5.2 The strength of towing arrangements is to be sufficient for all relevant angles of towline during towing operations, i.e. up to 90° from the ship's centreline to port and starboard and 30° vertical downwards. The safety factor of main components of towing arrangements is not to be less than 2. For safe working loads (SWL) of main components of towing arrangements, see Table 3.5.5.2.

Table 3.5.5.2 - Safe Working Load of Components

Deadweight of Ship (t)	Safe Working Load (kN)
20,000 to 50,000	1,000
≥ 50,000	2,000

3.5.6 Requirements for the arrangements and components

3.5.6.1 The towing pennant is to have a hard eye-formed termination allowing connection to a standard bow shackle. The towing pennant is to have a length of at least $2H + 50$ m (H being the lightest seagoing ballast freeboard height at the fairlead, in m).

3.5.6.2 Different solutions on design of chafing gear may be used. If a chafing chain is used, the following requirements are to be complied with:

- (1) the chafing chain is to be stud link chain and is to extend from the strongpoint to a point at least 3 m beyond the fairlead;
- (2) one end of the chafing chain is to be suitable for connection to the strongpoint. The other end is to be fitted with a standard pear-shaped open link allowing connection to the towing pennant via a standard bow shackle. A typical outboard chafing chain end and a pear-shaped open link are shown in Figure 3.5.6.2(2);

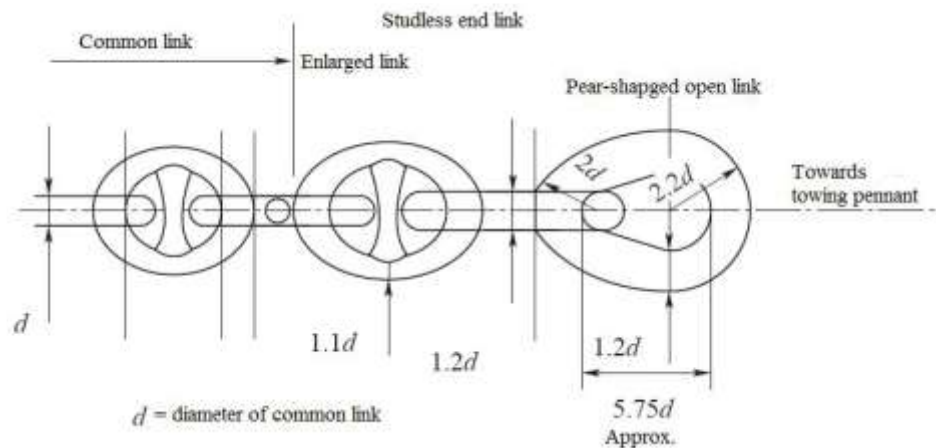


Figure 3.5.6.2(2) Typical Outboard Chafing Chain End

- (3) in addition to this Section, the chafing chain is to be designed, manufactured, tested and certified in accordance with the relevant requirements of Section 2, Chapter 10 of PART ONE of ISC Rules for Materials and Welding;
- (4) chafing chains are to be made of M2 or M3 chain steel by manufacturers approved by ISC;
- (5) the nominal diameter of common links for chafing chains is to comply with the values indicated in Table 3.5.6.2(5) and the nominal diameter of other links are to be determined according to Figure 3.5.6.2(2);
- (6) the chafing chain is to be stowed in such a way that it can be rapidly connected to the strongpoint.

Table 3.5.6.2(5)- Minimum Nominal Diameter of Common Link

Type of Emergency Towing Arrangement (ETA)	Minimum Nominal Diameter of Common Link (d)	
	Grade 2	Grade 3
ETA1000	62 mm	52 mm
ETA2000	90 mm	76 mm

3.5.6.3 The fairleads may be mooring fairleads or fairleads with cable rollers. Fairleads are to have an opening large enough to pass the largest portion of the chafing gear, towing pennant and associated components. The recommended size of such openings is 450 mm × 600 mm. The fairlead is to be located as close as possible to the deck and, in any case, in such a position that the chafing chain is approximately parallel to the deck when it is under strain between the strongpoint and the fairlead. The fairlead is to have an adequate bearing surface, and the bending ratio (towing pennant bearing surface diameter to towing pennant diameter) is not to be less than 7:1.

3.5.6.4 The strongpoint is the inboard end fastening of the towing arrangement and is to be a stopper or bracket or other fitting of equivalent strength. The strongpoint may be designed integral with the fairlead.

SECTION 6 - SHIPBOARD FITTINGS AND SUPPORTING HULL STRUCTURES ASSOCIATED WITH TOWING AND MOORING ON CONVENTIONAL VESSELS

3.6.1 General requirements

3.6.1.1 This Section applies to design and construction of shipboard fittings and supporting structures used for the normal towing and mooring operations.

3.6.1.2 The minimum net scantlings of the supporting hull structure are to comply with the requirements given in 3.6.3.5 and 3.6.4.5 of this Section. The net thicknesses, t_{net} , are the member thicknesses necessary to obtain the above required minimum net scantlings. The required gross thicknesses are obtained by adding the total corrosion additions, t_c , given in 3.6.6 of this Section, to t_{net} .

3.6.1.3 This Section applies to ships the contract of which is placed on or after 1 July 2018.

3.6.1.4 This Section is not applicable to escort towing, canal transit towing and emergency towing for tankers.

3.6.2 Definitions

3.6.2.1 Conventional vessels mean new displacement-type vessels of 500 GT and above, excluding high speed craft, special purpose vessels, and offshore units of all types. Special purpose ship means a mechanically self-propelled ship which by reason of its function carries on board more than 12 special personnel.

3.6.2.2 Shipboard fittings mean those components limited to the following: bollards and bitts, fairleads, stand rollers, chocks used for the normal mooring of the vessel and the similar components used for the normal towing or other towing of the vessel. Other components such as capstans, winches, etc. are not covered by this Section. Any weld or bolt or equivalent device connecting the shipboard fitting to the supporting structure is part of the shipboard fitting and if selected from an industry standard subject to that standard.

3.6.2.3 Supporting hull structures mean that part of the ship structure on/in which the shipboard fitting is placed and which is directly submitted to the forces exerted on the shipboard fitting. The supporting hull structure of capstans, winches, etc. used for the normal towing or other towing and mooring operations mentioned above is also subject to this Section.

3.6.2.4 Industry standard means international standard (ISO, etc.) or standards issued by national association which are recognized in the country where the ship is built.

3.6.2.5 Normal towing means towing operations necessary for manoeuvring in ports and sheltered waters associated with the normal operations of the ship.

3.6.2.6 Other towing means for ships, not subject to Section 5 of this Chapter, but intended to be fitted with equipment for towing by another ship or a tug, e.g. such as to assist the ship in case of emergency.

3.6.2.7 Escort towing means towing service, in particular, for laden oil tankers or LNG carriers, required in specific estuaries. Its main purpose is to control the ship in case of failures of the propulsion or steering system.

3.6.2.8 Canal transit towing means towing service for ships transiting canals.

3.6.2.9 Emergency towing for tankers means towing service to assist tankers in case of emergency, see Section 5 of this Chapter.

3.6.2.10 The nominal capacity condition is defined as the theoretical condition where the maximum possible deck cargoes are included in the ship arrangement in their respective positions. For container ships the nominal capacity condition represents the theoretical condition where the maximum possible number of containers is included in the ship arrangement in their respective positions.

3.6.2.11 Ship Design Minimum Breaking Load (MBLSD) means the minimum breaking load of new, dry mooring lines or tow line for which shipboard fittings and supporting hull structures are designed in order to meet mooring restraint requirements or the towing requirements of other towing service.

3.6.2.12 Line Design Break Force (LDBF) means the minimum force that a new, dry, spliced, mooring line will break at. This is for all synthetic cordage materials.

3.6.3 Towing

3.6.3.1 The strength of shipboard fittings used for normal towing or other towing operations at bow, sides and stern and their supporting hull structures are to comply with the requirements of 3.6.3.2 to 3.6.3.6 of this Section. For fittings intended to be used for, both, towing and mooring, 3.6.4 applies to mooring.

3.6.3.2 Shipboard fittings for towing are to be located on stiffeners and/or girders, which are part of the deck construction so as to facilitate efficient distribution of the towing load. Other arrangements may be accepted (for chocks in bulwarks, etc.) provided the strength is confirmed adequate for the intended service.

3.6.3.3 Load considerations

The minimum design load applied to supporting hull structures for shipboard fittings is to be:

- (1) For normal towing operations, 1.25 times the intended maximum towing load (e.g. static bollard pull) as indicated on the towing and mooring arrangements plan.

- (2) For other towing service, the ship design minimum breaking load of the towline corresponding to equipment no. *N* in Table 3.2.1.1(2) is to be applied.

Note: Side projected area including that of deck cargoes as given by the ship nominal capacity condition is to be taken into account for selection of towing lines and the breaking loads of towing lines are used as the design loads.

- (3) For fittings intended to be used for, both, normal and other towing operations, the greater of the design loads according to (1) and (2).
- (4) When a safe towing load TOW greater than that determined according to 3.6.3.6 is requested by the applicant, then the design load is to be increased in accordance with the appropriate TOW/design load relationship.
- (5) The design load is to be applied to fittings in all directions that may occur by taking into account the arrangement shown on the towing and mooring arrangements plan. Where the towing line takes a turn at a fitting the total design load applied to the fitting is equal to the resultant of the design loads acting on the line, however, the load need not be more than twice the design load.

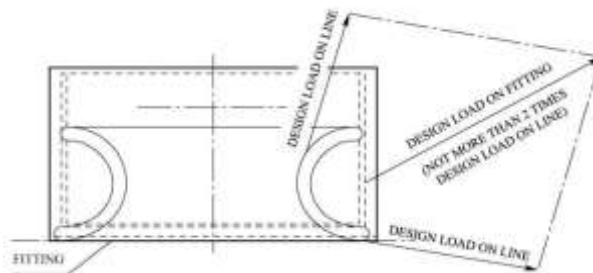


Figure 3.6.3.3(5)

3.6.3.4 Shipboard fittings may be selected from an accepted industry standard and at least based on the following loads.

- (1) For normal towing operations, the intended towing load (e.g. static bollard pull) as indicated on the towing and mooring arrangements plan,
- (2) For other towing service, the ship design minimum breaking load of the tow line according to Table 3.2.1.1(2) (see Notes in 3.6.3.3(2)),
- (3) For fittings intended to be used for, both, normal and other towing operations, the greater of the loads according to (1) and (2).

Towing bitts (double bollards) may be chosen for the towing line attached with eye splice if the industry standard distinguishes between different methods to attach the line, i.e. figure-of-eight or eye splice attachment.

When the shipboard fitting is not selected from an accepted Industry standard, the design load used to assess its strength and its attachment to the ship is to be in accordance with 3.6.3.3 and 3.6.3.5. Towing bitts (double bollards) are required to resist the loads caused by the towing line attached with eye splice.

For strength assessment beam theory or finite element analysis using net scantlings is to be applied, as appropriate. Corrosion additions are to be as defined in 3.6.6. A wear down allowance is to be

included as defined in 3.6.7. At the discretion of the Society, load tests may be accepted as alternative to strength assessment by calculations.

3.6.3.5 Supporting hull structure

(1) Arrangement:

The reinforced members beneath shipboard fittings are to be effectively arranged for any variation of direction (horizontally and vertically) of the towing forces acting upon the shipboard fittings, see Figure 3.6.3.5(1) below for a sample arrangement. Proper alignment of fitting and supporting hull structure is to be ensured.

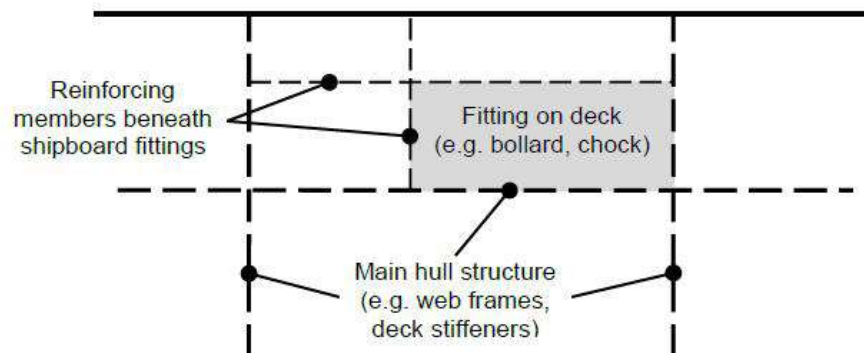


Figure 3.6.3.5(1)

(2) Acting point of towing force:

The acting point of the towing force on shipboard fittings is to be taken at the attachment point of a towing line or at a change in its direction. For bollards and bitts the attachment point of the towing line is to be taken not less than $4/5$ of the tube height above the base, see Figure 3.6.3.5(2).

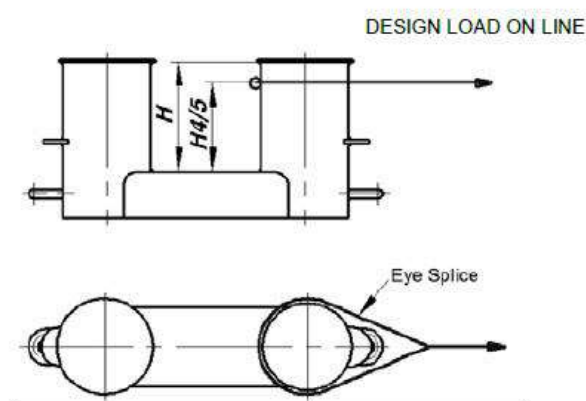


Figure 3.6.3.5(2)

(3) Allowable stresses:

Allowable stresses under the design load conditions as specified in 3.6.3.3 of this Section are as follows:

(1) For strength assessment with beam theory or grillage analysis:

Normal stress: $1.0R_{eH}$; Shearing stress: $0.6R_{eH}$;

Normal stress is the sum of bending stress and axial stress with the corresponding shearing

stress acting perpendicular to the normal stress. No stress concentration factors being taken into account.

- (2) For strength assessment with finite element analysis:

Von Mises stress: $1.0R_{eH}$.

For strength calculations by means of finite elements, the geometry is to be idealized as realistically as possible. The ratio of element length to width is not to exceed 3. Girders are to be modelled using shell or plane stress elements. Symmetric girder flanges may be modelled by beam or truss elements. The element height of girder webs must not exceed one-third of the web height. In way of small openings in girder webs the web thickness is to be reduced to a mean thickness over the web height. Large openings are to be modelled. Stiffeners may be modelled by using shell, plane stress, or beam elements. The mesh size of stiffeners is to be fine enough to obtain proper bending stress. If flat bars are modeled using shell or plane stress elements, dummy rod elements are to be modelled at the free edge of the flat bars and the stresses of the dummy elements are to be evaluated. Stresses are to be read from the centre of the individual element. For shell elements the stresses are to be evaluated at the mid plane of the element. R_{eH} is the specified minimum yield stress of the material.

3.6.3.6 Safe Towing Load (TOW)

- (1) The safe towing load (TOW) is the safe load limit of shipboard fittings used for towing purpose.
 - (2) TOW used for normal towing operations is not to exceed 80% of the design load per 3.6.3.3 (1).
- (2) TOW used for other towing operations is not to exceed 80% of the design load according to 3.6.3.3 (2).
- (4) For fittings used for both normal and other towing operations, the greater of the safe towing loads
 - (3) according to (2) and (3) is to be used.
- (4) TOW, in t, of each shipboard fitting is to be marked (by weld bead or equivalent) on the deck fittings used for towing. For fittings intended to be used for, both, towing and mooring, SWL, in t, according to
 - (5) 3.6.4.6 is to be marked in addition to TOW.
- (6) The above requirements on TOW apply for the use with no more than one line. If not otherwise chosen, for towing bitts (double bollards) TOW is the load limit for a towing line attached with eye-splice.
- (7) The towing and mooring arrangements plan mentioned in 3.6.5 is to define the method of use of towing lines.

3.6.4 Mooring

3.6.4.1 The strength of shipboard fittings used for mooring operations and of their supporting hull structures as well as the strength of supporting hull structures of winches and capstans is to comply with the requirements of 3.6.4.2 to 3.6.4.6 of this Section.

3.6.4.2 Shipboard fittings, winches and capstans for mooring are to be located on stiffeners and/or girders, which are part of the deck construction so as to facilitate efficient distribution of the

mooring load. Other arrangements may be accepted (for chocks in bulwarks, etc.) provided the strength is confirmed adequate for the service. For fittings intended to be used for, both, mooring and towing, 3.6.3 applies to towing.

3.6.4.3 Load considerations

- (1) The minimum design load applied to supporting hull structures for shipboard fittings is to be 1.15 times the ship design minimum breaking strength of the mooring line according to 3.2.4 of this Chapter.

Note: Side projected area including that of deck cargoes as given by the ship nominal capacity condition is to be taken into account for assessment of transverse wind load, tug arrangement and selection of mooring lines.

- (2) The minimum design load applied to supporting hull structures for winches is to be 1.25 times the intended maximum brake holding load, where the maximum brake holding load is to be assumed not less than 80% of the ship design minimum breaking strength of the mooring line according to 3.2.4 of this Chapter. For supporting hull structures of capstans, 1.25 times the maximum hauling-in force is to be taken as design load.
- (3) When a safe working load SWL greater than that determined according to 3.6.4.6 is requested by the applicant, then the design load is to be increased in accordance with the appropriate SWL/design load relationship.
- (4) The design load is to be applied to fittings in all directions that may occur by taking into account the arrangement shown on the towing and mooring arrangements plan. Where the mooring line takes a turn at a fitting the total design load applied to the fitting is equal to the resultant of the design loads acting on the line, refer to Figure 3.6.3.3(5). However, in no case does the design load applied to the fitting need to be greater than twice the design load on the line.

3.6.4.4 Shipboard fittings may be selected from an accepted industry standard and at least based on the ship design minimum breaking strength according to 3.2.4 of this Chapter.

Mooring bitts (double bollards) are to be chosen for the mooring line attached in figure-of-eight fashion if the industry standard distinguishes between different methods to attach the line, i.e. figure-of-eight or eye splice attachment.

When the shipboard fitting is not selected from an accepted Industry standard, the design load used to assess its strength and its attachment to the ship is to be in accordance with 3.6.4.3 and 3.6.4.5 of this Section. Mooring bitts (double bollards) are required to resist the loads caused by the mooring line attached

in figure-of-eight fashion. It is to be observed that in this case either of the two posts of the mooring bitt can be subjected to a force twice as large as that acting on the mooring line. For strength assessment beam theory or finite element analysis using net scantlings is to be applied, as appropriate. Corrosion additions are to be as defined in 3.6.6. A wear down allowance is to be included as defined in 3.6.7. At the discretion of the classification society, load tests may be accepted as alternative to strength assessment by calculations.

3.6.4.5 Supporting hull structure

(1) Arrangement:

Arrangement of the reinforced members beneath shipboard fittings is to consider any variation of direction (horizontally and vertically) of the mooring forces acting upon the shipboard fittings, see Figure 3.6.3.5(1) for a sample arrangement. Proper alignment of fitting and supporting hull structure is to be ensured.

(2) Acting point of mooring force:

The acting point of the mooring force on shipboard fittings is to be taken at the attachment point of a mooring line or at a change in its direction. For bollards and bitts the attachment point of the mooring line is to be taken not less than $4/5$ of the tube height above the base, see a) in Figure 3.6.4.5(2) a). If fins are fitted to the bollard tubes to keep the mooring line as low as possible, the attachment point of the mooring line may be taken at the location of the fins, see Figure 3.6.4.5(2) b).

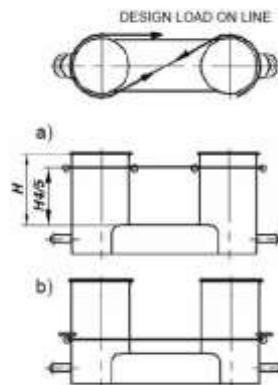


Figure 3.6.4.5(2)

(3) Allowable stresses:

Allowable stresses under the design load conditions as specified in 3.6.4.3 of this Section are as follows:

- 1) For strength assessment with beam theory or grillage analysis: Normal stress: $1.0R_{eH}$;
Shearing stress: $0.6R_{eH}$;

Normal stress is the sum of bending stress and axial stress with the corresponding shearing stress acting perpendicular to the normal stress. No stress concentration factors being taken into account.

- 2) For strength assessment with finite element analysis:
Von Mises stress: $1.0R_{eH}$.

For strength calculations by means of finite elements, the geometry is to be idealized as realistically as possible. The ratio of element length to width is not to exceed 3. Girders are to be modelled using shell or plane stress elements. Symmetric girder flanges may be modelled by beam or truss elements. The element height of girder webs must not exceed one-third of the web height. In way of small openings in girder webs the web thickness is to be reduced to a mean thickness over the web height. Large openings are to be modelled. Stiffeners may be modelled by using shell, plane stress, or beam elements. The mesh size

of stiffeners is to be fine enough to obtain proper bending stress. If flat bars are modeled using shell or plane stress elements, dummy rod elements are to be modelled at the free edge of the flat bars and the stresses of the dummy elements are to be evaluated. Stresses are to be read from the centre of the individual element. For shell elements the stresses are to be evaluated at the mid plane of the element.

3.6.4.6 Safe Working Load (SWL)

- (1) The Safe Working Load (SWL) is the safe load limit of shipboard fittings used for mooring purpose.
- (2) Unless a greater SWL is requested by the applicant according to 3.6.4.3(3), the SWL is not to exceed the ship design minimum breaking strength according to 3.2.4 of this Chapter.
- (3) The SWL, in t, of each shipboard fitting is to be marked (by weld bead or equivalent) on the deck fittings used for mooring. For fittings intended to be used for, both, mooring and towing, TOW, in t, according to 3.6.3.6 is to be marked in addition to SWL.
- (4) The above requirements on SWL apply for the use with no more than one mooring line.
- (5) The towing and mooring arrangements plan mentioned in 3.6.5 is to define the method of use of mooring lines.

3.6.5 Towing and mooring arrangements plan

- (1) The SWL and TOW for the intended use for each shipboard fitting is to be noted in the towing and mooring arrangements plan available on board for the guidance of the Master. It is to be noted that TOW is the load limit for towing purpose and SWL that for mooring purpose. If not otherwise chosen, for towing bitts it is to be noted that TOW is the load limit for a towing line attached with eye-splice.
- (2) Information provided on the plan is to include in respect of each shipboard fitting:
 - 1) location on the ship;
 - 2) fitting type;
 - 3) SWL/TOW;
 - 4) purpose (mooring/harbour towing/other towing); and
 - 5) manner of applying towing or mooring line load including limiting fleet angles i.e. angle of change in direction of a line at the fitting.

The purposes and method for applying loads are to be taken into account in the determination of SWL and TOW of fittings and submitted for approval.

Furthermore, information provided on the plan is to include:

- 1) the arrangement of mooring lines showing number of lines (N);
- 2) the ship design minimum breaking load (MBLSD);
- 3) the acceptable environmental conditions for ship design minimum breaking load for ships with Equipment Number EN > 2000, including 30 second mean wind speed from any direction and maximum current speed acting on bow or stern ($\pm 10^\circ$).
- (3) The information as given in (2) is to be incorporated into the pilot card in order to provide the pilot proper information on harbour/other towing operations.

3.6.6 Corrosion addition

The total corrosion addition, t_c , in mm, is not to be less than the following values:

- (1) For the supporting hull structure, 2 mm;
- (2) For pedestals and foundations on deck which are not part of a fitting according to an accepted industry standard, 2.0 mm.
- (3) For shipboard fittings not selected from an accepted industry standard, 2.0 mm.

3.6.7 Wear allowance

In addition to the corrosion addition given in 3.6.6 the wear allowance, t_w , for shipboard fittings not selected from an accepted industry standard is not to be less than 1.0 mm, added to surfaces which are intended to regularly contact the line.

3.6.8 Survey after construction

The condition of deck fittings, their pedestals or foundations, if any, and the hull structures in the vicinity of the fittings are to be examined in accordance with the Rules.

SECTION 7 - SUPPORT STRUCTURE FOR DECK EQUIPMENT**3.7.1 General requirements**

3.7.1.1 Information pertaining to the support structure of deck equipment and fittings, as listed in 3.7.1.2(1) to (5) of this Section, is to be submitted for approval. Support structure means that part of the ship structure on/in which deck equipment and fittings are placed and which is directly subjected to the forces acting on the deck equipment and fittings.

3.7.1.2 This Section includes scantling requirements for the support structure and foundations of the following pieces of equipment and fittings:

- (1) anchor windlasses;
- (2) anchoring chain stoppers;
- (3) deck cranes, derricks and lifting masts;
- (4) emergency towing arrangements;
- (5) other deck equipment and fittings which are subject to specific approval.

3.7.1.3 Where deck equipment is subject to multiple load cases, such as an operational load and a green seas load, the operational load and green seas load are to be applied independently for the evaluation of strength of foundations and support structure. Loads are to be applied in the direction of the anchor chain.

3.7.2 Supporting structures for anchoring windlass and chain stopper

3.7.2.1 The following plans and information are to be submitted for approval:

- (1) Details of the supporting structure for the anchor windlass;
- (2) Details of the windlass foundation design, including material specifications for holding down

bolts and the connection of the foundation to the deck;

- (3) Details of the chain stopper foundation design, including material specification and the connection of the foundation to the deck.

3.7.2.2 The following plans and information are also to be submitted:

- (1) General arrangement drawing of anchoring equipment;
- (2) Design loads as specified in 3.7.2.3 and 3.7.2.4 of this Section and associated reaction forces applied to the foundation and supporting structure.

3.7.2.3 The following load cases are to be examined for the strength of supporting structures of windlasses and chain stoppers:

- (1) windlass where chain stopper is provided: 45% of breaking load;
- (2) windlass where chain stopper is not provided: 80% of breaking load; (3) chain stopper: 80% of breaking load.

The breaking load is the minimum breaking load of chain as defined according to Table 3.2.1.1(2) of this Chapter. The loads are to be applied in the direction of chain.

3.7.2.4 For windlasses complying with the requirements of 3.2.5.1 of this Chapter, the strength of securing of windlasses on fore deck is also to be checked in accordance with the requirements of 3.2.5 of this Chapter.

3.7.2.5 When checking the strength of supporting structures and foundations, a three-dimensional finite element model is to be applied as far as possible in the analysis to more exactly describe the distribution of structural response in all directions. Where a beam system is or plate girders are used, the model is to be reasonably simplified and be more conservative. The analysis is to be based on the theory of linear elasticity. The thicknesses of structural members in the model are net ones. Corrosion allowance is in accordance with 1.6.5, Section 5, Chapter 1 of this PART.

3.7.2.6 The principles for extent, element types and boundary conditions of a three-dimensional model are as follows:

- (1) Extent and boundary conditions: The structural model is a local three-dimensional one (hereinafter referred to as local model), centred on the centroid of a plane rectangle ($a \times b$) for effects of the foundation and extending outwards for a distance respectively at least one time the length and width corresponding to the rectangle ($3a \times 3b$). This extension reaches vertically from the foundation plane to the first platform (deck) under main deck or at least $D/4$ (D being moulded depth). Where there is no primary support member of the structure at the boundary taken in the above way, the model is to further extend until the boundary is at such support member. Free or fixed support may be taken into account for boundary conditions. Where the boundary conditions or the extent of the model is sensitive to calculation results of the centre area, the extent taken for the local model is to be suitably extended again, provided that calculation results of the centre area will not be affected.

(2) Idealization of local model: The principles for element selection, properties and model meshing etc. are as given in 1.5.6, Section 5, Chapter 1 of this PART.

- (1) 3.7.2.7 For all loading conditions, the stresses taken in calculation for supporting structures and foundations are not to exceed the following permissible values: For strength assessment by means of beam theory or grillage analysis:

Normal stress: $1.0 ReH$

Shear stress: $0.6 ReH$

The normal stress is the sum of bending stress and axial stress. The shear stress to be considered corresponds to the shear stress acting perpendicular to the normal stress. No stress concentration factors are to be taken into account.

- (2) For strength assessment by means of finite element analysis: Von Mises stress: $1.0 ReH$
For strength assessment by means of finite element analysis the mesh is to be fine enough to represent the geometry as realistically as possible. The aspect ratios of elements are not to exceed 3. Girders are to be modelled using shell or plane stress elements. Symmetric girder flanges may be modelled by beam or truss elements. The element height of girder webs must not exceed one-third of the web height. In way of small openings in girder webs, the web thickness is to be reduced to a mean thickness over the web height. Large openings are to be modelled. Stiffeners may be modelled using shell, plane stress, or beam elements. The mesh size of stiffeners is to be fine enough to obtain proper bending stress. If flat bars are modeled using shell or plane stress elements, dummy rod elements are to be modelled at the free edge of the flat bars and the stresses of the dummy elements are to be evaluated. Stresses are to be read from the centre of the individual element. For shell elements the stresses are to be evaluated at the mid plane of the element. ReH is the specified minimum yield stress of the material.

3.7.3 Supporting structure for cranes, derricks and lifting masts

3.7.3.1 The supporting structures of lifting appliances which are identified as basic features of the ship, such as lifting appliances of floating crane and submersible handling system of submersible supply vessel are to comply with the requirements of ISC Rules for Lifting Appliances of Ships and Offshore Installations.

The supporting structures of other lifting appliances, including cranes, derricks and lifting masts with a safe working load greater than 30 kN, or a maximum overturning moment to the supporting structure greater than 100 kN·m, are to comply with the requirements of this Section.

3.7.3.2 These requirements do not cover the following items:

- (1) supports of lifting appliances for personnel or passengers, see 3.7.5.2 of this Section;
- (2) the structure of the lifting appliance pedestals or post above the area of the deck connection;
- (3) holding down bolts and their arrangement, which are considered part of the lifting appliance.

3.7.3.3 The term lifting appliance is defined as a crane, derrick or lifting mast.

3.7.3.4 The safe working load is defined as the maximum load which the lifting appliance is certified to lift at any specified outreach.

3.7.3.5 The self-weight is the calculated gross self-weight of the lifting appliance, including the weight of any lifting gear.

3.7.3.6 The overturning moment is the maximum bending moment, calculated at the connection of the lifting appliance to the ship structure, due to the lifting appliance operating at safe working load, taking into account outreach and self-weight.

3.7.3.7 The following plans and information are to be submitted for approval:

- (1) Details of the supporting structure of the lifting appliance, including its connection of the deck;
- (2) Details of the safe working load, self-weight, vertical reaction forces and the maximum overturning moment in the supporting structure of the lifting appliance;
- (3) For offshore operation, the maximum sea state in which the lifting appliance is to be used.

3.7.3.8 The general arrangement drawing of the crane/derrick/lifting mast is also to be submitted.

3.7.3.9 For lifting appliances which are limited to use in harbour, the load cases to be examined are to include 130% of the safe working load added to the lifting appliances self-weight.

3.7.3.10 For lifting appliances which may be used for offshore (refers to open waters, the sea condition of which will cause significant motion of the ship, and the wind force at sea normally exceeds Beaufort scale 2) operations, the following are to be submitted for approval:

- (1) The maximum sea state in which the lifting appliance is to be used;
- (2) The worst case vertical and horizontal accelerations;
- (3) The worst case wind loadings for the specified design sea state and wind environment.
- (4) The load scenario to be examined is to account for these environmental loads. As a minimum, the 150% of the safe working load added to the lifting appliances self-weight is to be examined.

3.7.3.11 For calculation and analysis requirements and modeling method, refer to 3.7.2.5 and 3.7.2.6 of this Section. The thicknesses of structural members in the model are as built ones.

3.7.3.12 In all conditions, the stresses taken in calculation for the supporting structures and foundations of lifting appliances are not to exceed the permissible values as follows:

- (1) Strength assessment by means of beam theory or grillage analysis:

Direct stress: $0.67ReH$

Shear stress: $0.39ReH$

Direct stress means the sum of bending stress and axial stress, with the corresponding shear stress acting perpendicular to the direct stress. Stress concentration factors are not

considered.

(2) Strength assessment by means of FE analysis method:

Von Mises stress: $0.80ReH$

ReH is specified minimum yield stress of material, in N/mm^2 .

3.7.3.13 In addition to the requirement of 3.7.3.12 of this Section, the capability of the supporting structure to resist buckling failure is to be checked according to the requirements of 1.5.9, Section 5, Chapter 1 of this PART. In buckling strength assessment, the standard thickness deduction of structural members is to be taken as 1.0 mm and the minimum buckling safety factor taken as 1.0.

3.7.4 Supporting structures for components used in emergency towing arrangements

3.7.4.1 Tankers (including oil tankers, chemical tankers and liquefied gas carriers) carrying flammable liquid cargoes in bulk, having a deadweight of not less than 20,000 tonnes are to be fitted with an emergency towing arrangement at both fore and aft ends.

3.7.4.2 The safe working load of emergency towing arrangements is as follows:

- (1) 1,000 kN for vessels having a deadweight greater than or equal to 20,000 tonnes, but less than 50,000 tonnes;
- (2) 2,000 kN for vessels having a deadweight greater than or equal to 50,000 tonnes.

3.7.4.3 The following plans are to be submitted for approval:

Details of the supporting structure for the emergency towing arrangement, including the connection to the deck.

3.7.4.4 The following supporting information is also to be submitted:

Details of the emergency towing arrangement showing sufficient detail to enable the position and direction of load actions to be ascertained.

3.7.4.5 The deck in way of strongpoints and fairleads is to have a minimum gross thickness of 15 mm.

3.7.4.6 The design load for the connection of the strongpoint and fittings to the deck and its supporting structure is to be taken as twice the safe working load. The assessment of the structure is to consider lines of action of the applied design load, taking into account the particular arrangements proposed.

3.7.4.7 For calculation and analysis requirements and modeling method, refer to 3.7.2.5 and 3.7.2.6 of this Section. The thicknesses of structural members in the model are as built ones.

3.7.4.8 For the design load specified in 3.7.4.6 of this Section, the stresses induced in the supporting structure and welds, in way of strongpoints and fairleads, are not to exceed the permissible values

given in 3.7.2.7 of this Section.

3.7.4.9 The capability of the structure to resist buckling failure is also to be assured.

3.7.5 Supporting structures for other deck equipment or fittings which are subject to specific approval

3.7.5.1 The following requirements relate to other items of deck equipment which are not covered by 3.7.2 to 3.7.4 of this Section. The following details are to be submitted for approval. They may be indicated separately or may be included on the main structural drawings:

- (1) Plans showing the supporting structure for deck equipment/fittings;
- (2) Details of the loads imposed on the structure by the deck equipment/fittings.

3.7.5.2 Support for lifting appliances for personnel is to be provided as follows:

- (1) in general, lifesaving appliances (lifeboats, life rafts and rescue boats) are to be stowed on a purpose built cradle, seat or deployment appliance. The design load imposed on the ship structure is to be established by the supplier of the lifesaving appliance (to include 2.2 times of bearing reaction and torque under maximum working load as a minimum). For calculation and analysis requirements and modeling method, refer to 3.7.2.5 and 3.7.2.6 of this Section. The thicknesses of structural members in the model are as built ones. The calculated stresses are not to exceed the permissible values given in Table 3.7.3.12. The supplier of the life-saving appliance is to provide corresponding calculation information;
- (2) the support structure is to be adequate for the design loads. Local stiffening and a local increase in plating thickness is to be provided. Primary supporting members may be required. Additional national and international Regulations are to be applied, where applicable;
- (3) support structure for crew lifts is to be provided in way of the anchor points of lift operating equipment;
- (4) support structure for boarding (accommodation) ladders is to be provided in way of the anchor points of accommodation ladders.

3.7.5.3 Support for mast structures fitted with navigation aids is to be provided as follows:

- (1) adequate primary support members for the mast are to be arranged in the form of bulkheads, deep beams or girders. Such members are to be arranged below or close to the mast structure;
- (2) in order to transmit the loads from the mast structure to the primary supporting members, underdeck stiffening members are to be arranged below the mast structure forming the attachment of the mast to the deck;
- (3) the deck thickness may be required to be increased to provide an adequate thickness for the weld attachments.

3.7.5.4 Supporting structure for breakwaters is to be designed to withstand the same design load as the breakwater itself. It is to be suitable for transmitting the loads from the breakwater into the main supporting members of the ship. Efficient underdeck stiffening is to be provided in way of

the breakwater structure that forms the deck connection.

3.7.5.5 The supporting structure of towing arrangements of tugs are to comply with the requirements of 10.5.3, Section 5 of Chapter 10 of this PART.

SECTION 8 - ENERGY-SAVING APPENDAGES IN FRONT OF PROPELLERS

3.8.1 General

3.8.1.1 The provisions in this Section is optional and apply to energy-saving appendages installed onboard in front of propellers. Ships applying for notation PSD are to comply with the provisions of this Chapter.

3.8.1.2 Appropriate vibration evaluation and control are recommended in the design and installation of energy-saving appendages in front of propellers. In general, the natural frequency of the energy-saving appendage and propeller excitation frequency are at least to guarantee 10% of the frequency reserve.

3.8.2 Plans and documents

3.8.2.1 The following plans and documents are to be submitted for approval. Where they are already included in the plans and documents required to be submitted for the ship, there is no need to submit them repeatedly:

- (1) Structural plan for the energy-saving appendage in front of the propeller.

3.8.2.2 The following plans and documents are to be submitted for information:

- (1) Arrangement for the energy-saving appendage in front of the propeller;
- (2) Profile for energy-saving appendages in front of the propeller (where applicable);
- (3) Structural strength calculation report (including loads for calculation) for the energy-saving appendage in front of the propeller;
- (4) Vibration frequency calculation report for the energy-saving appendage in front of the propeller.

3.8.3 Structural strength assessment

3.8.3.1 Structural strength calculation analysis is to be carried out for the energy-saving appendage in front of the propeller. Structural strength analysis for various conditions is to be carried out considering possible loads on the energy-saving appendage in front of the propeller in actual operation.

3.8.3.2 Explanatory notes to the calculation model:

- (1) Local three-dimensional structure model is generally used in modeling and analysis of the energy-saving appendage structure to reasonably simulate their shapes;
- (2) The general principles for element selection, characteristics and meshing of the energy-saving

appendage structure model are to be in accordance with the requirements of 1.5.6, Section 5, Chapter 1, PART TWO of the Rules. In order to better simulate its shape, the calculation model is to adopt appropriate element mesh size, which is recommended not to exceed 200 mm×200 mm.

3.8.3.3 The extent and boundary conditions of the model are as follows:

- (1) For the calculation model, the longitudinal extent is generally to include the entire energy-saving appendage in front of the propeller and extends to the aft end wall of the hull engine room; the vertical extent is from the baseline up to the first platform structure near the standard height above the propeller centerline, where the standard height is 1.5 times the distance between the propeller centerline and the highest point of the energy-saving appendage in front of the propeller;
- (2) The assumption of boundary conditions is to be based on the principle of not affecting the calculation results of the energy-saving appendage in front of the propeller and its reinforcement structure. Generally free support or fixed support is provided.

3.8.3.4 The loads on the energy-saving appendage in front of the propeller may be obtained from hydrodynamic calculation or model test or obtained as follows; the following loads are to be included as a minimum:

- (1) the hydrodynamic wave pressure, calculated according to 1.5.3.3(4), Section 5, Chapter 1, PART TWO of the Rules;
- (2) Inertia force of ship motion, calculated according to 1.5.2.2, Section 5, Chapter 1, PART TWO of the Rules;
- (3) Lateral rotating force, calculated according to 3.1.2.1(1), Section 1, Chapter 3, PART TWO of the Rules.

3.8.3.5 The calculation conditions are to include the most unfavorable stress condition of the energy-saving appendage structure in front of the propeller, or they can be selected according to experience and actual operation situation, and are to include the following conditions as a minimum:

- (1) navigation condition: inertia force of ship motion + hydrostatic pressure + hydrodynamic wave pressure (the wave direction is same as the navigation direction);
- (2) rotating condition: inertia force of ship motion + hydrostatic pressure + lateral rotating force.

3.8.3.6 See Table 3.8.3.6 for permissible stress.

Table 3.8.3.6 - Permissible stress

Type of element	Permissible stress
Plate element	$[\sigma_e]=0.5ReH$

Note: ReH —yield stress of material, in N/mm².

3.8.4 Welding

3.8.4.1 The steels used in weldment of the energy-saving appendage in front of the propeller are to comply with the relevant provisions in Chapters 3, 5 and 6, PART ONE of ISC Rules for Materials and Welding for hull structural steels, steel forgings, steel castings respectively. Alternative

materials may be adopted subject to ISC agreement.

3.8.4.2 Welding is to be performed by welders approved by ISC using welding consumables approved by ISC according to welding procedures approved by ISC. For relevant requirements, see Chapters 2, 3, 4 and 5, PART C of ISC Rules for Materials and Welding.

3.8.4.3 The fillet welds inside the energy-saving appendage in front of the propeller are generally to be continuous at both sides and the welding coefficient is to be taken as 0.2. When the surface shell cannot be connected to the internal web by fillet welds directly, a flat bar may be lined between the surface shell and the web. The surface shell and the flat bar can be connected by plug welding and the welding coefficient is to be taken as 0.44, or a groove can be opened on the surface shell, and the flat bar can be butt welded as a liner. Alternatively, other ISC approved welding connection methods may be adopted.

3.8.4.4 As shown in Figure 3.8.4.4, the fillet welds of the connection between the energy-saving appendage in front of the propeller (including the external supporting structure) and the hull as well as the fillet welds of the connection between the guide wheel and guide vane are to be full penetration fillet welds. Where welding at both sides is not possible, single-sided groove can be opened and welded with steel liner inside.

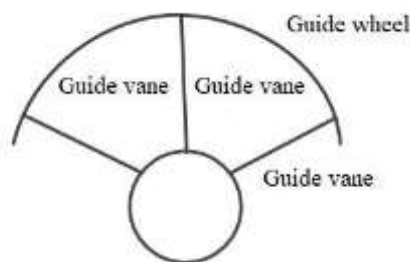


Figure 3.8.4.4 Energy-saving Appendage in Front of the Propeller

3.8.4.5 The joint weld of the energy-saving appendage in front of the propeller and the hull is to be ground smooth and the toes are to have a smooth transition.

3.8.4.6 100% external and at least 80% internal NDT is to be performed in the joint weld of surface shell of the energy-saving appendage in front of the propeller (including the external supporting structure) and the hull.

APPENDIX 1

GUIDELINES FOR CALCULATION OF BENDING MOMENT AND SHEAR FORCE DISTRIBUTION

1 General

1.1 Application

1.1.1 The evaluation of bending moments, shear forces and support forces for the system rudder–rudder stock may be carried out for some basic rudder types as outlined in 2.1 to 2.5 of this Appendix.

2 The Forces on Rudder–Rudder Stock

2.1 Spade rudder

Data for the analysis

l_{10} – l_{30} = lengths of the individual girders of the system, in m;

I_{10} – I_{30} = moments of inertia of these girders, in cm^4 .

Load of rudder body P_R :

$$P_R = C_R / (l_{10} 10^3) \quad \text{kN/m}$$

Moments and forces

The moments and forces may be determined by the following formulae:

$$M_b = C_R (l_{20} + (l_{10} (2c_1 + c_2) / 3(c_1 + c_2))) \quad \text{N}\cdot\text{m}$$

$$B_3 = \frac{M_b}{l_{30}} \quad \text{N}$$

$$B_2 = C_R + B_3 \quad \text{N}$$

where: C_R — rudder force, in N.

The maximum moment, M_C , in top of the cone coupling as shown in Figure 2.1 is applicable for the connection between the rudder and the rudder stock.

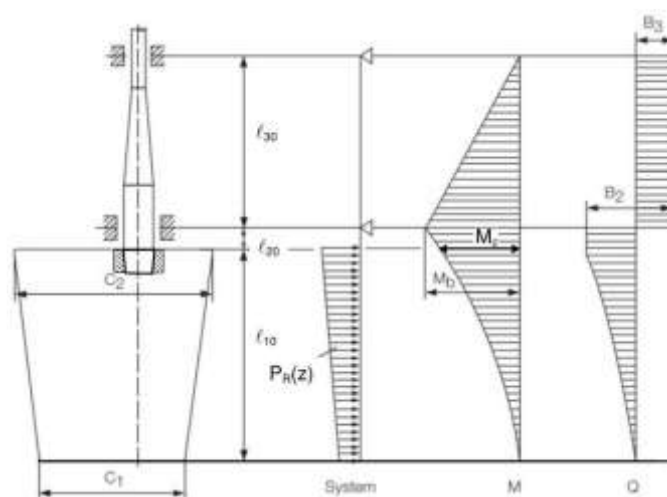


Figure 2.1 Spade rudder

2.2 Spade rudder with trunk

Data for the analysis

$l_{10} - l_{30}$ = lengths of the individual girders of the system, in m;

$I_{10} - I_{30}$ = moments of inertia of these girders, in cm^4 .

Load of rudder body P_R :

$$P_R = C_R / ((l_{10} + l_{20})10^3) \quad \text{kN/m}$$

Moments and forces

For a spade rudder with trunk extending inside the rudder, the strength is to be checked against the following two cases, and the moments and forces for the two cases defined above may be determined according to Figure 2.2(1) and 2.2(2), respectively.

(1) pressure applied on the entire rudder area;

Full rudder force $C_R = C_{R1} + C_{R2}$

total rudder torque $Q_R = Q_{R1} + Q_{R2}$

rudders stock bending moment $M_b = M_{CR2} - M_{CR1}$

(2) pressure applied only on rudder area below the middle of neck bearing. Rudder force C_{R2} corresponding to rudder torque Q_{R2} acting at rudder blade area A_2 with rudderstock bending moment, $M_b = M_{CR2}$

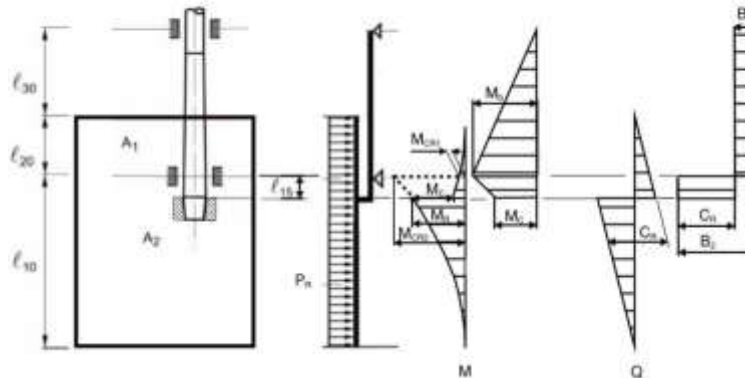


Figure 2.2(1)

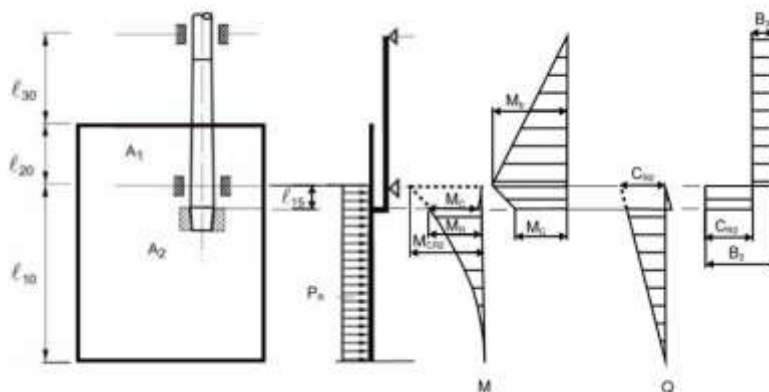


Figure 2.2(2)

$$M_{CR1} = C_{R1} (CG_{1Z} - l_{10}) \quad \text{Nm}$$

$$M_{CR2} = C_{R2} (l_{10} - CG_{2Z}) \quad \text{Nm}$$

where:

C_{R1} : rudder force over the rudder blade area A_1 ;

C_{R2} : rudder force over the rudder blade area A_2 ;

CG_{1Z} : vertical position of the centre of gravity of the rudder blade area A_1 ;

CG_{2Z} : vertical position of the centre of gravity of the rudder blade area A_2 ;

$$C_R = C_{R1} + C_{R2} \quad \text{N}$$

$$B_3 = (M_{CR2} - M_{CR1}) / (l_{20} + l_{30}) \quad \text{N}$$

$$B_2 = C_R + B_3 \quad \text{N}$$

2.3 Rudder supported by sole piece

Data for the analysis

l_{10} – l_{50} = lengths of the individual girders of the system, in m;

I_{10} – I_{50} = moments of inertia of these girders, in cm^4 .

For rudders supported by a sole piece the length l_{20} is the distance between lower edge of rudder body and centre of sole piece and I_{20} the moment of inertia of the pintle in the sole piece.

I_{50} = moment of inertia of sole piece around the z-axis, in cm^4 ;

l_{50} = effective length of sole piece, in m;

Load of rudder body P_R :

$$P_R = C_R / (l_{10} 10^3) \quad \text{kN/m}$$

Z — spring constant of support in the sole piece;

$$Z = 6.18 \times I_{50} / l_{50}^3 \quad \text{kN/m}$$

where: C_R — rudder force, in N.

Moments and forces

Moments and shear forces are indicated in Figure 2.3.

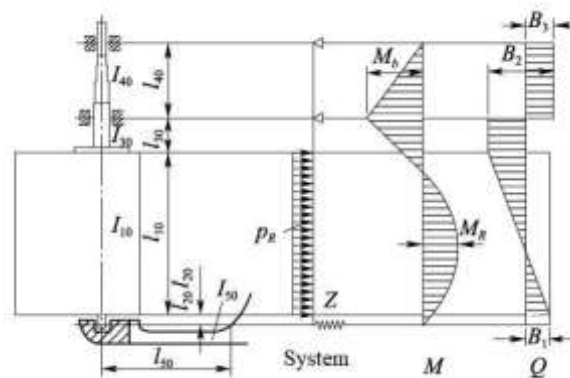


Figure 2.3 Rudder supported by sole piece

2.4 Semi spade rudder with one elastic support

Data for the analysis

l_{10} – l_{40} = lengths of the individual girders of the system, in m;

I_{10} – I_{40} = moments of inertia of these girders, in cm^4 .

Z — spring constant of support in the rudder horn:

$Z = 1/(f_b + f_t)$ kN/m, for the support in the rudder horn (see Figure 2.4.1);

f_b — unit displacement of rudder horn, in m, due to a unit force of 1 kN acting in the centre of support:

$$f_b = \frac{1.3h^3}{6.18I_x} \text{ m/kN (guidance value);}$$

I_n — moment of inertia of horizontal section of rudder horn around the x-axis, in cm^4 (see also Figure 2.4.1);

f_t — unit displacement due to torsion, in m/kN;

FT — mean of areas enclosed by outer and inner boundaries of the thin walled section of rudder horn (excluding the area of the inner hollow area), in m^2 ;

u_i — breadth in [mm] of the individual plates forming the FT area;

t_i — thickness within the individual breadth u_i , in mm;

h — Height of the rudder horn, in m, defined in Figure 2.4.1. This value is measured downwards from the upper rudder horn end, at the point of curvature transition, to the mid-line of the lower rudder horn pintle;

e — distance as defined in Figure 2.4.2, in m, measured to $h/2$ of the height of the rudder horn;

Load of rudder body:

$$p_{R10} = \frac{C_{R2}}{l_{10} \times 10^3} \text{ kN/m}$$

$$p_{R20} = \frac{C_{R1}}{l_{20} \times 10^3} \text{ kN/m}$$

where: C_R , C_{R1} , C_{R2} , see 2.2 of this Appendix.

Moments and forces

Moments and shear forces are indicated in Figure 2.4.1.

Rudder horn

The loads on the rudder horn are as follows:

M_b — bending moment = $B_1 z$, in $\text{N}\cdot\text{m}$;

$M_{b\max} = B_1 h$, in $\text{N}\cdot\text{m}$;

Q — shear force = B_1 , in N;

$MT(z)$ — torsional moment = $B_1 e(z)$, in $\text{N}\cdot\text{m}$.

An estimate for B_1 is:

$B_1 = C_R b / (l_{20} + l_{30})$, in N.

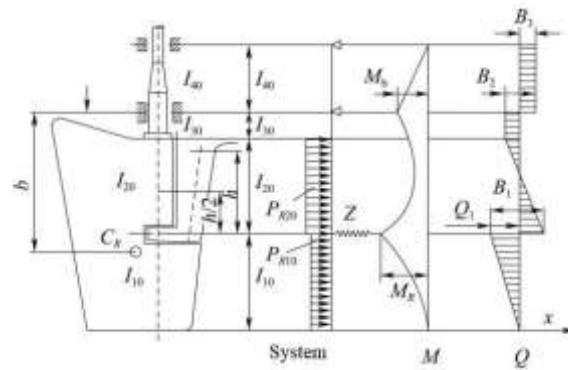


Figure 2.4.1 Semi spade rudder with one elastic support

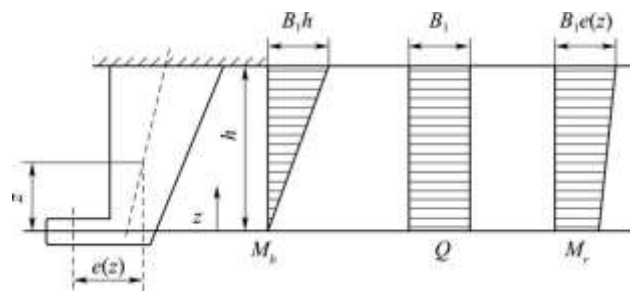


Figure 2.4.2 Rudder horn of semi spade rudder with one elastic support

2.5 Semi spade rudder with 2-conjugate elastic support

Data for the analysis

K_{11} , K_{12} , K_{22} : Rudder horn compliance constants calculated for rudder horn with 2-conjugate elastic supports (Figure 2.5.1). The 2-conjugate elastic supports are defined in terms of horizontal displacements, y_i ,

by the following equations:

at the lower rudder horn bearing:

$$y_1 = -K_{12} B_2 - K_{22} B_1$$

at the upper rudder horn bearing:

$$y_2 = -K_{11} B_2 - K_{12} B_1$$

where:

y_1 , y_2 — horizontal displacements, in m, at the lower and upper rudder horn bearings, respectively;

B_1 , B_2 — horizontal support forces, in kN, at the lower and upper rudder horn bearings, respectively;

K_{11} , K_{12} , K_{22} — obtained, in m/kN, from the following formulae:

$$K_{11} = 1.3 \times \frac{\lambda^3}{3EJ_{1h}} + \frac{e^2 \lambda}{GJ_{th}}$$

$$K_{12} = 1.3 \times \left[\frac{\lambda^3}{3EJ_{1h}} + \frac{\lambda^2 (h - \lambda)}{2EJ_{1h}} \right] + \frac{e^2 \lambda}{GJ_{th}}$$

$$K_{22} = 1.3 \times \left[\frac{\lambda^3}{3EJ_{1h}} + \frac{\lambda^2 (d - \lambda)}{EJ_{1h}} + \frac{\lambda (h - \lambda)^2}{EJ_{1h}} + \frac{(h - \lambda)^3}{3EJ_{2h}} \right] + \frac{e^2 \lambda}{GJ_{th}}$$

where: h — height of the rudder horn, in m, defined in Figure 2.5.1. This value is measured downwards from the upper rudder horn end, at the point of curvature transition, to the mid-line of the lower rudder horn pintle;

λ — length, in m, as defined in Figure 2.5.2. This length is measured downwards from the upper rudder horn end, at the point of curvature transition, to the mid-line of the upper rudder horn bearing. For $\lambda = 0$, the above formulae converge to those of spring constant Z for a rudder horn with 1-elastic support, and assuming a hollow cross section for this part;

e — rudder-horn torsion lever, in m, as defined in Figure 2.5.1 (value taken at $z = h/2$);

J_{1h} — moment of inertia of rudder horn about the x-axis, in m^4 , for the region above the upper rudder horn bearing. Note that J_{1h} is an average value over the length λ (see Figure 2.5.1);

J_{2h} — moment of inertia of rudder horn about the x-axis, in m^4 , for the region between the upper and lower rudder horn bearings. Note that J_{2h} is an average value over the length $h - \lambda$ (see Figure 2.5.1);

J_{th} — torsional stiffness factor of the rudder horn, in m^4 . For any thin wall closed section:

FT — mean of areas enclosed by outer and inner boundaries of the thin walled section of rudder horn (excluding the area of the inner hollow area), in m^2 ;

μ_i — length, in mm, of the individual plates forming the FT area;

t_i — thickness, in mm, of the individual plates mentioned above.

Note that the J_{th} value is taken as an average value, valid over the rudder horn height. Load of rudder body:

$$p_{R10} = \frac{C_{R2}}{l_{10} \times 10^3} \quad \text{kN/m}$$

$$p_{R20} = \frac{C_{R1}}{l_{20} \times 10^3} \quad \text{kN/m}$$

where: CR , $CR1$, $CR2$, see 2.2 of this Appendix.

Moments and forces

Moments and shear forces are indicated in Figure 2.5.1.

Rudder horn bending moment

The bending moment acting on the generic section of the rudder horn is to be obtained, in N·m, from the following formulae:

between the lower and upper supports provided by the rudder horn:

$$M_H = F_{A1} z \quad \text{N·m}$$

above the rudder horn upper-support:

$$M_H = F_{A1} z + F_{A2} (z - d_{lu}) \quad \text{N·m}$$

where: F_{A1} — support force at the rudder horn lower-support, in N, to be obtained

according to Figure 2.5.1, and taken equal to B_1 ;

FA_2 — support force at the rudder horn upper-support, in N, to be obtained according to Figure 2.5.1, and taken equal to B_2 ;

z — distance, in m, defined in Figure 2.5.2, to be taken less than the distance h , in m, defined in the same figure;

d_{lu} — distance, in m, between the rudder-horn lower and upper bearings (according to Figure 2.5.1, $d_{lu} = h - \lambda$).

Rudder horn shear force

The shear force QH acting on the generic section of the rudder horn is to be obtained, in N, from the following formulae:

between the lower and upper rudder horn bearings:

$$Q_H = F_{A1} \text{ N}$$

above the rudder horn upper-bearing:

$$Q_H = F_{A1} + F_{A2} \text{ N}$$

where: FA_1, FA_2 — support forces, in N.

The torque acting on the generic section of the rudder horn is to be obtained, in N·m, from the following formulae:

between the lower and upper rudder horn bearings:

$$M_T = F_{A1}e(z) \text{ N·m}$$

above the rudder horn upper-bearing:

$$M_T = F_{A1}e(z) + F_{A2}e(z) \text{ N·m}$$

where: FA_1, FA_2 — support forces, in N;

$e(z)$ — torsion lever, in m, defined in Figure 2.5.2.

Rudder horn shear stress calculation

For a generic section of the rudder horn, located between its lower and upper bearings, the following stresses are to be calculated:

τ_S — shear stress, in N/mm², to be obtained from the following formula:

$$\tau_s = \frac{F_{A1}}{A_H} \text{ N/mm}^2$$

τ_T — torsional stress, in N/mm², to be obtained for hollow rudder horn from the following formula:

$$\tau_T = \frac{M_T \cdot 10^{-3}}{2F_T t_H} \text{ N/mm}^2$$

For solid rudder horn, τ_T is to be calculated based on the specific geometrical shape.

For a generic section of the rudder horn, located in the region above its upper bearing, the following stresses are to be calculated:

τ_S — shear stress, in N/mm², to be obtained from the following formula:

$$\tau_s = \frac{F_{A1} + F_{A2}}{A_H} \text{ N/mm}^2$$

τ_T — torsional stress, in N/mm², to be obtained for hollow rudder horn from the following formula:

$$\tau_T = \frac{M_T 10^{-3}}{2F_T t_H} \quad \text{N/mm}^2$$

For solid rudder horn, τ_T is to be calculated based on the specific geometrical shape. where:

$FA1, FA2$ — support forces, in N;

AH — effective shear sectional area of the rudder horn, in mm^2 , in y -direction;

MT — torque, in $\text{N}\cdot\text{m}$;

FT — mean of areas enclosed by outer and inner boundaries of the thin walled section of rudder horn (excluding the area of the inner hollow area), in m^2 ;

tH — Plate thickness of rudder horn, in mm. For a given cross section of the rudder horn, the maximum value of τ_T is obtained at the minimum value of tH .

Rudder horn bending stress calculation

For the generic section of the rudder horn within the length h , the following stresses are to be calculated:

σ_B — bending stress, in N/mm^2 , to be obtained from the following formula:

$$\sigma_B = \frac{M_H}{W_X} \quad \text{N/mm}^2$$

where: MH — bending moment at the section considered, in $\text{N}\cdot\text{m}$;

W_X — section modulus, in cm^3 , around the x -axis (see Figure 2.5.2).

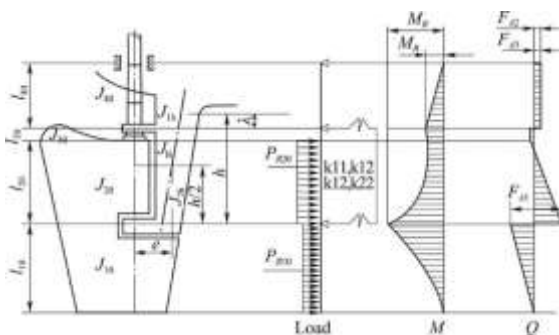


Figure 2.5.1

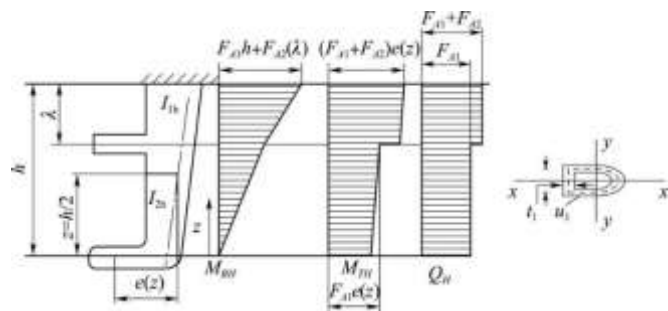


Figure 2.5.2

APPENDIX 2

DIRECT MOORING ANALYSES

1 General

1.1 As an alternative to the requirements for mooring lines in 3.2.4 of this Chapter, direct mooring analysis may be performed to determine the necessary mooring restraint, i.e. number and strength of mooring lines. Direct analyses allow to optimize mooring equipment and arrangement for the individual ship and the port mooring facilities typical for the considered ship type and size.

2 Documentation

2.1 The calculations should be documented in a report. The report should include all assumptions made in calculations for the finally chosen mooring equipment, including lines, and its arrangement, reflected in the mooring arrangement plan.

3 Analysis methodology

3.1 Three dimensional quasi-static calculations should be performed to determine the acting mooring line forces. As a minimum, loads from wind and current should be accounted for in the analysis. Geometrical and material nonlinearities of mooring lines and fenders or breasting dolphins should be considered. An iterative calculation procedure should be applied to arrive at a converged solution with forces acting on mooring lines and on fenders or breasting dolphins being in equilibrium with forces and moments applied to the ship.

4 Environmental conditions

4.1 Mooring line forces should be calculated for environmental conditions given in 3.2.4.3 of this Chapter. Additional loads, e.g. wave loads or cross currents, or increased wind and current loads may be considered for certain ship types or for specific ports intended to be regularly called.

5 Steps to be taken in a direct mooring analysis

Direct assessment of mooring forces and determination of the necessary number and strength of mooring lines comprise the following steps:

- (1) Determine port mooring facilities representative for the considered ship type and size
- (2) Determine shipboard mooring equipment and arrangement
- (3) Determine mooring line type(s) to be used
- (4) Determine mooring layout(s) to be assessed
- (5) Determine ship loading condition(s) to be assessed
- (6) Select or determine wind and current drag coefficients
- (7) Determine wind and current forces and moments
- (8) Compute forces acting on all mooring line
- (9) Determine necessary strength of mooring lines
- (10) If strength of mooring lines should be altered, modify steps (2), (3) and/or (4) with or without changing the number of mooring lines and repeat steps (8) and (9)

5.1 Port mooring facilities

5.1.1 Characteristics of port mooring facilities have strong influence on the resulting mooring line forces. Mooring analysis should be performed for port mooring facilities representative for the considered ship type and size, i.e. type of berth, type and arrangement of hooks/bollards, type and arrangement of fenders or breasting dolphins and height of pier above waterline.

5.1.2 Fenders or breasting dolphins in many cases may not affect the critical mooring line loads. Hence, initially, generic fender or dolphin arrangements and infinitely stiff load deformation characteristics may be considered. If no fender or dolphin loads occur for load cases yielding the critical mooring line loads, more specific fender or dolphin arrangements and characteristics may be omitted.

5.1.3 If there are substantially different port mooring facilities typically encountered by the considered ship type, additional calculations should be performed to consider these variations.

5.2 Shipboard mooring equipment and arrangement

5.2.1 The mooring equipment and arrangement need to be chosen for the mooring analysis, i.e. location of mooring decks and location of mooring winches and fairleads. As a starting point, mooring equipment for the number of lines as determined by 3.2.4 of this Chapter may be chosen.

5.3 Mooring lines

5.3.1 The mooring analysis should apply the mooring line type(s) intended to be supplied with the vessel. The geometrical and material nonlinearities of the mooring lines should be considered by the mooring analysis. Load-deflection characteristics of mooring lines can be taken from data sheets of rope manufacturers. If given, characteristics of the broken-in ropes should be applied.

5.3.2 To achieve a good distribution of mooring line forces, mooring line type and characteristics should be at least same for lines in the same service, e.g. for head and stern lines, breast lines and spring lines. For very stiff mooring lines, e.g. made of steel or high modulus synthetic fibers, the use of elastic tails should be considered to enhance the elasticity in the mooring system and taken into account for the mooring analysis.

5.4 Mooring layout

5.4.1 For the assessment of forces acting on mooring lines, a realistic mooring layout needs to be assumed, i.e. for each mooring line it needs to be determined from which bollard or winch, along which path, through which fairlead it is led and to which shoreside hook or bollard it is connected. Inboard parts of the mooring lines (between fairlead and shipboard fixation point) contribute to the elongation behavior of the line and should be included in the analysis.

5.4.2 The maximum number of lines connected to one shore mooring point needs to be limited to not load the shore side mooring points unrealistically high. For multipurpose piers the number of lines per shore bollard should be limited to three. For other types of berths, the number mooring

lines per shore mooring point is also limited, e.g., by the available number of hooks. Reasonable assumptions should be made based on typical berth types encountered by the considered ship type.

5.4.3 Alternative mooring layouts should also be assessed, considering possible and reasonable options to moor the ship to the assumed port mooring facilities. Also, a different position of the ship relative to the shoreside mooring bollards/hooks should be assessed to find the critical mooring line loads for the normal operation of the ship. Exemptions may be given to e.g. tankers, LNG carriers or ferries if typically moored in the same position relative to the shoreside mooring facilities.

5.5 Loading conditions

5.5.1 Mooring line forces should be calculated for loading conditions given in 3.2.4.3 of this Chapter.

5.6 Wind and current drag coefficients

5.6.1 To calculate the wind and current forces and moments acting on the ship, wind and current drag coefficients are needed for the considered ship type, size and loading condition. Drag coefficients should be as specific as possible for the considered ship and loading conditions.

5.6.2 There are different sources for drag coefficients. Some Industry Guidelines provide drag coefficients for tankers and LNG carriers which can be applied. Due to the similarity of hull forms and superstructures, these coefficients may also be used for bulk carriers and ore carriers. For other ship types drag coefficients may be taken from the literature, if available, or can be determined by CFD calculations or model tests. CFD calculations are to be justified with suitable validation and sensitivity studies.

5.6.3 There are some effects that can influence the drag coefficients, i.e. blockage (limited under keel clearance, solid quay walls), ship draft and wind shielding by solid quays and buildings or cargo stored on quays (e.g. container stacks). Effects from blockage and ship draft can only be accounted for by appropriate coefficients. Drag coefficient should be chosen or determined for realistic water depth to draft ratios and for the considered ship draft(s). Some Industry Guidelines provide current drag coefficients for ballast and loaded draft conditions and for different water depth to draft ratios. Wind shielding effects are typically not considered by the wind drag coefficients. The effect of wind shielding of solid quays may be considered by an equivalent reduction of the lateral wind area of the ship. Shielding by buildings or cargo stored on quays should not be considered as their presence is imponderable.

5.7 Calculation of wind and current forces and moments

5.7.1 Wind and current forces and moments can be calculated for the given environmental conditions with the geometrical particulars of the considered ship and the selected drag coefficients. Usually, the forces in longitudinal and transversal directions as well as the moment about the vertical ship axis (yaw) are calculated.

5.7.2 Wind forces and moments should be calculated for all directions in intervals of preferably 15°, but not more than 30°. Current forces and moments should be calculated for selected directions as per 3.2.4.3 of this Chapter. For ships regularly moored to non-solid piers or jetties, cross current may need to be considered in addition.

5.8 Calculation of mooring line forces

5.8.1 For all considered scenarios and all combinations of applied environmental conditions, the maximum mooring line force should be determined for groups of lines in the same service.

5.8.2 In case of all lines are intended to be attached to winches, brake rendering can be considered to better distribute line loads among all lines in a group of lines in the same service. Then, the average mooring line force of a group of lines may be determined and taken as mooring line force used to determine the necessary strength of the mooring lines according to section 5.9.

5.9 Strength of mooring lines

5.9.1 The necessary strength of mooring lines, i.e., the Ship Design Minimum Breaking Load (MBLSD), results from the calculated maximum mooring line force (FL_{max}) divided by the Work Load Limit (WLL) factor of mooring lines. The WLL factor and the resulting MBLSD for different mooring line materials are shown in the below table.

Table 5.9.1 - WLL factor and MBLSD

Mooring line material	WLL factor	MBL_{SD}
Steel wire	0.55	$1.82 \times FL_{max}$
Synthetic fibers	0.5	$2.0 \times FL_{max}$

5.9.2 Preferably, all lines supplied to the ship should have the same characteristics and strength to avoid confusion of lines. However, for significantly different maximum calculated line loads, lines in different service may also have different strength and characteristics, e.g. for head and stern lines other than for spring lines.

CHAPTER 4

DOUBLE HULL OIL TANKERS

SECTION 1 - GENERAL PROVISIONS

4.1.1 Application

4.1.1.1 This Chapter applies to the structures of cargo tanks and adjacent pump rooms, ballast tanks and cofferdams (excluding bulkheads not adjacent to cargo tanks) of double hull oil tankers having double bottoms and with machinery spaces being situated aft, intended to carry crude oil and petroleum products having a flash point not exceeding 60°C (closed cup test) and a Reid vapour pressure which is below the atmospheric pressure. If not covered in this Chapter, the relevant requirements of Chapters 2 and 6 of this PART are to be complied with.

4.1.1.2 The double hull oil tankers intended to carry oils having a flash point exceeding 60°C (closed cup test) only are also to comply with the requirements of this Chapter. Where the temperature of heated cargo oils is at least 10 °C below their flash point, the requirements of 4.1.4.4 to 4.1.4.8 and 4.4.1.3 of this Chapter may not be applicable. The scantlings and arrangements of tankers intended for cargoes other than the above oil will be specially considered in relation to the characteristics and density of the cargo. For oil tankers intended for the carriage of liquids with a density greater than 1.025 t/m³, the structural strength of the cargo tank region is to be specially considered.

4.1.1.3 CSR oil tankers are to comply with the relevant requirements of PART NINE of the Rules.

4.1.2 Class notations

4.1.2.1 For oil tankers complying with the requirements of this Chapter, the notation of Oil Tanker, Double Hull, F.P. ≤ 60°C or Oil Tanker, Double Hull, F.P. > 60°C may be assigned.

4.1.2.2 For oil tankers complying with the requirements of PART NINE of the Rules, a notation of Oil Tanker, Double Hull, CSR is to be assigned.

4.1.3 Plans and documents

4.1.3.1 The following plans and documents are to be submitted for approval in addition to those required in Section 1 of Chapter 2 of this PART:

- (1) Connections of longitudinals with other members;
- (2) Details at intersections of transverse and longitudinal framing;
- (3) Closing arrangements for all deck openings;
- (4) Any dry cargo tanks or tanks for water ballast only, which are empty in the fully loaded condition, are to be indicated on the principal structural and arrangement plans;
- (5) The location of all openings in the deck is to be indicated on the structural plan of deck.

4.1.4 Limitations of size and arrangement of cargo tanks

4.1.4.1 The wing cargo tank mentioned here refers to a cargo tank, with inner hull forming one of its boundaries, of an oil tanker with oil-tight longitudinal bulkheads. Other cargo tanks are referred to as centre tanks.

4.1.4.2 With regard to subdivision, size of cargo tanks, distance from side shell to inner hull and depth of double bottom, the requirements of Section 12, Chapter 1 of this PART are to be complied with. For oil tankers with *DW* less than 5,000 tons and the capacity of each cargo oil tank not exceeding 700 m³, if arranged as double hull, the spacing *W* of double hull is not to be less than:

$$W = 0.4 + 2.4 DW / 20000 \quad \text{m}$$

The minimum value of *W* = 0.76 m

where: *DW* means the deadweight, in t.

4.1.4.3 Segregated ballast tanks, dedicated clean ballast tanks and slop tanks are to be arranged in compliance with the requirements of Section 12, Chapter 1 of this PART.

4.1.4.4 Cofferdams are to be provided at the forward and aft ends of the cargo tanks region so as to separate oil tanks from engine rooms, boiler rooms, dry cargo holds and accommodation spaces.

Cofferdams are to have an adequate spacing between their end bulkheads to permit easy access and cover the whole area of the end bulkheads of the cargo tank region. The spacing between the bulkheads is in general not to be less than 760 mm. For small oil tankers, where it is difficult to arrange cofferdams, smaller spacing may be accepted, but it is not to be less than 600 mm. Where a corner-to-corner situation occurs, protection may be formed by a diagonal plate across the corner. A pump room, water ballast tank or oil fuel tank may be accepted in lieu of a cofferdam.

4.1.4.5 Any access to spaces adjacent to a cargo tank is to be from the open deck. Passages or tunnels passing through or adjacent to a cargo tank and not separated from it by a cofferdam, are to be provided with mechanical ventilation, and any access is also to be from the open deck.

4.1.4.6 Where the lower portion of the pump room is recessed into the machinery space, the height of the recess is not, in general, to exceed 1/3 of the moulded depth above the baseline except that in the case of ships of not more than 25,000 metric tons deadweight, ISC may permit a recess in excess of such height, but not exceeding one half of the moulded depth of the ship.

4.1.4.7 The wheelhouse, where fitted above the cargo tank region, is to be separated from the cargo tank deck by means of an open space with a height of at least 2 m.

4.1.4.8 Means are to be provided to keep deck spills away from the accommodation and service areas. This may be accomplished by provision of a permanent continuous coaming of not less than 300 mm in height extending from side to side. Special consideration is to be given to the arrangements associated with stern loading and unloading for the prevention of deck spill from flowing over board.

4.1.5 Structural details

4.1.5.1 For oil tankers of over 65 m in length, the deck, bottom and inner bottom within the cargo tank region of tankers are to be longitudinally framed. Where the length of ship exceeds 190 m, the side shell, inner hull and longitudinal bulkheads are generally to be longitudinally framed. The hull structures beyond the cargo tank region may be framed either transversely or longitudinally. Constructional arrangements are to be made to ensure a gradual transition from the longitudinal framing to the transverse framing.

4.1.5.2 The typical midship section of double hull oil tankers and the structural members referred to in this Chapter are as shown in Figure 4.1.5.2.

4.1.5.3 Cargo tanks are enclosed by double bottom, wing ballast tank, empty cofferdams and deck. The loading of cargo and fuel oils is not permitted in the double bottoms and wing ballast tanks.

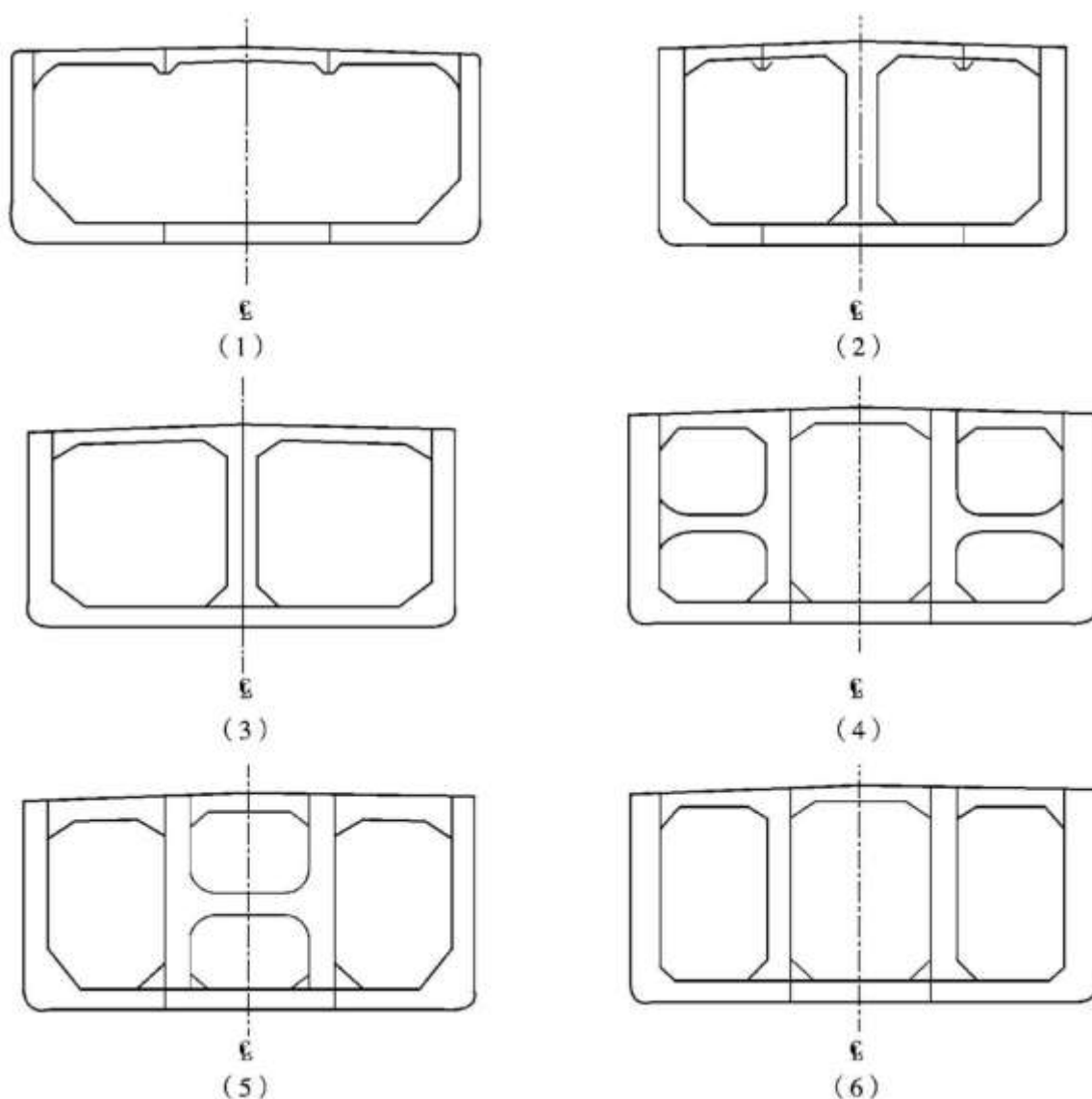
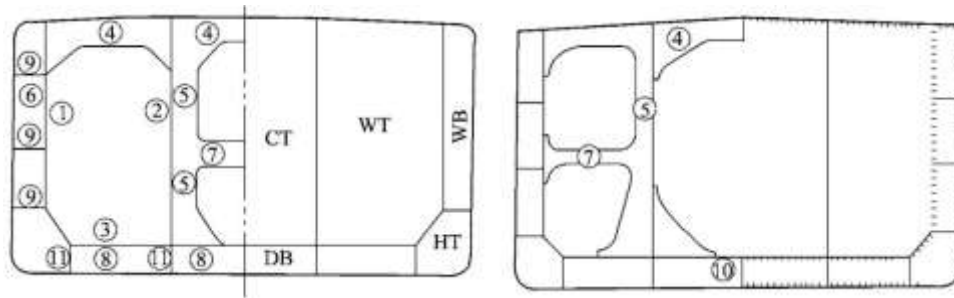
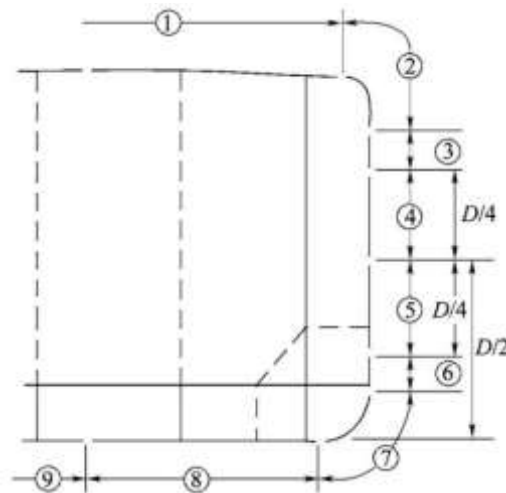


Figure 4.1.5.2(1) Typical Midship Section



- 1 — Inner hull; 2 — Longitudinal bulkhead;
 3 — Inner bottom; 4 — Deck transverse;
 5 — Vertical web on longitudinal bulkhead; 6 — Vertical web in wing ballast tank;
 7 — Cross ties; 8 — Floor; 9 — Horizontal girder in wing ballast tank; 10 — Double bottom girder;
 11 — Double bottom side girder; WB — Wing ballast tank; WT — Wing cargo tank;
 CT — Centre cargo tank; HT — Hopper tank; DB — Double bottom



- 1 — Deck plating; 2 — Deck stringer and sheer strake;
 3 — Side shell plating 1; 4 — Side shell plating 2;
 5 — Side shell plating 3; 6 — Side shell plating 4;
 7 — Bilge plating; 8 — Bottom shell plating; 9 — Plate keel

Figure 4.1.5.2(2) Typical Midship Section and Structural Members

4.1.6 Minimum thickness

4.1.6.1 Within the cargo tank region (including wing ballast tanks, empty cofferdams at the ends of the cargo tank region or between cargo tanks), the minimum thickness t of primary member webs and face plates, shell plating, deck plating, bulkhead plating and inner hull plating is not to be less than that obtained from the following formula:

$$t = 6.5 + L/50 \text{ mm, but not less than 7.5 mm}$$

where: L — length of ship, in m, taken not greater than 300 m.

The minimum thickness of secondary structural members are also to comply with the requirements mentioned above, but need not be greater than 11 mm.

4.1.6.2 The minimum thickness t of the members in pump rooms, cofferdams and other void spaces may be 1 mm less than that required in 5.1.6.1, but not less than 7.5 mm.

4.1.7 Longitudinal strength of double hull oil tankers

4.1.7.1 Double hull oil tankers are to comply with the longitudinal strength requirements specified in Section 2, Chapter 2 of this PART.

4.1.8 Direct calculations and fatigue assessment of hull structural strength

4.1.8.1 For oil tankers of 150 m or over in length, direct strength calculations are to be carried out for the primary members (longitudinal or transverse) in the cargo tank region according to the Appendix 1 of this Chapter.

4.1.8.2 For oil tankers of 150 m or over in length, the fatigue strength check is to be carried out for the following structural members in the cargo tank region in accordance with ISC Guidelines for Fatigue Strength of Ship Structure:

- (1) connections of longitudinals (bottom, side, deck and inner shell) to transverse web frames;
- (2) connections of longitudinals (bottom, side, deck and inner shell) to transverse bulkheads;
- (3) connections of hopper tanks or inner shell to inner bottoms.

SECTION 2 - SHELL PLATING

4.2.1 General requirements

4.2.1.1 The formulae of this Section are applicable to the determination of thickness of longitudinally framed bottom shell plating, plate keels, bilge plating, side shell plating and shear strakes.

4.2.2 Bottom shell plating

4.2.2.1 The thickness t of bottom shell plating within $0.4L$ amidships is not to be less than that obtained from the following formulae:

$$t_1 = 0.052s(L_1 + 170)\sqrt{\frac{F_b}{K}} \text{ mm}$$

$$t_2 = 4.9s\sqrt{(h_w + 0.8d)K} \text{ mm}$$

where: s — spacing of longitudinals, in m, to be taken as not less than standard spacing of longitudinals;

d — draught, in m;

L_1 — length of ship, in m, to be taken as not more than 190 m;

F_b — reduction factor, see 2.2.5.6 of Section 2, Chapter 2 of this PART;

K — material factor;

$$h_w = 0.2B^{0.66} + \left(0.25 + \frac{0.82}{\sqrt{L}}\right)C$$

where: B — breadth of ship, in m;

L — length of ship, in m;

C — see 2.2.3.1 of Section 2, Chapter 2 of this PART.

4.2.3 Plate keels

4.2.3.1 The breadth b of the plate keel within the cargo tank region is not to be less than that obtained from the following formula:

$$b = 900 + 3.5L \text{ mm}$$

And the thickness t is not to be less than:

$$t = t_0 + 2.0 \text{ mm } L \leq 190 \text{ mm}$$

$$t = t_0 + 3.0 \text{ mm } L > 190 \text{ mm}$$

where: L — length of ship, in m;

t_0 — the thickness of the bottom shell plating, in mm, as determined in 5.2.2.1 of this Section.

4.2.4 Bilge plating

4.2.4.1 The thickness t of bilge plating within $0.4L$ amidships is to be the same as that of bottom shell plating.

4.2.4.2 Where longitudinal bottom and side framing is adopted and no longitudinals are fitted at

bilge, the thickness of bilge plating is not to be less than $\frac{rF_b}{165K}$ (r being the radius of the bilge, in mm, K being material factor, and F_b being reduction factor of bottom). The framing associated with such an arrangement is to comply with the requirements of 5.4.4.1 of Section 4 of this Chapter.

4.2.5 Side shell plating

4.2.5.1 Where longitudinal side framing is adopted, the thickness t of side shell plating within $0.4L$ amidships is to comply with the following requirements:

- (1) The thickness t of side shell plating above $3/4 D$ from the baseline is not to be less than that obtained from the following formulae:

$$t_1 = 0.058s(L + 110)\sqrt{\frac{F_d}{K}} \text{ mm}$$

$$t_2 = 7.1s\sqrt{h_w K} \text{ mm}$$

where: s — spacing of longitudinals, in m, not to be less than standard spacing of longitudinals;

L — length of ship, in m, to be taken as not greater than 190 m;

F_d — reduction factor, see 2.2.5.6 of Section 2, Chapter 2 of this PART;

K — material factor;

h_w — see 4.2.2.1 of this Section. (2) The thickness t of side shell plating below $1/4 D$

from the baseline is not to be less than that obtained

- (2) The thickness t of side shell plating below $1/4D$ from the baseline is not to be less than that obtained from the following formulae:

$$t_1 = 0.06s(L+110)\sqrt{\frac{F_b}{K}} \quad \text{mm}$$

$$t_2 = 5.2s\sqrt{(h_w + 0.8d - 0.2D)K} \quad \text{mm}$$

- (3) The thickness t of side shell plating above $3/4 D$ that obtained from the following formulae: and below $1/4 D$ from the following formulae:

$$t1 = s [t11 + (t12 - t11)h] \text{ mm}$$

$$t2 = s [t21 + (t22 - t21)h] \text{ mm}$$

where: $t_{11} = \frac{t_{1,z=0.25D}}{s_{z=0.25D}}$

$$t_{12} = \frac{t_{1,z=0.75D}}{s_{z=0.75D}}$$

$$t_{21} = \frac{t_{2,z=0.25D}}{s_{z=0.25D}}$$

$$t_{22} = \frac{t_{2,z=0.75D}}{s_{z=0.75D}}$$

$$h = \frac{z - 0.25D}{0.5D}$$

$s_{z=0.25D}$ — spacing of longitudinals, in m, at $0.25D$, not to be less than the standard spacing of longitudinals;

$s_{z=0.75D}$ — spacing of longitudinals, in m, at $0.75D$, not to be less than the standard spacing of longitudinals;

$t_{1,z=0.25D}$ — thickness t_1 of plating, in mm, at $0.25D$;

$t_{1,z=0.75D}$ — thickness t_1 of plating, in mm, at $0.75D$;

$t_{2,z=0.25D}$ — thickness t_2 of plating, in mm, at $0.25D$;

$t_{2,z=0.75D}$ — thickness t_2 of plating, in mm, at $0.75D$;

s — spacing of longitudinals at the point under consideration, in m, not to be less than the standard spacing of longitudinals;

D — moulded depth, in m;

z — distance between the point under consideration and baseline.

- (4) In calculation of $t1$, except the minimum range of high tensile steel stipulated in Section 2 of Chapter 2, the material factor K may be taken as 1.

4.2.6 Sheer strakes

4.2.6.1 The breadth of the sheer strakes is to meet the requirements of 2.3.5.1 of Section 3, Chapter 2 of this PART.

4.2.6.2 The thickness t of sheer strakes within $0.4L$ amidships is not to be less than that obtained from the following formulae, also not to be less than that of the adjacent side shell plating:

$$t_1 = 0.06s(L_1 + 110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 0.9s\sqrt{(L + 75)K} \quad \text{mm}$$

where: s — spacing of longitudinals, in m, to be taken not less than standard spacing of longitudinals;

L — length of ship, in m;

$L_1 = L$, L being the length of ship, in m, to be taken not more than 190 m in calculation;

K — material factor;

F_d — reduction factor, see 2.2.5.6 of Section 2, Chapter 2 of this PART.

4.2.7 End shell plating

4.2.7.1 The thickness of shell plating at ends is to be in accordance with the relevant requirements of Section 3, Chapter 2 of this PART.

SECTION 3 – DECKS

4.3.1 General requirements

4.3.1.1 The formulae of this Section are applicable to the determination of thickness of strength deck plating within $0.4L$ amidships.

4.3.2 Strength deck plating

4.3.2.1 The thickness t of strength deck plating within $0.4L$ amidships is not to be less than that obtained from the following formulae:

$$t_1 = 0.06s(L_1 + 110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 0.9s\sqrt{(L + 75)K} \quad \text{mm}$$

where: s — spacing of longitudinals, in m, to be taken not less than standard spacing of longitudinals;

L — length of ship, in m;

$L_1 = L$, L being the length of ship, in m, to be taken not more than 190 m in calculation;

K — material factor;

F_d — reduction factor, see 2.2.5.6 of Section 2, Chapter 2 of this PART.

4.3.2.2 The thickness of strength deck plating at ends is to comply with the relevant requirements of Section 3 of Chapter 2 of this PART.

4.3.3 Connections of deck stringers to sheer strakes

4.3.3.1 The connections of deck stringers to sheer strakes are to comply with the relevant requirements of Section 3 of Chapter 2 of this PART.

SECTION 4 - DOUBLE BOTTOM STRUCTURE

4.4.1 General requirements

4.4.1.1 The scantlings and arrangement of the double bottoms in cargo tanks are to be as required in Section 6, Chapter 2 of this PART, except as otherwise specified in this Section.

4.4.1.2 The integrity of the double bottom is to be maintained. Manholes are not to be fitted on the inner bottom of cargo tanks and the access is not to be via the engine room. Access to double bottom tanks is to be provided by trunks from the exposed deck.

4.4.1.3 Arrangements are to be provided to enable double bottom tanks situated below cargo tanks to be filled with water ballast to eliminate flammable gases which possibly exist in these tanks.

4.4.1.4 Where a duct keel or pipe tunnel is fitted, the duct keel or pipe tunnel is not to be interconnected with the engine room. At least two accesses to open deck are to be provided at a maximum distance from each other. Where one of such accesses passes through a pump room, the access from the pump room to the duct keel or pipe tunnel is to be provided with a watertight cover.

4.4.1.5 Manholes are to be fitted in floors and side girders in compliance with the requirements in 2.6.1 of Section 6, Chapter 2 of this PART as well as those in Section 12, Chapter 1 of this PART.

4.4.1.6 Drain holes and vent holes are to be fitted in floors, side girders, bottom longitudinals and inner-bottom longitudinals in compliance with the requirements in 2.6.1 of Section 6, Chapter 2 of this PART.

4.4.2 Bottom girders

4.4.2.1 The centre girders or duct keels are to be arranged at the longitudinal centerline of double bottoms. Side girders are also to be provided at sides.

4.4.2.2 Girders are to be provided below lower stools of the longitudinal or longitudinal corrugated bulkhead, whereas side girders are to be provided below hopper tank slope plating.

4.4.2.3 In way of vertically corrugated transverse bulkheads supported by stools, additional local girders are to be arranged in accordance with the requirements in 5.9.3.2 of Section 9 of this Chapter.

4.4.2.4 The thickness of centre keels is not to be less than that obtained from the following formula, and is also to comply with the requirements for deep tanks in Section 13, Chapter 2 of this PART:

$$t = (0.008h_0 + 1.0)\sqrt{K} \quad \text{mm}$$

where: h_0 — considered height of centre keels, in mm, see 2.6.2.1 of

Section 6, Chapter 2 of this PART;

K — material factor.

4.4.2.5 The thickness of side plating of duck keels is not to be less than that obtained from the following formula, and is also to comply with the requirements for deep tanks in Section 13, Chapter 2 of this PART:

$$t = 0.008 h_0 \sqrt{K} \quad \text{mm}$$

where: h_0 , K — the same as that in 5.4.2.4 of this Section.

4.4.2.6 The thickness of side girders is not to be less than that obtained from the following formula, and is to comply with the requirements for deep tanks in Section 13, Chapter 2 of this PART where side girders are watertight:

$$t = (0.007 h_0 + 1.0) \sqrt{K} \quad \text{mm, but need not be greater than 14 mm}$$

where: h_0 , K — the same as that in 5.4.2.4 of this Section.

4.4.2.7 For ships whose breadth is greater than 12 m, but not greater than 20 m, at least one side girder is to be provided at each side of the longitudinal centerline (including side girders in way of hopper tanks). For ships whose breadth is greater than 20 m, two side girders may be provided at each side of the longitudinal centerline (including side girders in way of hopper tanks and below longitudinal bulkheads). The number of side girders to be provided may also be determined by direct calculation.

4.4.2.8 Horizontal stiffeners are to be provided at centre girders, duck keels and side girders, of which the section moment of inertia is to comply with the requirements in 4.12.2.5 of this Chapter.

4.4.2.9 Brackets extending to adjacent longitudinals are to be provided at every other frame space at both sides of centre girders between solid floors. The thickness of brackets is to be the same as that of solid floors.

4.4.2.10 The inner framing of duct keels is to comply with the following requirements:

(1) Transverse bottom frames and inner bottom frames are to be provided in way of every other frame space in duct keels, and the section modulus W is not to be less than that obtained from the following formula:

$$W = 22 s d l^2 K \quad \text{cm}^3$$

where: s — spacing of frames, in m;

d — draft, in m;

l — span, in m, taken as spacing between both side plates of duct keels;

K — material factor.

(2) Both ends of transverse bottom frames and inner bottom frames are to be gradually enlarged and to be connected to side plating of duct keels, with the enlarged height being not be less than 1.5 times that of the frames. Brackets having a plate thickness equal to that of solid floors are to be provided at the corresponding position of outer side of the side plating and to be connected to the bottom and inner bottom longitudinals.

(3) Inner bottom longitudinals and bottom longitudinals are to be fitted within the duct keel on the centreline of the ship, which may be intercostal in way of transverse framing members.

4.4.2.11 For oil tankers of 90 m in length and upwards, the scantlings of centre keels, duct keels and side girders are to be checked by means of direct calculation, which is to comply with the requirements of Appendix 1 of this Chapter. Where the ship length is less than 150 m, other approved equivalent direct calculation methods may be used.

4.4.3 Bottom floors

4.4.3.1 Solid floors are to be provided below lower stools of transverse bulkheads and corrugated transverse bulkheads.

4.4.3.2 The spacing of solid floors is, in general, to be not greater than $0.006L + 3.2$ in m, L being length of ship.

4.4.3.3 The thickness t of solid floors is not to be less than that obtained from the following formula:

$$t = (0.007h_0 + 1.0)\sqrt{K} \text{ mm, but need not be greater than 14 mm}$$

where: h_0 , K — the same as that in 5.4.2.4 of this Section.

Watertight solid floors are also to comply with the requirements for deep tanks.

4.4.3.4 For oil tankers of 90 m in length and upwards, the thickness of floors is to be checked by means of direct calculation, which is to comply with the requirements of Appendix 1 of this Chapter. Where the ship length is less than 150 m, other approved equivalent direct calculation methods may be used. Attention is to be given to alignment of the floors when cut apart in way of girders so as to ensure the transverse continuity.

4.4.3.5 Vertical stiffeners are to be provided between bottom longitudinals and inner bottom longitudinals in way of solid floors.

4.4.4 Bilge brackets

4.4.4.1 Where longitudinal bottom and side framing is adopted and no longitudinals are fitted at bilge, an appropriate number of centre bilge brackets are to be provided at bilge between solid floors and connected to longitudinals at upper and lower turns of bilge. The spacing S between bilge brackets and solid floors or between bilge brackets is not to be greater than that obtained from the following formula:

$$S = 8 \times 10^6 \frac{t^3}{Dr} \sqrt{\frac{t}{r}} \text{ mm}$$

where: t — thickness of bilge strake, in mm;

D — moulded depth, in m;

r — radius of bilge, in mm.

The thickness of bilge brackets is to be the same as that of solid floors.

4.4.5 Bottom longitudinals

4.4.5.1 The maximum spacing of bottom longitudinals is not to be greater than 1 m.

4.4.5.2 The section modulus W of bottom longitudinals is not to be less than that obtained from the following formula:

$$W = 11.5sd l^2 K \text{ cm}^3$$

where: s — spacing of longitudinals, in m;

d — draft, in m;

l — span of longitudinal, in m;

K — material factor.

4.4.5.3 Where penetrating non-watertight floors, the longitudinals are to be welded to the floors and vertical stiffeners on the floors. Where a longitudinal is cut at watertight floors, the longitudinal is to be bracketed to the watertight floors. The size of the brackets is to comply with the requirements in 1.2.6 of this PART. For ships over 190 m in length or where higher tensile steel is adopted for longitudinals, the bottom longitudinals are to penetrate watertight floors, but an appropriate equivalent structure may be adopted as an alternative.

4.4.6 Inner bottom plating and inner bottom longitudinals

4.4.6.1 The thickness t of inner bottom plating is not to be less than that obtained from the following formula:

$$t_1 = \frac{s}{70\sqrt{K}} \times 10^3 \quad \text{mm}$$

where: s — spacing of inner bottom longitudinals, in m;

K — material factor. For higher strength steels, if the material factor of lower strength level could meet the requirements of buckling check for direct strength calculation, the value K of lower strength level may be taken;

$$t_2 = 4s\sqrt{hK} + 2.5 \quad \text{mm}$$

where: K — material factor;

h — vertical distance between inner bottom plating in way of longitudinal centerline and top of the tank, in m.

4.4.6.2 Inner bottom longitudinals and the corresponding bottom longitudinals are to be in the same vertical section.

4.4.6.3 The section modulus W of inner bottom longitudinals is not to be less than that obtained from the following formula:

$$W = 8.4s (h + 1.2) l^2 K \text{ cm}^3$$

where: s, h — see 5.4.6.1 of this Section;
 l — span of longitudinals, in m;
 K — material factor.

4.4.7 Sloping plating and slope plating longitudinals of hopper tanks

4.4.7.1 The thickness of sloping plating of hopper tanks is not to be less than those obtained from the following formula, and is not to be less than that of the adjacent inner hull plating:

$$t_1 = \frac{s}{70\sqrt{K}} \times 10^3 \quad \text{mm}$$

where: s — spacing of sloping plating longitudinals, in m;
 K — material factor. For higher strength steels, if the material factor of lower strength level could meet the requirements of buckling check for direct strength calculation, the value K of lower strength level may be taken;

$$t_2 = 4s\sqrt{hK} + 2.5 \quad \text{mm}$$

where: K — material factor;
 h — vertical height, in m, measured from lower edge of strake to the tank top in way of longitudinal centerline.

4.4.7.2 The section modulus of slope plating longitudinals is not to be less than that obtained from the following formula, and not to be less than that of the adjacent inner hull plating longitudinals:

$$W = 8.4s(h + 1.2)l^2K \quad \text{cm}^3$$

where: s — spacing of sloping plating longitudinals, in m;
 h — vertical height, in m, measured from sloping plating longitudinals to the tank top in way of longitudinal centerline;
 K — material factor.

SECTION 5 - DOUBLE HULL CONSTRUCTION

4.5.1 General requirements

4.5.1.1 This Section applies to the determination of arrangement and scantlings of frames in double hull within the cargo tank region of double hull oil tankers.

4.5.1.2 Manholes are to be provided in transverse bulkheads and horizontal girders. The manholes may either be round or elliptical. The long axis of elliptical manholes is to be vertical to or along the length of the ship. Except for access openings, the holes on upper and lower adjacent horizontal girders are in general not to be on the same vertical line. The edge around the holes is to be strengthened.

4.5.1.3 For double hull oil tankers with the wing tanks as the ballast tanks, the inner hull structures are to comply with the requirements for deep tanks in Section 13, Chapter 2 of this PART.

4.5.2 Structural arrangement of double hull

4.5.2.1 Longitudinal continuous horizontal girders within double hull structures are to be provided at the same height as the transverse bulkhead horizontal girders of cargo tanks. A horizontal girder is to be provided at the top of the hopper tank (manhole may not be provided on the longitudinal girder for the sake of stability). The horizontal girders in wing ballast tanks, on cargo tank transverse bulkheads and on longitudinal bulkheads are to form a horizontal ring structure.

4.5.2.2 Transverse frames or transverse webs are to be provided in wing ballast tanks in line with the transverse bulkheads of cargo tanks.

4.5.2.3 Transverse frames or transverse webs are to be spaced not more than $0.006L + 3.2$ m apart and fitted in wing ballast tanks in line with double bottom transverses. Transverse frames or vertical webs, together with deck transverses of cargo tanks, vertical webs of longitudinal bulkheads, cross ties between inner hull and longitudinal bulkheads or between longitudinal bulkheads (if provided, see Figure 4.1.5.2(2)) of Section 1 of this Chapter) and double bottom transverses, are to form a transverse ring structure.

4.5.3 Side longitudinals

4.5.3.1 The section modulus W of side longitudinals is not to be less than that obtained from the following formula:

$$W = 7.2s (h+1.2) l^2 K \text{ cm}^3$$

where: s — spacing of longitudinals, in m;

h — vertical distance, in m, measured from longitudinals under consideration to deck at side amidships, but to be taken as not less than $0.25D$;

l — span of longitudinal, in m;

D — moulded depth, in m;

K — material factor.

4.5.3.2 For ships over 150 m in length or where higher tensile steel is adopted for longitudinals, the side longitudinals within $0.1D$ from bottom and strength deck are to penetrate continuously watertight transverse bulkheads.

Where side longitudinals are cut at watertight transverse bulkheads, they are to be bracketed to transverse bulkheads. The brackets are to have face plates and their arm length is to be increased by 20% over that required in 1.2.6 of Chapter 1 of this PART. Where the face plate is flanged, the breadth of the flange is not to be less than 8 times its thickness.

4.5.4 Side frames

4.5.4.1 The section modulus W of side frames is not to be less than that obtained from the following formula:

$$W = 7.2s(h + 1.2)l^2K \text{ cm}^3$$

where: s — spacing of frames, in m;

h — vertical distance, in m, measured from frames under consideration to deck at side amidships, but to be taken as not less than $0.25D$;

l — span of frame, in m, but not to be less than 2.5 m;

D — moulded depth, in m;

K — material factor.

4.5.4.2 Brackets are to be provided at both ends of side frame. The scantlings of bracket are to comply with the requirements of 1.2.6 of this PART.

4.5.5 Inner hull plating and its stiffeners

4.5.5.1 The inner hull plating is to extend as deep as possible at side or from top of the double bottom to the uppermost deck. The inner hull plating is to be so arranged that all cargo tanks are at the inner side of wing ballast tanks, and the inner shell is to extend as far forward and aft as practicable and effectively connected to the structures in way with adequate transition arrangements.

4.5.5.2 The thickness of inner hull plating is not to be less than that obtained from the following formula:

$$t = 3.75s\sqrt{hK} + 2.5 \text{ mm}$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, measured from lower edge of strake to the tank top in way of longitudinal centerline, but not less than $0.4D$;

K — material factor;

D — moulded depth, in m.

4.5.5.3 The spacing of inner hull longitudinals is to be the same as that of side longitudinals. The section modulus W of longitudinals is to comply with the requirements of 5.8.4.4, Section 8 of this Chapter.

4.5.5.4 For ships over 150 m in length or where higher tensile steel is adopted for longitudinals, the inner hull longitudinals within $0.1D$ from bottom and deck are to penetrate continuously webs. Where longitudinals are cut at such webs, they are to be bracketed to the webs. The scantlings of the brackets are to comply with the requirements of 5.5.3.2 of this Section.

4.5.5.5 The section modulus W of vertical stiffeners of inner hull plating is to meet the requirements of 4.8.3.3 of Section 8 of this Chapter.

4.5.5.6 Brackets are to be provided at both ends of vertical stiffeners. The scantlings of brackets are to be comply with the requirements of 1.2.6 of this PART.

4.5.6 Horizontal girders

4.5.6.1 The thickness t of non-watertight horizontal girders within double hull structures that are provided at the same height as the transverse bulkhead horizontal girders of cargo tanks is to comply with the requirements of 4.1.6, Section 1 of this Chapter.

4.5.6.2 The scantlings of longitudinals of horizontal girders are to comply with the requirements of 4.12.2.5 of this Chapter.

4.5.6.3 On the horizontal girders, stiffeners are to be provided between side frames and vertical stiffeners of inner hull plating. The scantlings of stiffeners are to meet the requirements of 5.12.2.5 of this Chapter.

4.5.7 Transverse webs in double hull

4.5.7.1 Watertight transverse webs and stiffeners in double hull are to comply with the requirements for deep tanks as specified in Section 13, Chapter 2 of this PART.

4.5.7.2 Side longitudinals and inner hull longitudinals penetrating watertight transverse webs are to comply with the requirements of 4.5.3.2 and 4.5.5.4 of this Section. Stiffeners are to be provided on transverse webs between side longitudinals and inner hull longitudinals.

4.5.7.3 Non-watertight transverse webs supporting side longitudinals and inner hull longitudinals in double hull are to be provided in line with double bottom transverses. The thickness of non-watertight transverse webs is to comply with the requirements of 4.1.6, Section 1 of this Chapter. The side longitudinals and inner hull longitudinals are to penetrate such transverse webs. Compensation plates are to be provided at the openings to connect longitudinals and transverse structures. Stiffeners are to be provided on transverse webs between side longitudinals and inner hull longitudinals.

SECTION 6 - DECK FRAMING

4.6.1 General provisions

4.6.1.1 This Section applies to arrangement method and scantling determination of longitudinal deck framing within cargo oil tanks of double hull oil tankers.

4.6.2 Deck transverses

4.6.2.1 Deck transverses are to be fitted in every plane of the bottom transverses.

4.6.2.2 The section modulus W of deck transverses is not to be less than that obtained from the following formula:

$$W = CLS (I + 1)K \text{ cm}^3$$

where: C — coefficient, $C = 1.80$ for centre oil tanks, $C = 1.92$ for wing oil tanks;

S — spacing of deck transverses, in m;

L — length of ship, in m, to be taken as not less than 65 m,
but need not be more than 190 m;

I — span of deck transverse, in m;

K — material factor.

4.6.2.3 The section moment of inertia I of the deck transverse is not to be less than that obtained from the following formula:

$$I = 7.5WL/K \text{ cm}^4$$

where: W , I and K — as defined in 5.6.2.2 of this Section.

In addition, the web depth of deck transverses mentioned above is not to be less than 2.5 times the depth of the cut-outs for the passage of deck longitudinals.

4.6.2.4 Stiffeners normal to the face plate are to be fitted on the web plate of deck transverses at alternate longitudinals. Where the web depth of deck transverses exceeds $210t/K$ (t being the thickness of the web plate and K being material factor), an additional horizontal stiffener is to be fitted at a distance of $1/4$ web depth from the face plate. The scantlings of stiffeners are to comply with the requirements of 5.12.2.5 of this Chapter.

Tripping brackets, spaced not more than 4.5 m or 20 times the width of the face plate (whichever is the lesser) apart, are generally to be fitted close to the toes of end brackets of deck transverses and elsewhere. The tripping brackets is to comply with the requirements of 1.2.5.4, Chapter 1 of this PART.

4.6.2.5 Deck transverses are to be connected by end brackets to inner hull plating, longitudinal bulkheads, side framing and continuous deck girders. The scantlings of the brackets are to comply with the requirements of 1.2.7, Chapter 1 of this PART. Where connected to continuous deck girders, the brackets are to extend to the face plate of girders and to be welded to it.

4.6.3 Deck girders

4.6.3.1 The section modulus W of the continuous deck girders is not to be less than that obtained from the following formula:

$$W = 0.1LbI^2K \text{ cm}^3$$

where: L — length of ship, in m;

b — mean width of load-bearing area of the continuous deck girders, in m;

I — span of the continuous deck girder, in m;

K — material factor.

4.6.3.2 Where the web height of continuous deck girders are greater than $65t$ K (where t is web thickness, K is material factor), they are to be stiffened parallel to the girder face plate. The stiffeners are to comply with the requirements of 5.12.2.5 of this Chapter.

Tripping brackets are to be fitted to the continuous deck girders in accordance with the requirements of 1.2.5.4, Chapter 1 of this PART.

4.6.3.3 The connection of deck girders to transverse bulkheads or to the vertical webs on transverse bulkheads is to comply with the requirements of 1.2.7, Chapter 1 of this PART.

4.6.4 Deck longitudinals

4.6.4.1 The section modulus W of deck longitudinals is not to be less than that obtained from the following formula:

$$W = csI^2K \text{ cm}^3$$

where: s — spacing of longitudinals, in m;

I — span of longitudinal, in m, but not to be less than 2.5 m;

c — coefficient, to be taken as the greater of the following values: $c = 0.35L$ or $c = 0.12L + 12.6$, where L being the length of ship, in m; for $L > 190$ m, to be taken as 190 m;

K — material factor.

4.6.4.2 Deck longitudinals, in association with the deck plating, may be gradually tapered outside $0.4L$ amidships towards the ends. At $0.075L$ from ends, the section modulus of deck longitudinals is not to be less than 80% of the value obtained from 5.6.4.1 of this Section and in addition, not to be less than that required in 2.8.5.1, Chapter 2 of this PART for deck longitudinals at the ends of ships.

4.6.4.3 Connections of deck longitudinals to transverse bulkheads are to provide adequate fixity and continuity of longitudinal strength. For ships over 150 m in length or where higher tensile steel is adopted for deck longitudinals, the longitudinals are to be continuous through the transverse bulkheads. Where the deck longitudinals are cut in way of the transverse bulkheads, they are to be bracketed to the bulkheads, and the scantlings of the brackets are to comply with the relevant provisions in 1.2.6, Chapter 1 of this PART. Where flanged face plates are used for the brackets, the breadth of the flange is not to be less than 8 times its thickness. Deck longitudinals are to be welded to the web of deck transverses, and to be welded to the stiffeners of deck transverses when intersecting the stiffeners.

SECTION 7 - PLANE TRANSVERSE OILTIGHT BULKHEADS

4.7.1 General requirements

4.7.1.1 The stiffening on the plane transverse bulkheads, in general, may be arranged vertically in association with horizontal girders or horizontally in association with vertical webs.

4.7.1.2 Horizontal girders of transverse bulkheads are to be fitted in line with the horizontal girders in double hull and with horizontal girders of longitudinal bulkheads. The vertical stiffeners are to be fitted on the same longitudinal section as bottom and inner bottom longitudinals.

4.7.1.3 Vertical webs, if fitted, are to be fitted on the same longitudinal section as deck girders and bottom girders. The horizontal stiffeners are to be fitted at the same level as side longitudinals and inner hull longitudinals.

4.7.2 Thickness of bulkhead plating

4.7.2.1 The thickness t of the bulkhead plating is not to be less than that obtained from the following formula:

$$t = 3.75s\sqrt{hK} + 2.5 \text{ mm}$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, measured from lower edge of strake to the tank top in way of longitudinal centerline, but not less than $0.4D$;

K — material factor.

4.7.2.2 The thickness t of the bulkhead plating is to comply with the following requirements: (1) Where horizontal girders and vertical stiffeners are fitted on the bulkhead:

$$t \geq \frac{s}{70\sqrt{K}} \text{ mm, for the upper 3/4 of the bulkhead}$$

$$t \geq \frac{s}{60\sqrt{K}} \text{ mm, for the lower 1/4 of the bulkhead}$$

(2) Where vertical webs and horizontal stiffeners are fitted on the bulkhead:

$$t \geq \frac{s}{85\sqrt{K}} \text{ mm, for the upper 3/4 of the bulkhead}$$

$$t \geq \frac{s}{70\sqrt{K}} \text{ mm, for the lower 1/4 of the bulkhead}$$

where: s — spacing of stiffeners, in m;

K — material factor. In the case of higher tensile steel where the material factor for a Lower strength level can still satisfy the requirements for plate buckling check (see also 1.5.9, Chapter 1 of this PART) in direct calculation, the value of K for a lower strength level may be taken.

4.7.3 Horizontal girders and vertical stiffeners

4.7.3.1 The section modulus W of horizontal girders is not to be less than that obtained from the following formula:

$$W = 10.5b(h + 1.2)l^2K \text{ cm}^3$$

where: b — width of plating supported by the girder, i.e. half the sum of the lengths of the intersected vertical stiffener above and below the horizontal girder, in m;

h — vertical distance, in m, measured from horizontal girder to the tank top in way of longitudinal centreline;

l — span of horizontal girder, in m;

K — material factor.

The web depth of the horizontal girder is not to be less than 2.5 times the depth of the cut-outs for the passage of vertical stiffeners.

4.7.3.2 Where the horizontal girders together with the horizontal girders on longitudinal bulkheads and the horizontal girders in double hull do not form a ring structure, the brackets at both ends of the horizontal girders are to extend to the adjacent vertical web or webs. The thickness of the brackets is to be the same as the web thickness of the horizontal girders, and the face plate of the brackets is to be the same as that of the horizontal girders.

4.7.3.3 End brackets, which are to comply with the requirements of 1.2.7 of Section 2, Chapter 1 of this PART, are to be fitted at both ends of horizontal girders. Supporting brackets are to be additionally fitted at the other side of the bulkhead in line with the end brackets.

4.7.3.4 Tripping brackets, spaced not more than 4.5 m or 15 times the width of the face plate (whichever is the lesser) apart, are generally to be fitted close to the toes of end brackets of horizontal girders and elsewhere. The tripping brackets are to comply with the requirements of 1.2.5.4, Chapter 1 of this PART.

4.7.3.5 The web thickness of horizontal girders is not to be less than $s/80$ (s being the spacing of stiffeners, in m). Stiffeners normal to the face plate are to be fitted on one side of every vertical stiffener on the web plate of horizontal girders. Where the web depth of horizontal girders exceeds $165t$ (t being the thickness of the web plate), an additional stiffener is to be fitted parallel to and at a distance of $1/4$ web depth from the face plate.

4.7.3.6 Where continuous deck girders are fitted in way of the longitudinal centreline on deck, a vertical centreline web is also to be fitted. The scantlings are to be determined by direct calculation. The connection between them is to comply with the requirement of 1.2.7, Chapter 1 of this PART.

4.7.3.7 The section modulus W of vertical stiffeners is not to be less than that obtained from the following formula:

$$W = 7.2s(h + 1.2)l^2K \text{ cm}^3$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, measured from mid-span of stiffeners to the tank top in

way of longitudinal centerline, but to be taken as not less than $0.25D$;

l — span of stiffener, in m;

K — material factor.

4.7.3.8 The stiffeners are to be connected to the inner bottom and deck longitudinals by brackets at both ends. The brackets are to comply with the requirements of 1.2.6, Chapter 1 of this PART. The stiffeners are to be welded to the web of horizontal girders and vertical stiffeners on the web when penetrating horizontal girders.

4.7.4 Vertical webs and horizontal stiffeners

4.7.4.1 The section modulus W of vertical webs is not to be less than that obtained from the following formula:

$$W = Cb(h + 1.2)l^2K \text{ cm}^3$$

where: b — width of plating supported by the vertical web, i.e. half the total length of the horizontal stiffener intersecting the vertical web, in m;

h — vertical distance, in m, measured from mid-span of the vertical web to the tank top in way of longitudinal centreline;

l — span of vertical web, in m;

C — coefficients: $C = 11$, for the vertical web at the centreline; $C = 8.8$, for the vertical web not on the centreline but supporting the horizontal stiffeners;

K — material factor.

The web depth of vertical webs is not to be less than 2.5 times the depth of the cut-outs for the passage of horizontal stiffeners.

4.7.4.2 Where vertical webs, bottom girders and deck girders do not form a ring structure, the brackets at both ends of the vertical web are to extend to the adjacent deck transverse or bottom transverse. The thickness of the brackets is to be the same as the web thickness of the vertical webs, and the face plate of the brackets is to be the same as that of the vertical webs, or an alternative effective structural configuration is to be adopted to ensure the continuity of the structure.

4.7.4.3 End brackets, which are to comply with the requirements of 1.2.7 of Section 2, Chapter 1 of this PART, are to be fitted at both ends of the vertical webs. Supporting brackets are to be additionally fitted at the other side of the bulkhead in line with the end brackets.

4.7.4.4 Tripping brackets, spaced not more than 4.5 m or 15 times the width of the face plate (whichever is the lesser) apart, are generally to be fitted close to the toes of end brackets of vertical webs and elsewhere. The tripping brackets are to comply with the requirements of 1.2.5.4, Chapter 1 of this PART.

4.7.4.5 Vertical webs are to be fitted with stiffeners parallel to the girder face plate and spaced not more than $60K$ (K being material factor) times the web thickness apart. When horizontal stiffeners on transverse bulkheads are supported by vertical girders, stiffeners normal to the face plate are to

be fitted at every horizontal stiffener. The scantlings of stiffeners are to comply with the requirements of 4.12.2.5 of this Chapter.

4.7.4.6 The section modulus W of horizontal stiffeners is not to be less than that obtained from the following formula:

$$W = 7.2s(h + 1.2)l^2K \text{ cm}^3$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, measured from the stiffener to the tank top in way of longitudinal centreline, but not to be less than $0.25D$, in m;

l — span of stiffener, in m;

K — material factor.

4.7.4.7 The stiffeners are to be connected to the inner hull and the horizontal stiffeners of longitudinal bulkheads by brackets having the scantlings as required in 1.2.6, Chapter 1 of this PART. Horizontal stiffeners are to be welded to the web plate and stiffeners of the vertical webs.

SECTION 8 - PLANE LONGITUDINAL OILTIGHT BULKHEADS

4.8.1 General requirements

4.8.1.1 Longitudinal bulkheads are to be continuous throughout all cargo tanks, and are to extend as far forward and aft as possible. Where the longitudinal bulkheads are cut, large brackets or other longitudinal transitional members are to be fitted to ensure effective continuity.

4.8.1.2 The stiffening on the longitudinal bulkheads may be arranged vertically in association with horizontal girders or horizontally in association with vertical webs. Horizontal girders are to be fitted at the same level as those of transverse bulkheads, and vertical stiffeners are to be fitted on the transverse section of transverse frames. Vertical webs are to be fitted on the same transverse section as bottom floors, and horizontal stiffeners are to be fitted at the same level as side longitudinals.

4.8.1.3 Continuous girders are to be fitted in double bottom at plane longitudinal bulkheads.

4.8.2 Thickness of bulkhead plating

4.8.2.1 The thickness t of the longitudinal bulkhead plating is not to be less than that obtained from the following formula:

$$t = 3.75s\sqrt{hK} + 2.5 \text{ mm}$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, measured from the lower edge of strake to the tank top in way of longitudinal centreline; but not less than $0.4D$, in m;

K — material factor;

D — moulded depth of ship, in m.

4.8.2.2 The thickness of the longitudinal bulkhead plating within 0.1D from deck need not exceed the sheer strake thickness with the same frame spacing.

4.8.3 Horizontal girders and vertical stiffeners

4.8.3.1 The section modulus of horizontal girders is to be calculated in accordance with 5.7.3.1 of this Chapter and to comply with relevant requirements, but the span under consideration is not to be less than 3 m.

4.8.3.2 Horizontal girders and those of transverse bulkheads are to be connected as required in 1.2.7 of this PART.

4.8.3.3 The section modulus W of vertical stiffeners is not to be less than that obtained from the following formula:

$$W = 7.2s (h + 1.2) l^2 K \text{ cm}^3$$

where: s , h , l and K are the same as that in 5.7.3.7 of this Chapter.

4.8.3.4 Stiffeners are to be bracketed at both ends. These brackets are to extend to the nearest inner bottom and deck longitudinals and the scantlings of these brackets are to comply with the requirements of 1.2.6 of this PART, but the depth of the lower bracket along the stiffener is not to be less than 15% of the distance between the ship's bottom and the adjacent horizontal girder. Vertical stiffeners are to be welded to the web plate and stiffeners of the horizontal girders.

4.8.4 Vertical webs and horizontal stiffeners

4.8.4.1 Where one longitudinal bulkhead is fitted, vertical webs symmetrical to the longitudinal centerline are to be fitted in line with floors. The vertical webs may also to be fitted at one side of the longitudinal bulkhead. Where two longitudinal bulkheads are fitted, vertical webs are to be fitted in compartments with cross ties.

4.8.4.2 The section modulus of vertical webs is not to be less than that obtained from the following formula:

$$W = CS (h + 1.2) l^2 K \text{ cm}^3$$

where: S — spacing of vertical webs, in m;

h — vertical distance, in m, measured from the mid-span of vertical webs to tank top;

l — span of vertical webs, in m;

C — coefficient:

$C = 11$, without horizontal cross tie; $C = 3.2$, with 1 horizontal cross tie; $C = 3$, with 2 horizontal cross ties;

K — material factor.

4.8.4.3 The end brackets of vertical webs are to comply with the requirements of 1.2.7, Chapter 1 of this PART.

4.8.4.4 The section modulus W of horizontal stiffeners is not to be less than that obtained from the following formula: $W = 7.2s(h + 1.2) l^2 K \text{ cm}^3$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, measured from stiffeners to tank top at longitudinal centerline, but not less than $0.25D$;

l — span of stiffener, in m;

K — material factor.

4.8.4.5 For ships over 150 m in length or where higher tensile steel is adopted, the horizontal stiffeners on longitudinal bulkheads within $0.1D$ from bottom and deck are to be continuous through transverse bulkheads. Where the horizontal stiffeners are cut at the transverse bulkheads, they are to be bracketed to the transverse bulkheads. Where the transverse bulkheads are stiffened vertically, the brackets at the ends of horizontal stiffeners are to extend to the nearest vertical stiffeners of the transverse bulkheads; the scantlings of the brackets are to be in accordance with the requirements of 4.5.3.2 of this Chapter. Horizontal stiffeners are to be welded to the web plate and stiffeners of the vertical webs.

4.8.5 Cross ties

4.8.5.1 In oil tankers having two longitudinal bulkheads, horizontal cross ties are to be arranged in the transverse ring structure as shown in Figure 4.1.5.2(2). The cross ties are to be located as follows: where one horizontal cross tie is arranged, the centerline of the cross tie is to be between $0.5D$ and $0.7D$ from deck; where two horizontal cross ties are arranged, the centerline of the upper one is to be between $0.4D$ and $0.5D$ from deck, while the centerline of the lower one is to be between $0.7D$ and $0.8D$ from deck. Cross ties may be omitted in transverse ring structures adjacent to watertight transverse bulkheads.

4.8.5.2 The sectional area A and section moment of inertia I of the horizontal cross ties are not to be less than those obtained from the following formulae:

$$A = 1.1Kbs(h + 1.2) + 50K \quad \text{cm}^2$$

$$I = 2.1bs(h + 1.2) l^2 \quad \text{cm}^4$$

where: b — width of plating supported, in m, taken as half of the moulded depth when one cross tie is arranged or half the distance from deck or bottom to the adjacent cross tie when two cross ties are arranged;

h — vertical distance, in m, measured from the centerline of the cross tie to deck at side;

s — spacing of transverse ring structures, in m;

K — material factor;

l — length of cross ties, in m.

4.8.5.3 Substantial vertical and horizontal brackets are to be fitted at ends of cross ties for connection of cross ties to the vertical webs of inner hull and longitudinal bulkheads. The vertical brackets are to be in line with the cross tie web plates, and the horizontal brackets are to be in line with the cross tie face plates.

4.8.5.4 Stiffeners parallel to the face plate are to be fitted on the web plate of cross ties. Where $L \leq 90$ m, the distance between the stiffener and the face plate or between two stiffeners is not to exceed $80 t \sqrt{K}$ (t being the thickness of cross tie webs, K being material factor); where $L \geq 190$ m, the distance is not to exceed $55 t \sqrt{K}$. Intermediate values are to be obtained by interpolation. Brackets are to be fitted on the web plate of cross ties to support the face plate and horizontal stiffeners.

4.8.5.5 Cross ties are to be subject to buckling check.

SECTION 9 - CORRUGATED TRANSVERSE OILTIGHT BULKHEADS

4.9.1 General requirements

4.9.1.1 Except where otherwise specified, the symbols for dimensions of corrugations are shown in Figure 1.2.4.3 of Chapter 1 of this PART.

4.9.1.2 Vertical corrugations are generally to be adopted for corrugated transverse bulkheads except in special cases. The angle between flange and web portions of the corrugation is not to be less than 40°.

4.9.1.3 For oil tankers of 190 m or over in length, lower stools and in general, upper stools are to be provided for vertical corrugated bulkheads.

4.9.2 Corrugation dimensions and bulkhead plating

4.9.2.1 The thickness of transverse corrugated bulkheads is to be determined according to 5.7.2.1 of this Chapter. In calculation, s is to be taken as the width of corrugation flange or that of corrugation web, whichever is the greater, and is to comply with the following formula:

$$t \geq \frac{s}{70\sqrt{K}} \text{ mm}$$

where: s — the width of corrugation flange or that of corrugation web, in mm, whichever is the greater;

K — material factor. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check (see also 1.5.9, Chapter 1 of this PART) in direct calculation, the value of K for a lower strength level may be taken.

4.9.2.2 The section modulus W and moment of inertia I of a corrugation of bulkheads are not to be less than those obtained from following formulae respectively:

$$W = 8.8s (h + 1.2) I^2 K \text{ cm}^3 \quad I = 3.2WI/K \text{ cm}^4$$

where: s — breadth of a corrugation, in m;

h — vertical distance, in m, measured from the mid-span of the corrugation to the tank top in way of longitudinal centerline;

I — span of corrugation, in m;

K — material factor.

4.9.3 Lower stools

4.9.3.1 Lower stools are to comply with the requirements of 8.9.4.1 of this PART.

4.9.3.2 Where the spacing of longitudinal girders in double bottom under the lower stool is greater than 3.8 m, local girders are to be provided. Longitudinal webs are to be provided at center girders, side girders and local girders in the lower stool.

4.9.4 Upper stools

4.9.4.1 Upper stools are to comply with the requirements of 8.9.4.1 of this PART.

4.9.5 Arrangement of structure with no lower stool or upper stool

4.9.5.1 Where no upper stool or lower stool is fitted, the upper and lower structures of transverse bulkheads are to be arranged as required in 8.9.4.1 of this PART.

4.9.6 Horizontal girders

4.9.6.1 Where horizontal girders are provided for corrugated transverse bulkheads, the scantlings and structures of the horizontal girders are to comply with the requirements for plane bulkhead horizontal girders specified in 5.7.3 of this Chapter.

4.9.6.2 The considered depth of the web of horizontal girders is to be taken as the minimum distance between the face plate and the bulkhead.

SECTION 10 - CORRUGATED LONGITUDINAL OILTIGHT BULKHEADS

4.10.1 General requirements

4.10.1.1 Except where otherwise specified, the symbols for dimensions of corrugations are shown in Figure 1.2.4.3 of Chapter 1 of this PART.

4.10.1.2 The angle between web and flange of the corrugation is generally not to be less than 40°.

4.10.1.3 Corrugated longitudinal bulkheads are not recommended for oil tankers of 190 m or over in length.

4.10.1.4 Corrugated longitudinal bulkheads may be horizontally or vertically corrugated. Any arrangement, with both longitudinal and transverse bulkheads being horizontally corrugated, is to be avoided.

4.10.2 Vertically corrugated longitudinal bulkheads

4.10.2.1 The thickness of plating of corrugated longitudinal bulkheads is to comply with the requirements of 5.8.2.1 of this Chapter. In calculation, s is to be taken as the width of corrugation flange or that of corrugation web, whichever is the greater, and is to comply with the following formula:

$$t \geq \frac{s}{70\sqrt{K}} \text{ mm}$$

where: s — the width of corrugation flange or that of corrugation web, in mm, whichever is the greater;

K — material factor. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check (see also 1.5.9, Chapter 1 of this PART) in direct calculation, the value of K for a lower strength level may be taken.

4.10.2.2 The section modulus W and moment of inertia I of a corrugation of bulkheads are not to be less than those obtained from following formulae:

$$W = 8.8s(h + 1.2)l^2K \text{ cm}^3$$

$$I = 3.2Wl/K \text{ cm}^4$$

where: s — breadth of a corrugation, in m;

h — vertical distance, in m, measured from the mid-span of the corrugation to the tank top in way of longitudinal centerline; h is not to be less than 2.5 m;

l — span of corrugation, in m;

K — material factor.

4.10.2.3 Upper stools and lower stools are generally to be fitted at vertically corrugated longitudinal oiltight bulkheads.

4.10.2.4 The height of the lower stools is generally not to be less than 3 times the depth of the corrugations. The thickness and material grade of the stool top plate are not to be less than those required for the bulkhead plating above. The thickness and material grade of the upper portion of vertical or sloping stool side plating, within the depth equal to the corrugation flange width from the stool top, are not to be less than the flange plate thickness and material grade needed to meet the bulkhead stiffness requirements at the lower end of the corrugation.

The distance from the edge of the stool top plate to the surface of the corrugation flange is not to be less than 1.5 times the corrugation flange plate thickness. The stool bottom is to be fitted in line with duct keels in double bottoms and is to have a width not less than 2.5 times the mean depth of the corrugation.

Vertical stiffeners are to be fitted on the lower stool side plating in line with the frames mentioned in 4.4.2.10 of this Chapter. Both ends of the stiffeners are to be bracketed to upper and lower ends of the stool. Horizontal stiffeners, of which the moment of inertia I may be determined according to 4.12.2.5(2) of this Chapter, are also to be fitted on the lower stool side plating. Diaphragms, the thickness of which is to be the same as that of double bottom solid floors, are to be fitted inside the lower stool in line with solid floors. Scallops in the brackets and diaphragms in way of the connections to the stool top plate are to be avoided.

4.10.2.5 The upper stool is to have a height generally between 2 and 3 times the depth of corrugations. Rectangular stools are to have a height generally equal to 2 times the depth of

corrugations, but greater than the height of deck transverses. The width of the stool bottom plate is generally to be the same as that of the lower stool top plate. The top of non-rectangular stools is to have a width not less than 2 times the depth of corrugations. The side plating of the upper stool may be connected directly to the deck, and to be bracketed transversely to beams.

The thickness and material of the stool bottom plate are to be the same as those of the bulkhead plating below. The thickness of the stool side plating is not to be less than 80% of that required for the upper part of the bulkhead plating where the same material is used. Where vertical stiffeners are fitted at side plating of the upper stool, both ends of the stiffeners are to be bracketed to the upper and lower ends of the stool.

Horizontal stiffeners are also to be fitted at side plating of the upper stool. Diaphragms, the thickness of which is to be the same as that of the web of deck transverses, are to be fitted inside the stool in line with deck transverses.

Scallops in the brackets and diaphragms in way of the connection to the stool top plate are to be avoided.

4.10.2.6 If no bottom stool is fitted, the corrugation flanges are to be in line with the side plating of duct keels and connected to the inner bottom plating by full penetration welds.

4.10.2.7 Where horizontal girders are fitted, they are to comply with the requirements of 4.9.6 of this Chapter.

4.10.3 Horizontally corrugated longitudinal bulkheads

4.10.3.1 The thickness of plating of horizontally corrugated longitudinal bulkheads is to comply with the requirements of 4.8.2.1 of this Chapter. In calculation, s is to be taken as the width of corrugation flange or that of corrugation web, whichever is the greater.

4.10.3.2 The section modulus of a corrugation of the bulkhead is to be determined according to 4.10.2.2 of this Chapter.

4.10.3.3 The flat bottom of horizontally corrugated bulkheads is to be in line with longitudinal girders in double bottom and connected to the inner bottom plating by full penetration welds. The top is welded directly to deck. Both the width of bottom and top flat portion are not to be less than $0.1D$ for ships of more than 150 m in length.

4.10.3.4 Where the width of the flat bottom and top is greater than that of corrugation flange or web, an appropriate stiffening structure is to be provided.

4.10.3.5 Vertical webs of horizontally corrugated bulkheads are to be fitted in line with solid floors, and are to comply with the requirements of 5.8.4 of this Chapter. The web depth of the vertical

webs is to be taken as the minimum distance between the face plate of vertical webs and the bulkhead.

SECTION 11 - NON-OILTIGHT BULKHEADS AND WASH BULKHEADS

4.11.1 General requirements

4.11.1.1 Where transverse non-oiltight or wash bulkheads are fitted in the cargo tanks, they are to have an area of perforations not less than 10% of the total area of the bulkhead, and the area of perforations is not to be more than 25% of the total area of the bulkhead for longitudinal non-oiltight bulkheads.

4.11.1.2 Where non-oiltight bulkheads support the bottom centre girder, the perforations are to be so arranged as not to impair the efficiency of the bulkhead as a support to the hull structure. Essential openings (such as openings for pipes, access, etc.) in the lower portion of bulkheads are to be circular with edge stiffening.

4.11.1.3 Non-oiltight or wash bulkheads are to be provided with access openings not less than 600 mm × 800 mm in size.

4.11.2 Bulkhead plating and stiffening

4.11.2.1 The thickness of bulkhead plating is not to be less than that required in 5.1.6 of this Chapter. The thickness of the transverse bulkhead plating supporting centre girders, in addition, is to meet the requirements of 5.7.2.2 of this Chapter and in no case are the panel dimensions to exceed 180 times the thickness of the bulkhead plating.

4.11.2.2 The net vertical sectional area A of the non-oiltight transverse bulkhead supporting centre girders is not to be less than that obtained from the following formula:

$$A = 0.14 l_x b D_x K \text{ cm}^2$$

where: l_x — the distance, in m, between the bulkheads (oiltight or non-oiltight) adjacent to the non-oiltight bulkhead under consideration;

b — overall breadth of oil tank, in m;

D_x — actual depth of non-oiltight transverse bulkheads or transverse wash bulkheads, in m;

K — material factor.

4.11.2.3 The section modulus W of stiffeners is not to be less than that obtained from the following formula:

$$W = 125 s^2 K \frac{l_x}{L} \text{ cm}^3$$

where: s — spacing of stiffeners, in m;

- l — span of stiffener, in m;
 K — material factor;
 l_x — see 5.11.2.2 of this Section;
 L — length of ship, in m.

4.11.2.4 Stiffeners are to be bracketed at their ends. The scantlings of the brackets are to comply with the requirements of 1.2.6, Chapter 1 of this PART.

4.11.3 Vertical webs and horizontal girders

4.11.3.1 Horizontal girders, vertical webs or stiffeners are to be fitted on the non-oiltight or wash bulkheads in line with the strength members which are supported by the bulkheads.

4.11.3.2 The section modulus of vertical webs is not to be less than one half of that required for the vertical webs of oiltight bulkheads arranged in the same way.

4.11.3.3 The section modulus W of horizontal girders is not to be less than that obtained from the following formula:

$$W = 150bl^2K\frac{l_x}{L} \quad \text{cm}^3$$

where: b — width of plating supported by the girder, in m, i.e. half the sum of the lengths of the intersected stiffener above and below the girder, in m;

- l — span of girder, in m;
 K — material factor;
 l_x — see 4.11.2.2 of this Section;
 L — length of ship, in m.

SECTION 12 - SPECIAL REQUIREMENTS

4.12.1 General requirements

4.12.1.1 The symmetrical section is to be adopted as far as applicable for side longitudinals and inner hull longitudinals between 2 m below the ballast waterline and 2 m above the full-loaded waterline. The symmetrical section is also recommended for longitudinals within the above-mentioned extent of longitudinal bulkheads to avoid additional torsional stress. Where higher tensile steel is adopted for side longitudinals and vertical stiffeners or brackets on primary transverse structural webs are connected directly to side longitudinals, the toes of stiffeners or brackets within the above-mentioned extent are to be well radiused (see Figure 5.12.1.1). Where ISC fatigue assessment requirements are complied with, other structural arrangements will be considered.

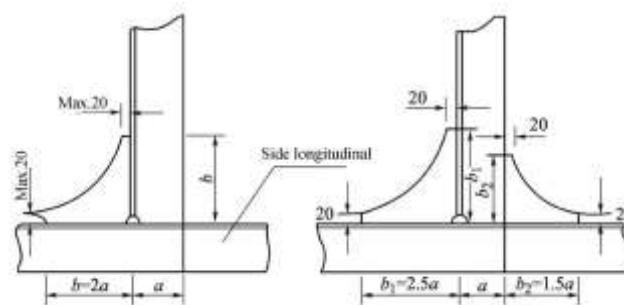
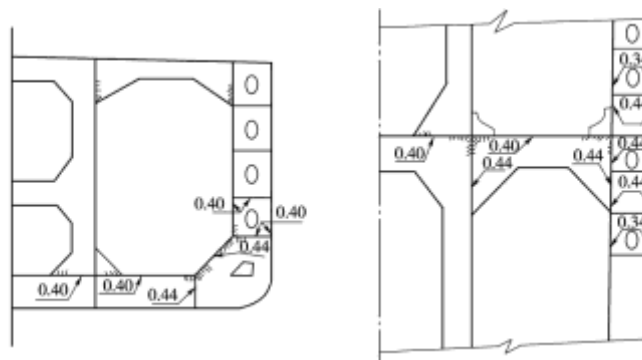


Figure 4.12.1.1

4.12.1.2 Where side longitudinals of higher tensile steel pass through watertight transverse bulkheads in the cargo tank region, radiused brackets of the same material are to be fitted on both the fore and aft sides of the connection between the upper edge of bilge and 0.8D above the draft line, and attention is to be given to ensure the alignment of the brackets.

4.12.1.3 For oil tankers greater than 250 m in length, special attention is to be given to the alignment for connection of the transverse ring system and transverse bulkhead horizontal girders as shown in Figure 4.12.1.3 to relevant adjacent members and to the application of full penetration or increased throat thickness for fillet welds. The length of the increased throat thickness is not to be less than $2s$ or 1.2 m, whichever is the greater, where s is spacing of secondary members, in m.



Note: Deep penetration welds are required for shadow areas, and increased throat thickness based on weld factors as shown in the Figure is required for other areas.

Figure 4.12.1.3

4.12.2 Structure details

4.12.2.1 Where flat steel is adopted for longitudinals, the ratio of height to thickness is not to be greater than $18\sqrt{K}$ (K being material factor) for the longitudinals penetrating bulkheads and not greater than $15\sqrt{K}$ for the longitudinals cut at bulkheads. Where flat steel is adopted for stiffeners, the ratio of height to thickness is not to be greater than $18\sqrt{K}$.

4.12.2.2

- (1) The diameter of lightening holes of primary members is not to be greater than 20% of the web height. The distance between the edge of the hole and face plate is not to be less than 40% of the web height, and an equal distance is in general to be kept from the edge of the hole to the corner of notches for the passage of frames. The holes are to be kept clear of notches and bracket toes. The edge of holes are to be well rounded with smooth edges.
- (2) Openings with a diameter larger than that specified above are subject to check by direct calculation according to the requirements in Appendix 1 of this Chapter.
- (3) Lightening holes are not to be provided on webs of primary members (e.g. side girders, longitudinal bulkhead horizontal girders) in way of cross ties and their end connections.

4.12.2.3 The holes on webs of primary longitudinal members within $0.1D$ (D being moulded depth) from deck and bottom are generally to be strengthened. Access holes on deep longitudinal and transverse girders are to be provided with suitable compensation, so as to satisfy the requirement for resistance to local deformation and shear buckling in the web.

4.12.2.4 The lower edge of holes cut for oil heating piping is not to be less than 100 mm from the shell plating; where notches are cut for the passage of longitudinals, adjacent to such holes, the notches are to be collared.

4.12.2.5 The web depth of stiffeners of primary members is not to be less than 75 mm. Where stiffeners are to be provided both parallel and vertical to the face plate, the scantlings of stiffeners parallel to the face plate are not to be less than those of stiffeners vertical to the face plate. The section moment of inertia of stiffeners is to comply with the following requirements respectively:

- (1) The section moment of inertia I of stiffeners vertical to the face plate of primary members is not to be less than that obtained from the following formula:

$$I = 0.175 \left(\frac{h}{s} \right)^{2.4} st^3 \quad \text{cm}^4$$

where: h — spacing of horizontal stiffeners for main structural member, or depth of web without stiffeners, in m;

s — spacing of stiffeners, in m;

t — thickness of web, in mm.

In calculation, 1 is to be taken for $h/s < 1$ and 3.3 for $h/s > 3.3$.

- (2) The section moment of inertia I of stiffeners parallel to the face plate of primary members is not to be less than that obtained from the following formula:

For longitudinal stiffeners:

$$I = 1.62l^2 A \text{ cm}^4$$

For other stiffeners:

$$I = 0.82l^2 A \text{ cm}^4$$

where: l — spacing of stiffeners, in m;

A — sectional area of stiffeners with attached plates, in cm^2 .

4.12.2.6 Stiffeners are to be provided for large brackets so that the side length of the non-stiffened triangle of the bracket is not greater than 100 times the thickness of the bracket. Stiffeners are to be parallel to the face plate. The distance from the stiffeners near the face plate to the face plate is not to be greater than 30 times the thickness of the bracket. The spacing of other stiffeners may not be greater than 45 times the thickness of bracket plating. The face plate and stiffeners are to be appropriately supported against tripping. Where the face plate is non-continuous at the structural member, both ends of the face plate are to be sniped.

4.12.2.7 The height of bracket stiffeners is not to be less than 75 mm, and their section moment of inertia I is specified as follows:

For the brackets of deck stringers and keel, not to be less than:

$$I = 3l^2 A \text{ cm}^4$$

For those of other primary members, not to be less than:

$$I = 2l^2 A \text{ cm}^4$$

where: l — span of stiffeners, in m;

A — sectional area of stiffeners with attached plates, in cm^2 .

4.12.2.8 In the cargo tank region, integral brackets with continuous face plates are to be adopted as far as practicable for end brackets of primary members. Where the thicknesses of face plates connecting two primary members are different, the primary member with the larger face plate is to have the width of its face plate being maintained to the mid-point of the free side of the bracket and gradually tapered to the smaller face plate of the other primary member. The taper is generally not to exceed 1:3 and where the width of the face plate is greater than 500 mm, the taper is not to exceed 1:4. Where a thick face plate is connected to a thinner one, the difference in thickness is not to exceed 4 mm and in the event that the difference exceeds 4 mm, the taper on thickness is to be 1:3.

SECTION 13 - CARGO TANK HATCHWAYS

4.13.1 General requirements

4.13.1.1 Cargo tank hatchways and ladders are to be fitted in compliance with Section 12, Chapter 1 of this PART.

4.13.2 Requirements for cargo tank hatchways

4.13.2.1 The height of the hatch coaming is not to be less than 600 mm, and the thickness of the coaming plating is not to be less than 10 mm. Where the height of coaming exceeds 600 mm, the coaming is to be increased in thickness and reinforced by horizontal stiffeners on the upper portion.

4.13.2.2 The thickness of hatch covers is not to be less than 12 mm. Where the area of the cover exceeds 1.2 m^2 , the cover is to be reinforced by stiffeners or increased in thickness.

4.13.2.3 Hatch covers are to be secured by bolts spaced generally not more than 460 mm apart, and not more than 230 mm from hatch corners.

4.13.2.4 Sighting ports having a diameter not less than 150 mm are to be provided in the covers. These holes are to be provided with effective closing appliances to ensure oil-tightness.

APPENDIX 1

DIRECT STRENGTH CALCULATION OF DOUBLE HULL OIL TANKERS

1 GENERAL

1.1 Application

1.1.1 This Appendix applies to direct calculations, required by this Chapter, of the structural strength of double hull oil tankers.

1.1.2 Where not stipulated in this Appendix, the relevant requirements of Section 5, Chapter 1 of this PART are to be complied with.

1.1.3 For partially filled cargo tanks, consideration is to be given to the sloshing strength under the sloshing pressure due to liquid motion.

2 DESIGN LOADS

2.1 General requirements

2.1.1 Unless stipulated otherwise in the Appendix, the design loads are to be referred to in Section 5, Chapter 1 of this PART.

2.1.2 Unless stipulated otherwise in the Appendix, the still water bending moment in the global load condition is to be taken as the allowable value $\overline{M}$, provided by the designer; the wave bending moment M_W is to be calculated according to 1.5.6.1(2) of Section 5, Chapter 1 of this PART.

2.1.3 For harbour conditions, the effect of wave loads (pressure and bending moment) is not considered; the allowable still water bending moment $\overline{M}_s$ is determined by the designer, but is to envelop the design still water bending moment under the loading and unloading conditions in harbour given in the loading manual.

3 LOADING CONDITIONS

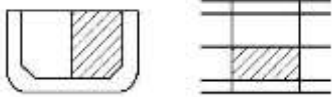
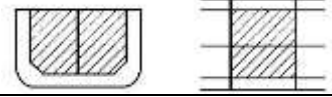
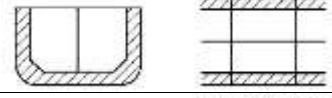
3.1 General requirements

3.1.1 Normally, the corresponding loading conditions are to be selected from Tables 3.2.1 to 3.2.3 of this Appendix for check. For other more severe loading conditions in the loading manual which are not covered by these Tables, direct strength calculation is also to be carried out.

3.2 Loading conditions

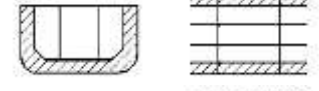
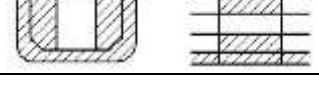
3.2.1 The loading conditions of oil tankers with one longitudinal bulkhead are referred to in Table 3.2.1. For the conditions of LC2, LC3, LC5, LC6, if the structures are not symmetrical to the longitudinal centreline, the loading conditions of tanks on starboard and port sides are to be included respectively.

Table 3.2.1 - Loading Conditions

Loading condition	Draught	Still water bending moment	Wave bending moment	Mode of loading
LC1	d	$\overline{M}_s$	M_w	
LC2	d	$\overline{M}_s$	M_w	
LC3	$0.35D$	$\overline{M}_{sp}$	–	
LC4	$0.35D$	$\overline{M}_{sp}$	–	
LC5	d	$\overline{M}_s$	M_w	
LC6	$0.25D$	$\overline{M}_{sp}$	–	
LC7	Ballast draught	$\overline{M}_s$	M_w	
LC8	Heavy ballast draught	$\overline{M}_s$	M_w	

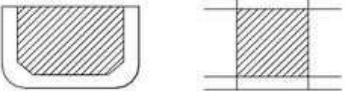
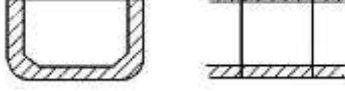
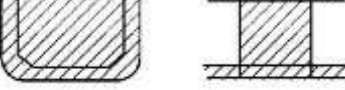
3.2.2 For oil tankers with two longitudinal bulkheads, loading conditions are referred to in Table 3.2.2.

Table 3.2.2 - Loading Conditions

Loading condition	Draught	Still water bending moment	Wave bending moment	Mode of loading
LC1	d	$\overline{M}_s$	M_w	
LC2	d	$\overline{M}_s$	M_w	
LC3	d	$\overline{M}_s$	M_w	
LC4	$0.25D$	$\overline{M}_{sp}$	-	
LC5	$0.25D$	$\overline{M}_{sp}$	-	
LC6	$0.35D$	$\overline{M}_{sp}$	-	
LC7	$0.35D$	$\overline{M}_{sp}$	-	
LC8	Ballast draught	$\overline{M}_s$	M_w	
LC9	Heavy ballast draught	$\overline{M}_s$	M_w	
LC10	Heavy ballast draught	$\overline{M}_s$	M_w	

3.2.3 For oil tankers without longitudinal bulkheads, loading conditions are referred to in Table 3.2.3.

Table 3.2.3 - Loading Conditions

Loading condition	Draught	Still water bending moment	Wave bending moment	Mode of loading
LC1	d	$\overline{M}_s$	M_w	
LC2	$0.35D$	$\overline{M}_{sp}$	-	
LC3	Ballast draught	$\overline{M}_s$	M_w	
LC4	Heavy ballast draught	$\overline{M}_s$	M_w	

4 STRUCTURAL MODELING

4.1 General requirements

4.1.1 Unless stipulated otherwise in this Appendix, the requirements for structural modeling are to be referred to in Section 5, Chapter 1 of this PART (for typical finite element model, see Figure 4.1.1).

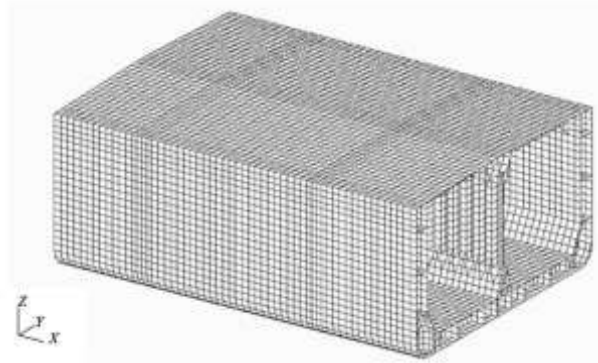


Figure 4.1.1 Finite Element Model

4.2 Boundary conditions

Boundary condition with the structures symmetrical to longitudinal centerline section

If a half-breadth FE model is used, the displacements in transverse direction of nodes on the longitudinal centerline section and the rotations around the two coordinate axes on the longitudinal centerline section are restrained, i.e.: $\delta y = \theta x = \theta z = 0$.

If a full-breadth FE model is used, the displacements in transverse direction of intersection G of the longitudinal centerline section in way of forward and aft bulkheads of midship cargo tanks and bottom plating are restrained, i.e.: $\delta y = 0$.

Boundary conditions for local loads (see Table 4.2.2)

Symmetrical conditions are applied respectively to end planes A and B, the displacements in the longitudinal direction of nodes and the rotations around the two coordinate axes within the end plane are to be restrained, i.e.: $\delta x = \theta y = \theta z = 0$.

Vertical spring elements are to be provided at intersections of side shell plating, inner hull plating and longitudinal bulkhead with forward and aft bulkheads in midship cargo tanks. The coefficient of elasticity of spring elements is to be distributed evenly and calculated by the following formula:

$$K = \frac{5GA}{6l_H n} \quad \text{N/mm}$$

where: G — shear modulus of elasticity of material, $G = 0.792 \times 10^5 \text{ N/mm}^2$ for steel;

A — shearing area of side shell plating, inner hull plating or longitudinal bulkhead plate in way of forward and aft bulkheads, in mm^2 ;

l_H — length of midship cargo tank, in mm;

n — number of nodes on vertical intersections of side shell plating, inner hull plating or longitudinal bulkhead plate.

Table 4.2.2 - Boundary Conditions for Local Loads

Position	Displacement Constraint			Rotation Constraint		
	δx	δy	δz	θx	θy	θz
Longitudinal centerline section (half-breadth model)	–	Constraint	–	Constraint	–	Constraint
Node G (full-breadth model)	–	Constraint	–	–	–	–
End planes A, B	Constraint	–	–	–	Constraint	Constraint
Intersection line C	–	–	Spring	–	–	–

Boundary conditions for global load (see Table 4.2.3)

An independent point H is to be set in way of intersection of the neutral axis with the longitudinal centerline section within end planes A and B , the longitudinal bending moment is to be applied on the point H , and the degrees of freedom δy independent point. and δz of each member node for end planes is linked to the 4.2.3.2 The displacements of the independent point H within end planes A and B in transverse direction, vertical direction, and the rotation around longitudinal axes are restrained, i.e.: $\delta y = \delta z = \theta x = 0$; the displacement of the independent point H within the end plane A in longitudinal direction is restrained, i.e.: $\delta x = 0$.

Table 4.2.3 - Boundary Conditions for Global Load

Position	Displacement Constraint			Rotation Constraint		
	δx	δy	δz	θx	θy	θz
Longitudinal centerline section (half-breadth model)	–	Constraint	–	Constraint	–	Constraint
Node G (full-breadth model)	–	Constraint	–	–	–	–
End planes A, B	Link	Link	Link	–	–	–
Independent point H (end plate A)	Constraint	Constraint	Constraint	Constraint	Bending moment	–
Independent point H (end plate B)	–	Constraint	Constraint	Constraint	Bending moment	–

4.2.4 For boundary conditions of the model, see Figure 4.2.4.

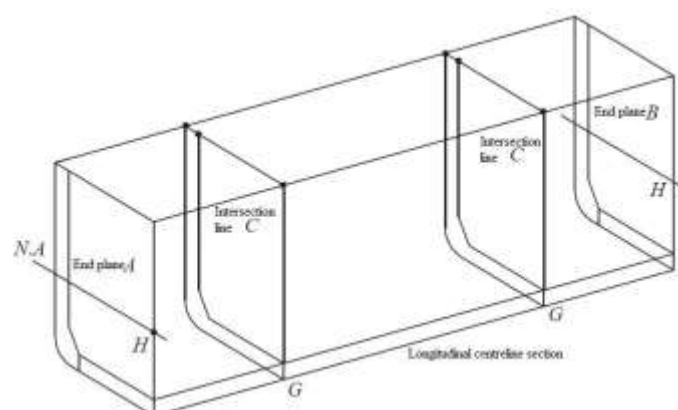


Figure 4.2.4 Boundary Conditions

5 YIELD STRENGTH EVALUATION

5.1 Allowable stresses

Strength evaluation is to be carried out for all primary members in the cargo tanks amidships (including bulkheads) within the longitudinal extent. The evaluation is to be based on the combined stress, which are derived from local load case and global load case in accordance with 1.5.1.9(2) of Chapter 1 of this PART.

The allowable stresses for primary structural members are given in Table 5.1.2.

Table 5.1.2 - Allowable Stresses

Structural Member	Allowable Stress (N/mm ²)	
	[σ_e]	[τ]
Deck	220 / K	–
Bottom shell plating, inner bottom plating	220 / K	–
Side shell plating, inner hull plating, sloping plating of hopper tank, longitudinal bulkhead, horizontal girder in double hulls	220 / K	115 / K
Bottom girder	235 / K	115 / K
Double bottom floor	175 / K	95 / K
Transverse bulkhead	175 / K	95 / K
Side plating of lower, upper stools	195 / K	95 / K
Transverse web frame	195 / K	95 / K
Others	195 / K	–

Note: K— material factor.

6 BUCKLING STRENGTH EVALUATION

6.1 Buckling safety factors

The standard thickness deduction of members is given in Table 6.1.1.

Table 6.1.1 - Standard Thickness Deduction

Position		Standard Thickness Deduction (mm)
Within 1.5 m below weather deck	Deck and shell plating	1
	Inner hull and longitudinal bulkhead	2
	Internal structure including transverse bulkhead ①	2
Elsewhere	Shell plating	1
	Inner hull and longitudinal bulkhead	1
	Internal structure including transverse bulkhead ①	1
Note: ① In uncoated tanks for refined oils where an inert gas system is not fitted, the thickness deduction is to be increased by 1 mm		

The safety factor γ against plate panel buckling is not to be less than the minimum one in Table 6.1.2.

Table 6.1.2 - Minimum Buckling Safety Factor

Structural Member	Minimum Buckling Safety Factor
Deck	0.8
Bottom plating, inner bottom plating	0.8
Side shell plating, inner hull plating, sloping plating of hopper tank, longitudinal bulkhead	0.8
Double bottom girder, horizontal girder in double hulls	1
Transverse bulkhead, lower stool, upper stool	0.8
Web plating of transverse structure including midship web frame and bulkhead horizontal and vertical webs	1

CHAPTER 5

SINGLE HULL OIL TANKERS

SECTION 1 - GENERAL PROVISIONS

5.1.1 Application

5.1.1.1 This Chapter applies to the structures of cargo tanks and adjacent pump rooms, ballast tanks and cofferdams (excluding bulkheads not adjacent to cargo tanks) of oil tankers with single hull and single bottom or with single hull and double bottom.

5.1.1.2 Those not covered in this Chapter are to comply with the relevant provisions in Chapter 2 and Chapter 5 of this PART.

5.1.2 Class notations

5.1.2.1 For oil tankers complying with the provisions of this Chapter, a notation of Oil Tanker, F.P. $\leq 60^{\circ}\text{C}$ or Oil Tanker, F.P. $> 60^{\circ}\text{C}$ will be assigned.

5.1.3 Structural arrangement

5.1.3.1 Cargo tanks, double bottom, etc., are to be arranged in compliance with Section 12, Chapter 1 of this PART.

5.1.3.2 For oil tankers of 65 m or over in length, deck, bottom and inner bottom in the cargo tank region are to be longitudinally framed, while the sides may either be longitudinally framed or transversely framed. For oil tankers of less than 65 m in length, all such framing may be transverse.

5.1.4 Minimum thickness

5.1.4.1 The minimum thicknesses of structural members in cargo tank regions, pump rooms, cofferdams and other void spaces are to comply with the requirements of 5.1.6 of Section 1, Chapter 5 of this PART.

SECTION 2 - SHELL PLATING AND DECKS

5.2.1 General requirements

5.2.1.1 The thickness of transversely framed shell plating and decks in the cargo tank region may be determined by the relevant provisions of this Section.

5.2.2 Bottom shell plating and bilge strake

5.2.2.1 The thickness t of bottom shell plating within $0.4L$ amidships is not to be less than that obtained from the following formulae:

$$t_1 = 0.072sE^{-1}(L+170)\sqrt{\frac{F_b}{K}} \quad \text{mm}$$

$$t_2 = 7.0s\sqrt{(d+h_1)F_bK} \quad \text{mm}$$

where: s — spacing of frames, in m, to be taken as not less than the standard spacing of frames;

d — draft, in m;

L — length of ship, in m;

F_b — reduction factor, see 2.2.5.6, Chapter 2 of this PART;

K — material factor;

$E = \frac{1 + \frac{s^2}{S^2}}{S^2}$, S being spacing of bottom girders or keels, in m;

h_1 — $0.26C$, to be taken as not greater than $0.2d$;

C — coefficient, see 2.2.3.1, Chapter 2 of this PART.

5.2.2.2 The thickness of bilge strakes is not to be less than that of bottom shell plating obtained from the calculation in 6.2.2.1 and not to be less than the actual thickness of the adjacent bottom shell plating.

5.2.3 Plate keels

5.2.3.1 The breadth of plate keels is not to be less than the requirements in 5.2.3.1, Chapter 5 of this PART, while the thickness of plate keels is not to be less than that of bottom shell plating as required in this Section plus 2 mm and not less than that of the adjacent bottom shell plating.

5.2.4 Side shell plating

5.2.4.1 The thickness t of side shell plating within $0.4L$ amidships is to comply with the following requirements:

(1) The thickness t of side shell plating above $3D/4$ from the base line is not to be less than that obtained from the following formulae:

$$t_1 = 0.075sE^{-1}(L+110)\sqrt{\frac{F_d}{K}} \quad \text{mm}$$

$$t_2 = 4.2s\sqrt{(d+h_2)K} \quad \text{mm}$$

(2) The thickness t of side shell plating below $D/4$ from the baseline is not to be less than that obtained from the following formulae:

$$t_1 = 0.075sE^{-1}(L+110)\sqrt{\frac{F_b}{K}} \quad \text{mm}$$

$$t_2 = 6.3s\sqrt{(d+h_1)F_bK} \quad \text{mm}$$

where: s, d, L, h_1, K — see 6.2.2.1 of this Section;

F_b, F_d — reduction factors, see 2.2.5.6, Chapter 2 of this PART;

h_2 — $0.5C$, but not to be greater than $0.36d$; C being coefficient to be taken from 2.2.3.1, Chapter 2 of this PART;

$E = \frac{1 + \frac{s^2}{S^2}}{S^2}$ S being spacing of side stringers, in m.

(3) The thickness of side shell plating above $D/4$ and below $3D/4$ from the baseline is to be determined by interpolation from the values obtained from (1) and (2) above.

(4) For calculation of t_1 , except for the minimum scope of higher tensile steels specified in Section 2 of Chapter 2, the material factor K may be taken as 1.

5.2.5 Shear strakes

5.2.5.1 The breadth of the shear strakes is not to be less than $0.1D$. The thickness of the shear strake plating is not to be less than that of the adjacent side shell plating.

5.2.5.2 The thickness t of shear strakes within $0.4L$ amidships is not to be less than that obtained from the following formulae:

$$\begin{aligned} t_1 &= 0.086sE^{-1}(L+110)\sqrt{\frac{F_d}{K}} \quad \text{mm} \\ t_2 &= 1.05s\sqrt{(L+75)K} \quad \text{mm} \end{aligned}$$

where: s, d, L, F_d, E, S, K — see 5.2.4.1 of this Section.

5.2.6 Strength deck plating

5.2.6.1 The thickness t of strength deck plating within $0.4L$ amidships is not to be less than that obtained from the following formulae:

$$\begin{aligned} t_1 &= 0.086sE^{-1}(L+110)\sqrt{\frac{F_d}{K}} \quad \text{mm} \\ t_2 &= 4.2s\sqrt{DK} \quad \text{mm} \end{aligned}$$

where: s — spacing of transverses, in m, to be taken as not less than the standard spacing of frames;

D — moulded depth, in m;

L, F_d, K — see 6.2.5.2 of this Section.

5.2.6.2 The thickness of strength deck plating is generally not to be less than that of side shear strakes obtained from the calculation in 6.2.5.2 of this Section.

SECTION 3 - LONGITUDINAL BOTTOM FRAMING

5.3.1 General requirements

5.3.1.1 This Section applies to longitudinally framed single bottom structure.

5.3.2 Bottom longitudinals

5.3.2.1 The section modulus W of bottom longitudinals is not to be less than that obtained from the following formula:

$$W = 10sDl^2K \text{ cm}^3$$

where: s — spacing of longitudinals, in m;

D — moulded depth, in m;

l — span of longitudinal, in m;

K — material factor.

5.3.2.2 The connections of bottom longitudinals to bulkheads are to provide adequate fixity and continuity of longitudinal strength. Where higher tensile steels are adopted, longitudinals are to be continuous through the transverse bulkheads.

5.3.2.3 Where the bottom longitudinals are cut in way of the bulkheads, the longitudinals are to be bracketed to the bulkheads. The scantlings of the bracket are to comply with the requirements of 1.2.6, Chapter 1 of this PART, and the flange width of the bracket is not to be less than 8 times the thickness of the bracket. Bottom longitudinals are to be welded to the web and vertical stiffeners of bottom transverses.

5.3.3 Bottom transverses

5.3.3.1 The spacing of bottom transverses is not to be greater than 3.6 m.

5.3.3.2 Where one longitudinal bulkhead is fitted in the cargo tank region at the centerline of the ship, the section modulus W and the section moment of inertia I of the bottom transverses are not to be less than those obtained from the following formulae:

$$W = 11SDI^2K \text{ cm}^3$$

$$I = 10.5WI/K \text{ cm}^4$$

where: S — spacing of bottom transverses, in m;

D — moulded depth, in m;

I — span of bottom transverse, in m;

K — material factor.

5.3.3.3 Where the continuous centerline girder complying with 6.3.4.2 of this Section are fitted in way of centre tanks of ships having two longitudinal bulkheads within the cargo tank region, the section modulus W of the bottom transverses of the centre tanks and the net sectional area A of the associated webs at span points of the longitudinal bulkheads are not to be less than those obtained by the following formulae:

$$W = C_1SDI^2K \text{ cm}^3$$

$$A = C_2SDIK \text{ cm}^2$$

where: S — spacing of bottom transverses, in m;

D — moulded depth, in m;

I — span of bottom transverse, in m;

K — material factor.

The bending moment factor C_1 and shear factor C_2 for centerline girders and bottom transverses are based on the number of bottom transverses in the tank and factor C , as given in Table 6.3.3.3 (intermediate values are to be obtained by interpolation). The factor C is to be calculated as follows:

$$C = \frac{l_G^3 I_F}{l_F^3 I_G}$$

where: l_G — span of centerline girder, in m;

l_F — span of bottom transverse, in m;

I_G — section moment of inertia of centerline girder, in cm^4 ;

I_F — section moment of inertia of bottom transverse, in cm^4 .

Table 5.3.3.3

3 Bottom Transverses	0.02	0.06	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
Girder C1	8.99	8.99	8.53	7.6	6.91	6.2	5.74	5.27	4.96	4.65	4.43	4.19
Girder C2	0.84	0.84	0.81	0.73	0.68	0.62	0.59	0.54	0.51	0.48	0.46	0.45
Bottom Transverse C1	1.55	1.74	1.98	2.48	2.85	3.22	3.47	3.66	3.84	4.03	4.15	4.28
Bottom Transverse C2	0.31	0.33	0.35	0.39	0.42	0.45	0.47	0.49	0.5	0.51	0.52	0.53
5 Bottom Transverses	0.02	0.06	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
Girder C1	12.71	12.25	11.63	10.23	9.24	8.22	7.53	6.82	6.29	5.74	5.43	5.12
Girder C2	1.43	1.39	1.33	1.21	1.12	1.03	0.97	0.91	0.87	0.83	0.8	0.77
Bottom Transverse C1	1.55	1.86	2.23	2.79	3.16	3.53	3.78	4.03	4.22	4.4	4.53	4.59
Bottom Transverse C2	0.32	0.34	0.37	0.41	0.44	0.47	0.49	0.51	0.53	0.54	0.55	0.56

Notes:

- (1) In the case of 2 bottom transverses, calculation may be performed as that for 3 bottom transverses, with C1 being reduced by 20% and C2 by 25% for centerline girders.
- (2) In the case of 4 bottom transverses, the factor may be obtained by interpolation. The net sectional area A of the web at mid-span of the bottom transverse is not to be less than $1\frac{1}{2}$ 1.6The above W and A may also be determined by direct calculation.

5.3.3.4 For ships having two longitudinal bulkheads within the cargo tank region, the scantlings (including the section modulus and the net sectional area of webs at span points) of bottom transverses of wing tanks are generally to be the same as those of bottom transverses of centre tanks.

5.3.3.5 The web depth of the bottom transverses is not to be less than 2.5 times the depth of the slot for the bottom longitudinals.

5.3.3.6 The ends of bottom transverse are to be bracketed to longitudinal bulkheads or ship side. The brackets are to comply with the requirements of 1.2.7, Chapter 1 of this PART. Where connected to ship side, the brackets are as far as possible to form a ring system.

Where the side shell and longitudinal bulkheads are framed transversely in wing cargo tanks, the raised ends of bottom transverse in the tank are to extend to the lowest side stringer and to the lowest horizontal girder of the longitudinal bulkhead. Where the side shell and longitudinal bulkheads are framed longitudinally in wing cargo tanks, the bottom transverses in the tank together with web frames, longitudinal bulkhead vertical webs and deck transverses are to form a transverse framing structure. The radius of rounded corners of the connection of the transverse framing structure to bottom transverses in the tank is generally not to be less than the web depth of adjacent members. The face plate at the connection is to be continuous and have a sectional area not less than that of the face plate of bottom transverses.

5.3.3.7 The web thickness of bottom transverses is not to be less than $s/80$ (s being the spacing of stiffeners). Vertical stiffeners are generally to be fitted on one side of the web plate of bottom transverses in line with the longitudinals.

Where the web depth of bottom transverses exceeds $165t/K$ (t being the web thickness, K being material factor), an additional stiffener is to be fitted parallel to and at a distance of $1/4$ web depth from the face plate. The scantlings of vertical and horizontal stiffeners are to comply with the relevant requirements of 5.12.2.5, Chapter 5 of this PART.

5.3.3.8 Bottom transverses are generally to be fitted with tripping brackets close to the toes of end brackets and elsewhere according to the relevant requirements in 1.2.5.4, Chapter 1 of this PART.

5.3.4 Bottom centerline girder and bottom side girders

5.3.4.1 Where the length of the ship exceeds 70 m and one centerline longitudinal bulkhead is fitted, one intercostal bottom side girder is generally to be fitted at about $1/4B$ from the centerline on each side.

5.3.4.2 For oil tankers without the centreline longitudinal bulkhead, a continuous bottom centerline girder is to be fitted. The section modulus of the continuous centerline girder and the net sectional area A of the web at any section are not to be less than those obtained from the following formulae:

$$W = 10SDb/K \text{ cm}^3$$

$$A = 1.45bDSK \text{ cm}^2$$

where: b — supporting breadth, in m, taken as half the distance between span points of the bottom transverse at both sides;

S — spacing of bottom transverses, in m;

D — moulded depth, in m;

l — span of the centerline girder, in m;

K — material factor.

5.3.4.3 The web depth of the bottom centerline girder is not to be greater than that of the bottom transverses. The web thickness of the bottom centerline girder is not to be less than that of the bottom transverses plus 2 mm.

5.3.4.4 The web thickness and face plate scantlings of the intercostal bottom side girders are to be the same as those of the bottom transverses in way, while the depth may be half of that of the bottom transverses.

5.3.5 Strengthening and end connections of bottom centreline girder

5.3.5.1 Docking brackets are to be fitted on both sides of the bottom centreline girder, midway between the bottom transverses or between the bottom transverse and the transverse bulkhead, and are to be connected to a suitable bottom longitudinal. These brackets are to have a face plate or a flange. The thickness of the brackets is to be the same as that of the web plate of the bottom centreline girder. The bracket on one side of the centreline girder is to be extended and welded to the face plate of the centreline girder but on the other side may be terminated at a suitable horizontal stiffener.

Tripping brackets are also to be fitted close to the toes of end brackets of the continuous bottom centreline girder.

5.3.5.2 Horizontal stiffeners are to be fitted on one side of the web of the continuous centreline girder. Additional vertical stiffeners are to be suitably fitted in way of vertical webs and end brackets. The horizontal stiffeners are to be spaced not more than $50tK$ apart (t being the web thickness of the centreline girder, K being material factor), and the scantlings of the horizontal stiffeners and vertical stiffeners are to comply with the relevant requirements of 5.12.2.5, Chapter 5 of this PART.

SECTION 4 - TRANSVERSE BOTTOM FRAMING

5.4.1 General requirements

5.4.1.1 This Section applies to transversely framed single bottom structure.

5.4.2 Bottom transverses

5.4.2.1 The solid floor is to be fitted at each bottom transverse. The web depth h , thickness t and face plate sectional area A are not to be less than those obtained from the following formulae:

$$\begin{aligned} h &= 42(B + d) - 70 \quad \text{mm} \\ t &= (0.01h + 3) \sqrt{K} \quad \text{mm, but need not be greater than 14 mm} \\ A &= (4.8d - 3)K \quad \text{cm}^2 \end{aligned}$$

where: B — breadth of ship, in m;

d — draft, in m;

K — material factor.

5.4.2.2 The thickness of the face plate of bottom transverses is not to be less than the web thickness of bottom transverses, while the breadth of the face plate is not to be less than 10 times its thickness, but need not be greater than 15 times.

5.4.3 Bottom centerline girder and bottom side girders

5.4.3.1 For oil tankers without the centreline longitudinal bulkhead, a continuous bottom centerline girder is to be provided. The web thickness t and face plate sectional area A of the centerline girder throughout the cargo tank region are not to be less than those obtained from the following formulae: $t = LK \sqrt{2}$ mm, and not less than 6 mm

$$\begin{aligned} t &= \sqrt{LK} + 2 \quad \text{mm, and not less than 6 mm} \\ A &= 0.67LK \quad \text{cm}^2, \text{ and not less than 12.5 cm}^2 \end{aligned}$$

where: L — length of ship, in m;

K — material factor.

5.4.3.2 The bottom centerline girder is generally to be going through the whole ship. Where terminated in way of a transverse bulkhead, the web plating of the bottom centerline girder is gradually to rise to the bulkhead within one frame space, with the raised depth being twice the original one. The face plate of the bottom centerline girder is to be extended to the bulkhead, and to have 15° scarfing as shown in Figure 5.4.3.2.

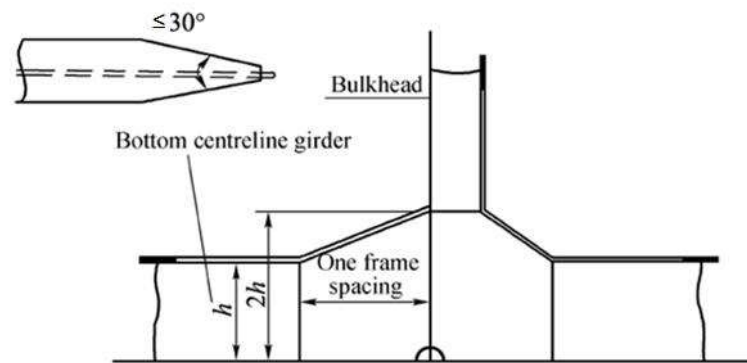


Figure 5.4.3.2

5.4.3.3 Where the breadth of the ship is equal to or less than 7 m, bottom side girders may not be provided; where the breadth is greater than 7 m but less than 12 m, at least one bottom side girder is to be provided at each side of the bottom centerline girder. Where the breadth of the ship is greater than 12 m, at least two bottom side girders are to be provided at each side of the bottom centerline girder. The bottom side girders are to be uniformly fitted so far as practicable and extended in the fore and aft direction.

5.4.3.4 The depth of bottom side girders is to be the same as that of the bottom transverses in way. The web thickness t and the face plate area A are not to be less than those obtained from the following formulae:

$$t = \sqrt{LK} \quad \text{mm, and not less than 6 mm}$$

$$A = 0.25L + 5 \quad \text{cm}^2, \text{ and not less than } 10 \text{ cm}^2$$

where: L — length of ship, in m;

K — material factor.

SECTION 5 - LONGITUDINAL SIDE FRAMING

5.5.1 Side longitudinals

5.5.1.1 The section modulus W of the side longitudinals is not to be less than that obtained from the following formula:

$$W = 8.4s(h + 1.2)^2 K \text{ cm}^3$$

where: s — spacing of longitudinals, in m;

h — vertical distance, in m, measured from the longitudinal under consideration to deck at side amidships, but not to be less than 2.5 m;

l — span of longitudinal, in m;

K — material factor.

5.5.1.2 The scantlings of bilge longitudinals are to be graduated between those required for the bottom and lowest side longitudinals.

5.5.1.3 Where longitudinal bottom and side framing is adopted, but bilge longitudinals are omitted, the spacing of transverses or equivalent bilge brackets are to comply with the requirements of 5.4.4.1, Chapter 5 of this PART.

5.5.1.4 Where the side longitudinals are cut at transverse bulkheads, these longitudinals are to be attached to the bulkheads by brackets. The arm length of the brackets are to be increased by 20% of that required in 1.2.6, Chapter 1 of this PART, and the flange width of the brackets is not to be less than 8 times their thickness. Side longitudinals are to be welded to the web plate of side transverses.

5.5.2 Side transverses

5.5.2.1 Side transverses are to be fitted in line with each solid floor in the longitudinally framed bottom.

5.5.2.2 The section modulus W of side transverses is not to be less than that obtained from the following formula:

$$W = CS (h + 1.2) l^2 K \text{ cm}^3$$

where: S — spacing of side transverses, in m;

h — vertical distance, in m, measured from the mid-span of the side transverse to deck at side;

l — span of side transverse, in m;

C — coefficient: $C = 11$, without horizontal cross ties; $C = 3.2$, with one horizontal cross tie; $C = 3$, with two horizontal cross ties;

K — material factor.

5.5.2.3 The section moment of inertia I of side transverses is not to be less than that obtained from the following formula:

$$I = 7.5Wl/K \text{ cm}^4$$

where: W — section modulus of side transverses, in cm^3 ;

l — span of side transverse, in m;

K — material factor.

5.5.2.4 Tripping brackets are generally to be fitted close to the toes of end brackets of side transverses, in way of cross ties and elsewhere in accordance with the relevant requirements of 1.2.5.4, Chapter 1 of this PART.

5.5.2.5 The web thickness of side transverses is not to be less than $s/80$ (s being the spacing of stiffeners or the depth of unstiffened web, in mm). Stiffeners normal to the face plate are generally to be fitted on one side of the web plate of side transverses in line with every side longitudinal. Where the web depth of side transverses exceeds $165t/K$ (t being the thickness of the web plate, K being material factor), an additional stiffener is to be fitted parallel to and at a distance of $1/4$ web depth from the face plate. The scantlings of stiffeners are to comply with the requirements of 5.12.2.5, Chapter 5 of this PART.

5.5.2.6 The connection of side transverses to deck transverses and bottom transverses is to form a transverse framing structure so far as practicable. The radius of rounded corners of the connection of the transverse framing structure is generally not to be less than the web depth of adjacent members. Where independent brackets are used at upper ends of side transverses, the scantlings of the brackets are to comply with the requirements of 1.2.7, Chapter 1 of this PART. The brackets connected to bottom transverses are to comply with the relevant requirements of 5.3.3.6 of this Chapter.

5.5.3 Cross ties

5.5.3.1 Where horizontal cross ties are to be arranged between side transverses and the vertical webs of longitudinal bulkheads, the scantlings, stiffening and end connection of the horizontal cross ties are respectively to comply with the relevant requirements of Chapter 5 of this PART.

SECTION 6 - TRANSVERSE SIDE FRAMING

5.6.1 Side frames

5.6.1.1 The section modulus W of side frames is not to be less than that obtained from the following formula:

$$W = 11s (h + 1.2) l^2 K \text{ cm}^3$$

where: s — spacing of side frames, in m;

h — vertical distance, in m, measured from the mid-span of the side frame to deck at side, but not to be less than 2.5 m;

l — span of side frame, in m, but not to be less than 2.5 m;

K — material factor.

Where side transverses are fitted, the section modulus of side frames may be reduced by 15% from that obtained from the above formula.

It is recommended that the section modulus of side frames fitted in line with the bottom and deck transverses be suitably increased.

5.6.1.2 The depth and breadth of the brackets connecting the side frames to deck transverses are, in general, not to be less than the depth of the web of the deck transverses.

5.6.1.3 Side frames not in line with the bottom and deck transverses are to be attached to the deck and bottom plating by brackets. The arm length of these brackets is to be 20% more than that required in 1.2.6, Chapter 1 of this PART. The brackets connected to deck are to have face plates or flanges not less than 80 mm, and are to extend to the nearest longitudinal of the deck and welded to it. The bilge brackets are to be extended to the nearest bottom longitudinal and welded to it, covering the entire bilge. The breadth of face plates of bilge brackets is not to be less than 120 mm.

5.6.1.4 Where the lower end of side frames is lapped to the bilge brackets, the length of overlap is not to be less than twice the depth of the frames. Side frames are to be welded to the web plate of side stringers.

5.6.2 Side transverses

5.6.2.1 Where the moulded depth D exceeds 11 m, or where the spacing of oiltight or non-oiltight transverse bulkheads exceeds 15 m, side transverses complying with the requirements of 6.5.2 of this Chapter are to be fitted in line with the solid floors in the longitudinally framed bottom. Where the side transverse does not support side stringers, the section modulus of the side transverse may be reduced by 20% from that required in 5.5.2.2 of this Chapter. For the tripping brackets fitted to the web plate of side transverses, see 5.5.2.4 of this Chapter. For the stiffeners fitted to the web plate of side transverse, see 5.5.2.5 of this Chapter. For brackets connecting the side transverse to deck and bottom transverses, see 5.5.2.6 of this Chapter.

5.6.3 Side stringers

5.6.3.1 Where the moulded depth is less than or equal to 7.5 m, one side stringer is to be fitted; where the moulded depth is less than 6.0 m, however, side stringers may be omitted. Where the moulded depth is more than 7.5 m, two side stringers are generally to be fitted.

5.6.3.2 The section modulus W of side stringers is not to be less than that obtained from the following formula:

$$W = 12b(h + 1.2)l^2K \text{ cm}^3$$

where: b — width of supported plating, in m, to be taken as half the total length of the intersected side frame above and below the side stringer under consideration;

h — vertical distance, in m, measured from side stringer to the tank top in way of longitudinal centreline;

l — span of side stringer, in m, taken as the spacing of side transverses where side transverses are fitted;

K — material factor.

Where two or more side stringers are fitted, the section modulus of the uppermost one is to be increased by 20% above that obtained from the above formula.

5.6.3.3 The web depth of side stringers is not to be less than 2.5 times the depth of the slot for the side transverses.

5.6.3.4 Tripping brackets are generally to be fitted close to the toes of end brackets of side stringers, in way of cross ties and elsewhere in accordance with the relevant requirements of 1.2.5.4, Chapter 1 of this PART.

5.6.3.5 The web thickness of side stringers is not to be less than $s/80$ (s being the spacing of stiffeners or the depth of unstiffened web, in m). Stiffeners normal to the face plate are generally to be fitted on one side of the web plate of side stringers in line with every frame. Where the web

depth of side stringers exceeds $165 t K$ (t being the thickness of the web plate, K being material factor), an additional stiffener is to be fitted parallel to and at a distance of $1/4$ web depth from the face plate. The scantlings of stiffeners are to comply with the relevant requirements of 5.12.2.5, Chapter 5 of this PART.

5.6.3.6 The connection of ends of side stringers to transverse bulkheads are to comply with the following requirements: where side stringers are connected to transverse bulkhead plating, they are to gradually rise to the depth of twice the original one within the depth of about one web plate from bulkhead plating. The web plates of the stringers are to be welded to bulkhead plating. The face plates of the stringers are to extend to bulkheads. Where side stringers are connected to the horizontal girders of transverse bulkheads, they are to comply with the requirements of 1.2.7, Chapter 1 of this PART.

5.6.4 Cross ties

5.6.4.1 Where horizontal cross ties are to be arranged between side stringers and horizontal webs of longitudinal bulkheads, the scantlings, stiffening and end connection of the horizontal cross ties are respectively to comply with the relevant requirements of Chapter 5 of this PART.

SECTION 7 - TRANSVERSE DECK FRAMING

5.7.1 Deck transverses

5.7.1.1 The section modulus W and moment of inertia I of deck transverses in the cargo tank region are not to be less than those obtained from the following formulae:

$$W = 10.8shl^2K \text{ cm}^3$$

$$I = 2.3WI/K \text{ cm}^4$$

where: s — spacing of transverses, in m;

h — design deck head, in m, to be determined according to 2.8.1.1, Chapter 2 of this PART, but not to be less than design pressure of the breathing valves of oil tanks;

l — span of transverse, in m, but not less than 2.5 m;

K — material factor.

5.7.1.2 Deck transverses are to be bracketed to side frames. The scantlings of the brackets are to comply with the requirements of 6.6.1.3 of this Chapter. Deck transverses are to penetrate continuous deck girders, and are to be welded to them.

5.7.2 Deck girders

5.7.2.1 On strength deck, continuous deck girders are generally to be fitted longitudinally in line with bottom girders.

5.7.2.2 The section modulus W and moment of inertia I of continuous deck girders are not to be less than those obtained from the following formulae:

$$W = 12bhl^2K \text{ cm}^3$$

$$I = 2.5WI/K \text{ cm}^4$$

where: b — mean breadth, in m, of areas supported by deck girders;
 h — design deck head, in m, the same as that in 6.7.1.1 of this Section;
 l — span of deck girder, in m;
 K — material factor.

5.7.2.3 The web depth of deck girders is generally not to be less than 2.5 times the depth of deck transverse opening.

5.7.2.4 The connection of deck girders to transverse bulkheads or vertical webs of transverse bulkheads is to comply with the requirements of 1.2.7, Chapter 1 of this PART.

5.7.2.5 Deck girders are to be fitted with tripping brackets as specified in 1.2.5.4, Chapter 1 of this PART.

SECTION 8 - TRUNK STRUCTURE

5.8.1 General requirements

5.8.1.1 The trunk structure is as shown in Figure 6.8.1.2. As a part of strength deck, the trunk structure is to be efficiently scarfed into the main hull structure.

5.8.1.2 Where a trunk is fitted, design moulded depth D_1 is to be measured from the baseline to equivalent deck, the position of which is to be determined from the following formulae:

$$D_1 = D + 0.6 \frac{b_t h_t}{B}, \quad \text{for } \frac{b_t}{B} \leq 0.8$$

$$D_1 = D + h_t \left(2.6 \frac{b_t}{B} - 1.6 \right), \quad \text{for } \frac{b_t}{B} > 0.8$$

where: D, B — moulded depth and breadth of ship respectively, in m;
 b_t, h_t — mean breadth and height of trunk, in m, see Figure 6.8.1.2.

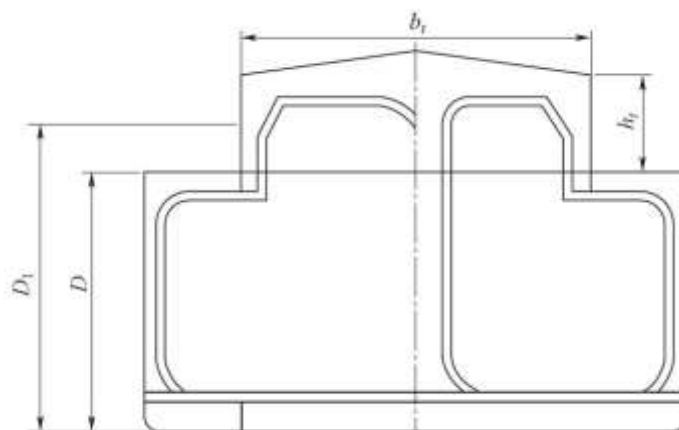


Figure 5.8.1.2

5.8.1.3 In calculation of side, deck, bottom and bulkhead scantlings where the moulded depth D is involved, it is to be replaced by the design moulded depth D_1 ; where the design pressure head is measured to deck at side, it is to be increased by $D_1 - D$.

5.8.2 Structural arrangement

5.8.2.1 The trunk structure is generally to extend over the full length of the cargo tanks and effectively in the fore and aft direction. The extension length of the trunk side plating at both ends is not to be less than 1.5 times the height of the trunk, and the ends are to form radiused extension brackets which are to have a face plate or flange.

5.8.2.2 The trunk deck and sides are generally to be longitudinally framed. Transverse strength members of the trunk deck are to be arranged in line with deck transverses.

5.8.2.3 The structural arrangement at the connection of the trunk side to deck transverses is to be such as to ensure adequate rigidity and continuity of strength.

5.8.2.4 Where deck is longitudinally framed and ship side is transversely framed, web frames are to be fitted in way of deck transverses. The considered span for the determination of the scantlings of deck transverses is to be measured from the span point at side to the longitudinal bulkhead. In addition, continuous deck girders are to be provided at trunk sides. The web depth of the continuous deck girders is not to be less than that of deck transverses. The sectional area of the face plate of continuous deck girders is not to be less than that of deck transverses.

5.8.2.5 Extension brackets and strengthened vertical stiffeners or equivalent structures are to be provided at fore and aft ends of the trunk so as to ensure the continuity of strength from the trunk structure into the main hull and superstructures. At fore and aft end bulkheads, the strength deck is to have radiused transition at corners of deck openings as required in 2.4.4, Chapter 2 of this PART.

5.8.2.6 Where strength members or longitudinal stiffeners are fitted externally to the trunk, the arrangements and scantlings of the members are to be specially considered.

5.8.3 Scantlings of members

5.8.3.1 The thickness of the trunk top and side plating as well as that of the strength deck outside the trunk sides are to comply with the requirements of Section 3, Chapter 5 of this PART.

5.8.3.2 The scantlings of trunk longitudinals and web beams are not to be less than those of the strength deck framing as required in Section 6, Chapter 5 of this PART.

5.8.3.3 The hull section modulus, at the trunk and keel, for each transverse section within 0.4L amidships is to comply with the relevant requirements of Section 2, Chapter 2 of this PART. All continuous longitudinal members in the trunk may be considered for the hull section modulus amidships.

CHAPTER 6 CONTAINER SHIPS

SECTION 1 - GENERAL PROVISIONS

6.1.1 Application

6.1.1.1 This Chapter applies to ships for the carriage of standard containers in holds and on deck. Container ships engaged in unrestricted service and of 150 m and over in length are to satisfy the requirements of ISC Rules for Structures of Container Ships.

6.1.1.2 Those not covered in this Chapter are to comply with the relevant requirements of Chapter 2 of this PART.

6.1.1.3 Where the hull structural higher tensile steels of more than 50 mm and up to 100 mm in thickness with the minimum yield strength greater than 355 N/mm² are used on board container ships, the requirements of ISC Guidelines for Application of Thick Higher Strength Steel Plates for Ships are to be complied with.

6.1.1.4 Where the hull structural higher tensile steels with the yield strength 390 N/mm² are used for strength deck and coaming plating on board container ships, the material factor *K* may be taken as 0.66 in accordance with 1.3.1 of Section 3, Chapter 1 of this PART, provided that:

- (1) the plating thickness is to be more than 50 mm;
- (2) the areas of higher tensile steels with 390 N/mm² is to be evaluated by means of fatigue spectrum analysis, the positions under evaluation are to include the connection between hatch coamings and supporting members, and other key positions with more severe response of bending moment and torque by hull girders, in addition to those as required in 4.1.5, Appendix 2 of this Chapter;
- (3) the key positions of deck and hatch coaming are to be subject to construction monitoring in accordance with the requirements of ISC Guidelines for Construction Monitoring of Hull Structures.

6.1.2 Class notation

6.1.2.1 Container ships complying with the requirements of this Chapter and fitted with the container securing arrangements complying with the requirements of Appendix 1 of this Chapter will be eligible to be assigned the class notation: Container Ship.

6.1.3 Plans and documents

6.1.3.1 In addition to the plans and documents required in Section 1, Chapter 2 of this PART, the following are to be submitted to ISC for approval:

- (1) Stowage arrangement of containers;
- (2) Details of reinforcement to structure in way of container corners/supports; (3) Arrangement and structural connections of cell guides.

6.1.4 Arrangement and structural configuration

6.1.4.1 The basic structural configuration required by this Chapter includes a double bottom, and a double side skin construction with an efficient torsion box girder fitted at the topsides. Where the strength of the hull structure is ensured, a double bottom and a single side skin construction with the torsion box girder or an alternative equivalent structure may be adopted.

6.1.4.2 Longitudinal framing is to be adopted for the topside and also in the double bottom for ships over 100 m in length.

6.1.4.3 Under the hydrodynamic torque of the hull, the average torsional angle of hatch openings in the strength deck is generally not to exceed $0.006^\circ/\text{m}$ and the elongation of the hatch opening diagonal is generally not to exceed 35 mm, except for open-top container ships.

6.1.5 Direct strength calculation and fatigue strength assessment for hull structure

6.1.5.1 For ships of 150 m or over in length or of the width of hatch openings in the strength deck greater than $0.85B$ (B being the breadth of ship), direct FE strength calculation for cargo holds is to be carried out according to the requirements of Appendix 2 of this Chapter. For container ships of 150 m or over in length, the fatigue strength check is to be carried out for the following structural members in the cargo area in accordance with ISC Guidelines for Fatigue Strength of Ship Structure:

- (1) connections of longitudinals (bottom, side, deck and inner shell) to transverse web frames;
- (2) connections of longitudinals (bottom, side, deck and inner shell) to transverse bulkheads;
- (3) connections of inner shell to inner bottoms.

6.1.5.2 For container ships complying with one of the following conditions, direct FE strength calculation and fatigue strength assessment for the whole ship are to be carried out according to the requirements of Appendix 2 of this Chapter:

- (1) 250 m or over in length;
- (2) where the breadth of ship is greater than 32.36 m;
- (3) where the width of hatch openings in the strength deck greater than $0.85B$ (B being the breadth of ship);
- (4) where the structural arrangement is of non-conventional type.

SECTION 2 - LONGITUDINAL STRENGTH

6.2.1 General requirements

6.2.1.1 Application

(1) Application

This Section applies to the following types of ships of 90 m and over in length: container ships and ships dedicated primarily to carry their loads in containers. For container ships up to or greater than 65 m but less than 90 m in length, the requirements of longitudinal strength are referred to in Section 2 of Chapter 2 of this PART.

(2) Load limitations

The wave loads as given in 7.2.2.3 of this Section apply to ships meeting the following criteria:

Length $90 \text{ m} \leq L \leq 500 \text{ m}$;

Proportion $5 \leq L/B \leq 9$; $2 \leq B/d \leq 6$;

Block coefficient at scantling draught $0.55 \leq C_b \leq 0.9$.

For ships that do not meet all of the aforementioned criteria, special considerations such as direct calculations of wave induced loads may be required by ISC.

(3) Longitudinal extent of strength assessment

The stiffness, yield strength, buckling strength and hull girder ultimate strength assessment are to be carried out in way of $0.2L$ to $0.75L$ with due consideration given to locations where there are significant changes in hull cross section, e.g. changing of framing system and the fore and aft end of the forward bridge block in case of two-island designs.

In addition, strength assessments are to be carried out outside this area. As a minimum assessments are to be carried out at forward end of the foremost cargo hold and the aft end of the aft most cargo hold.

(4) For container ships of 90 m and over in length and ships dedicated primarily to carry their loads in containers, the minimum section moduls W_0 at amidship of hull girder is to comply with the requirements of Section 2, Chapter 2 of this PART.

6.2.1.2 Symbols and definitions

(1) Symbols

L	length of ship, in m, see 1.1.2 of Chapter 1;
B	moulded breadth of ship, in m, see 1.1.2 of Chapter 1;
C	wave parameter, see 7.2.2.3(1);
d	draught, in m, see 1.1.2 of Chapter 1;
C_b	block coefficient, see 1.1.2 of Chapter 1;
C_w	waterplane coefficient at scantling draught d , to be taken as: $C_w = A_w / (LB)$
A_w	waterplane area at scantling draught d , in m^2 ; $R_e H$ minimum yield stress of material, in N/mm^2 ; K material factor;
E	Young's modulus, in N/mm^2 . to be taken as $E = 2.06 \times 10^5 \text{ N/mm}^2$ for steel;
M_S	vertical still water bending moment in seagoing condition, in $\text{kN}\cdot\text{m}$, at the cross section under consideration;
M_{Smax}, M_{Smin}	permissible maximum and minimum vertical still water bending moments in seagoing condition, in $\text{kN}\cdot\text{m}$, at the cross section under consideration, see 7.2.2.2(2);
M_W	vertical wave induced bending moment, in $\text{kN}\cdot\text{m}$, at the cross section consideration;
F_S	vertical still water shear force in seagoing condition, in kN, at the cross section under consideration;

FS_{max}, FS_{min}	permissible maximum and minimum vertical still water shearing forces in seagoing condition, in kN, at the cross section under consideration, see 7.2.2.2(2);
FW	vertical wave induced shearing force, in kN, at the cross section under consideration;
qv	shear flow along the cross section under consideration, to be calculated according to Appendix 3 of this Chapter;
f_{NL-Hog}	non-linear correction factor for hogging, see 7.2.2.3(2);
f_{NL-Sag}	non-linear correction factor for sagging, see 7.2.2.3(2);
f_R	factor related to the operational profile, see 7.2.2.3(2);
t_{net}	net thickness, in mm, see 7.2.1.3(1);
t_{res}	reserve thickness, to be taken as 0.5 mm;
I_{net}	net vertical hull girder moment of inertia at the cross section under consideration, to be determined using net scantlings as defined in 7.2.1.3, in m^4 ;
σ_{HG}	hull girder bending stress, in N/mm^2 , as defined in 7.2.2.5;
τ_{HG}	hull girder shearing stress, in N/mm^2 , as defined in 7.2.2.5;
X	longitudinal coordinate of a location under consideration, in m;
z	vertical coordinate of a location under consideration, in m;
zn	distance from the baseline to the horizontal neutral axis, in m.

(2) Fore end and aft end

The fore end (FE) of the rule length of ship (L), see Figure 7.2.1.2(1), is the perpendicular to the scantling draught waterline at the forward side of the stem.

The aft end (AE) of the rule length of ship (L), see Figure 7.2.1.2(1), is the perpendicular to the scantling draught waterline at a distance L aft of the fore end (FE).

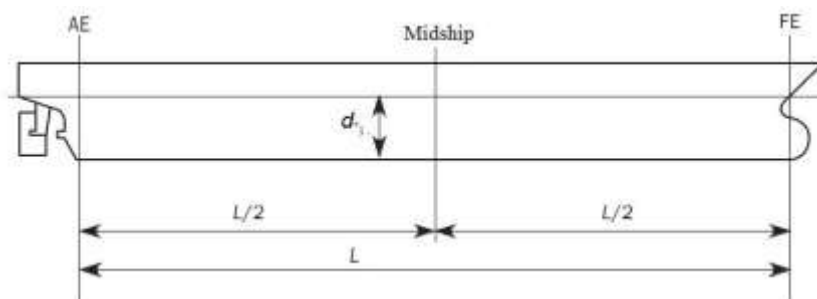


Figure 6.2.1.2(1) Ends of length of ship (L)

(3) Reference coordinate system

The ship's geometry, loads and load effects are defined with respect to the following righthand coordinate system (see Figure 7.2.1.2(2)):

Origin: At the intersection of the longitudinal plane of symmetry of ship, the aft end of L and the baseline.

x axis: longitudinal axis, positive forwards.

y axis: transverse axis, positive towards portside.

z axis: vertical axis, positive upwards.

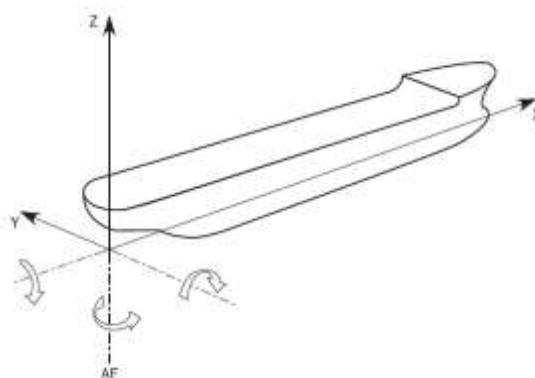


Figure 6.2.1.2(2) Reference coordinate system

6.2.1.3 Corrosion margin and net thickness

(1) Net scantling definition

The strength is to be assessed using the net thickness approach on all scantlings.

The net thickness, t_{net} , for the plates, webs and flanges is obtained by subtracting the voluntary addition

t_{vol_add} and the factored corrosion addition t_c from the as built thickness t_{as_built} , as follows:

$$t_{net} = t_{as\_built} - t_{vol\_add} - \alpha t_c$$

where α is a corrosion addition factor whose values are defined in Table 6.2.1.3(1). The voluntary addition, if being used, is to be clearly indicated on the drawings.

Table 6.2.1.3(1) - Values of corrosion addition factor

Structural requirement	Property / Analysis type	α
Strength assessment (6.2.3)	Section property	0.5
Buckling strength (6.2.4)	Section property (stress determination)	0.5
Buckling capability	1	
Hull girder ultimate strength (6.2.5)	Section property	0.5
Buckling / collapse capacity	0.5	

(2) Determination of corrosion addition

The corrosion addition for each of the two sides of a structural member, t_{c1} or t_{c2} is specified in Table 6.2.1.3(2). The total corrosion addition, t_c , in mm, for both sides of the structural member is obtained by the following formula:

$$t_c = (t_{c1} + t_{c2}) + t_{res}$$

For an internal member within a given compartment, the total corrosion addition, t_c is obtained from the following formula:

$$t_c = 2t_{c1} + t_{res}$$

The corrosion addition of a stiffener is to be determined according to the location of its connection to the attached plating.

Table 6.2.1.3(2) - Corrosion addition for one side of structural member

Compartment Type	One-Side Corrosion Addition (t_{c1} or t_{c2}) (mm)
Exposed to sea water	1
Exposed to atmosphere	1
Ballast water tank	1
Void and dry spaces	0.5
Fresh water, fuel oil and lube oil tank	0.5
Accommodation spaces	0
Container holds	1
Compartment types not mentioned above	0.5

(3) Determination of net section properties

The net section modulus, moment of inertia and shear area properties of a supporting member are to be calculated using the net dimensions of the attached plate, web and flange, as defined in Figure 6.2.1.3. The net cross-sectional area, the moment of inertia about the axis parallel to the attached plate and the associated neutral axis position are to be determined through applying a corrosion magnitude of $0.5 \alpha t_c$ deducted from the surface of the profile cross-section.

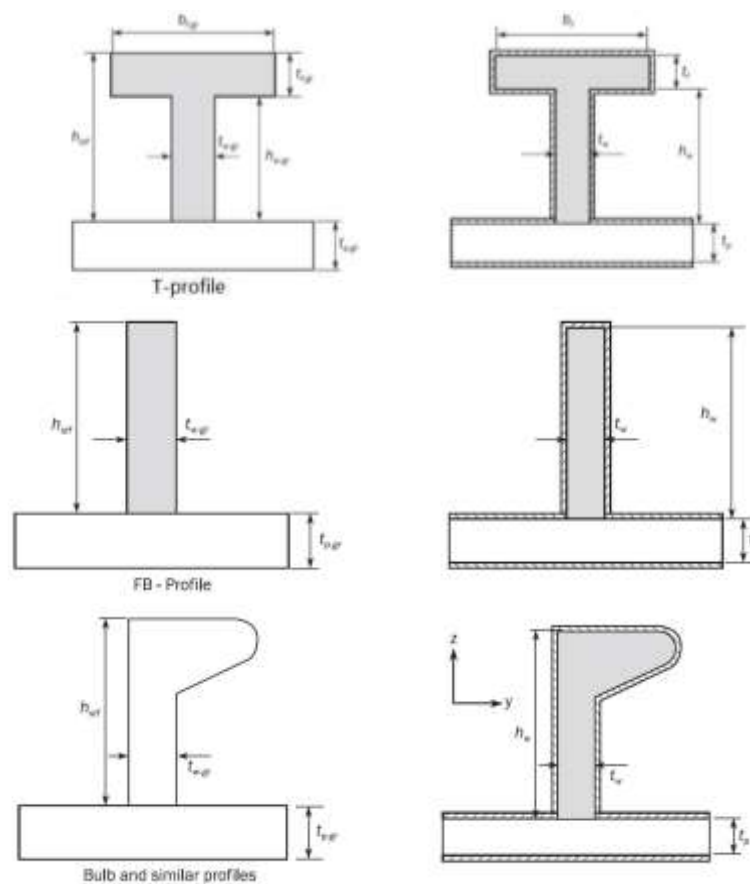


Figure 6.2.1.3 Net sectional properties of supporting members

6.2.2 Loads

6.2.2.1 Sign convention for hull girder loads

The sign conventions of vertical bending moments and vertical shear forces at any ship transverse section are as shown in Figure 7.2.2.1, namely:

- The vertical bending moments M_S and M_W are positive when they induce tensile stresses in the strength deck (hogging bending moment) and negative when they induce tensile stresses in the bottom (sagging bending moment).
- The vertical shear forces F_S , F_W are positive in the case of downward resulting forces acting aft of the transverse section and upward resulting forces acting forward of the transverse section under consideration. The shear forces in the directions opposite to above are negative.

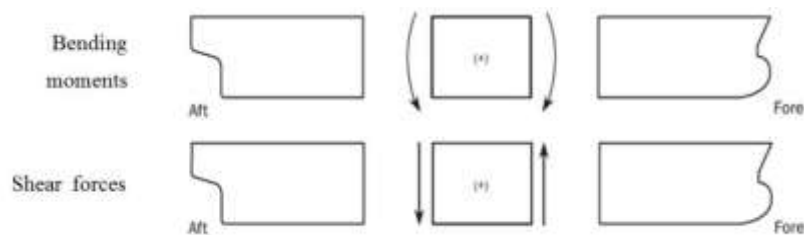


Figure 6.2.2.1 Sign conventions of bending moments and shear forces

6.2.2.2 Still water bending moments and shear forces

(1) General requirements

Still water bending moments, M_S in kNm, and still water shear forces, F_S in kN, are to be calculated at each section along the ship length for design loading conditions as specified in 6.2.2.2(2).

(2) Design loading conditions

In general, the design cargo and ballast loading conditions, based on amount of bunker, fresh water and stores at departure and arrival, are to be considered for the M_S and F_S calculations. Where the amount and disposition of consumables at any intermediate stage of the voyage are considered more severe, calculations for such intermediate conditions are to be submitted in addition to those for departure and arrival conditions. Also, where any ballasting and/or de-ballasting is intended during voyage, calculations of the intermediate condition just before and just after ballasting and/or de-ballasting any ballast tank are to be submitted and where approved included in the loading manual for guidance.

The permissible vertical still water bending moments MS_{max} and MS_{min} and the permissible vertical still water shear forces FS_{max} and FS_{min} in seagoing conditions at any longitudinal position are to envelop:

- the maximum and minimum still water bending moments and shear forces for the seagoing loading conditions defined in the Loading Manual;
- the maximum and minimum still water bending moments and shear forces specified by the designer.

The Loading Manual is to include the relevant loading conditions, which envelop the still water hull girder loads for seagoing conditions, including those specified in 2.2.2.3 of Section 2, Chapter 2 of this PART.

6.2.2.3 Wave loads

(1) Wave parameter

The wave parameter is defined as follows:

$$C = 1 - 1.50 \left(1 - \sqrt{\frac{L}{L_{ref}}} \right)^{2.2}, \text{ for } L \leq L_{ref}$$

$$C = 1 - 0.45 \left(\sqrt{\frac{L}{L_{ref}}} - 1 \right)^{1.7}, \text{ for } L > L_{ref}$$

where: L_{ref} — reference length of ship, in m, taken as:

$L_{ref} = 315 C_W^{-1.3}$ for the determination of vertical wave bending moments according to 7.2.2.3(2);

$L_{ref} = 330 C_W^{-1.3}$ for the determination of vertical wave shear forces according to 7.2.2.3(3).

(2) Vertical wave bending moments

The distribution of the vertical wave induced bending moments, M_W in kNm, along the ship length is given in Figure 7.2.2.3(2), where:

$$M_{W-Hog} = +1.5 f_R L^3 C C_W \left(\frac{B}{L} \right)^{0.8} f_{NL-Hog}$$

$$M_{W-Sag} = -1.5 f_R L^3 C C_W \left(\frac{B}{L} \right)^{0.8} f_{NL-Sag}$$

where: f_R — factor related to the operational profile, to be taken as:

$f_R = 0.85$;

f_{NL-Hog} — non-linear corrosion for hogging, to be taken as:

$$f_{NL-Hog} = 0.3 \frac{C_B}{C_W} \sqrt{d}, \text{ and not more than } 1.1;$$

f_{NL-Sag} — non-linear corrosion for sagging, to be taken as:

$$f_{NL-Sag} = 4.5 \frac{1 + 0.2 f_{Bow}}{C_W \sqrt{C_B} L^{0.3}}, \text{ and not less than } 1.0;$$

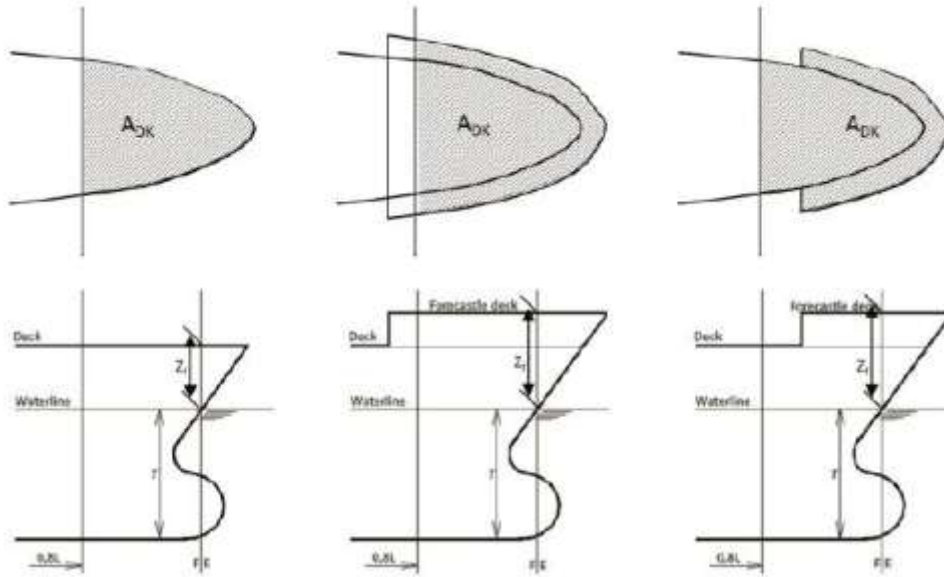
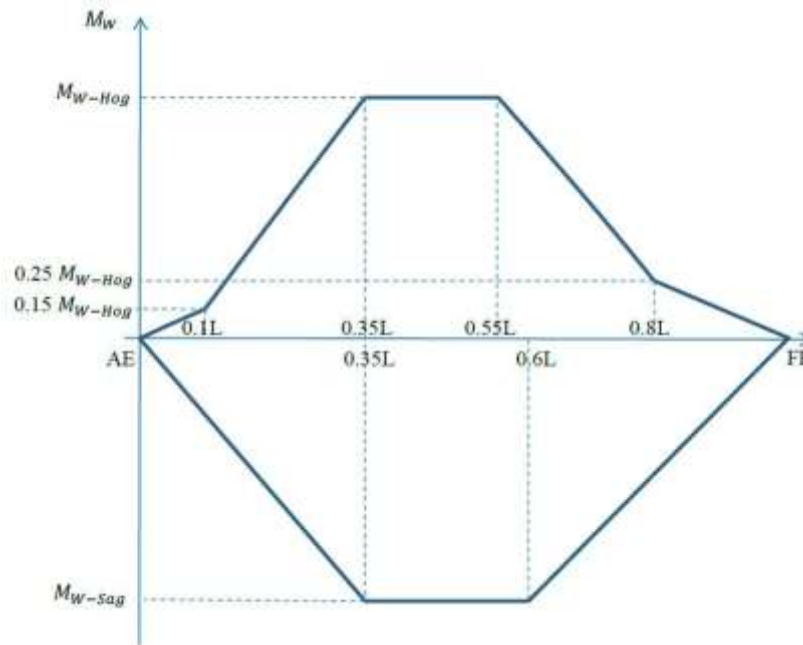
f_{Bow} — bow flare shape coefficient, to be taken as:

$$f_{Bow} = \frac{A_{DK} - A_{WL}}{0.2 L z_f};$$

A_{DK} — projected area in horizontal plane of uppermost deck, in m^2 , including the forecastle deck, if any, extending from $0.8L$ forward (see Figure 7.2.2.3(1)). Any other structures, e.g. plated bulwark, are to be excluded;

A_{WL} — waterplane area, in m^2 , at draught T , extending from $0.8L$ forward;

z_f — vertical distance, in m, from the waterline at draught d to the uppermost deck (or forecastle deck), measured at FE (see Figure 7.2.2.3(1)). Any other structures, e.g. plated bulwark, are to be excluded


 Figure 6.2.2.3(1) Projected area ADK and vertical distance zf

 Figure 6.2.2.3(2) Distribution of vertical wave bending moment M_W along the ship length

(3) Vertical wave shear force

The distribution of the vertical wave induced shear forces, F_W in kN, along the ship length is given in Figure 7.2.2.3(3), where,

$$F_{W_{Hog}}^{Aft} = +5.2 f_R L^2 C C_W \left(\frac{B}{L} \right)^{0.8} (0.3 + 0.7 f_{NL-Hog})$$

$$F_{W_{Hog}}^{Fore} = -5.7 f_R L^2 C C_W \left(\frac{B}{L} \right)^{0.8} f_{NL-Hog}$$

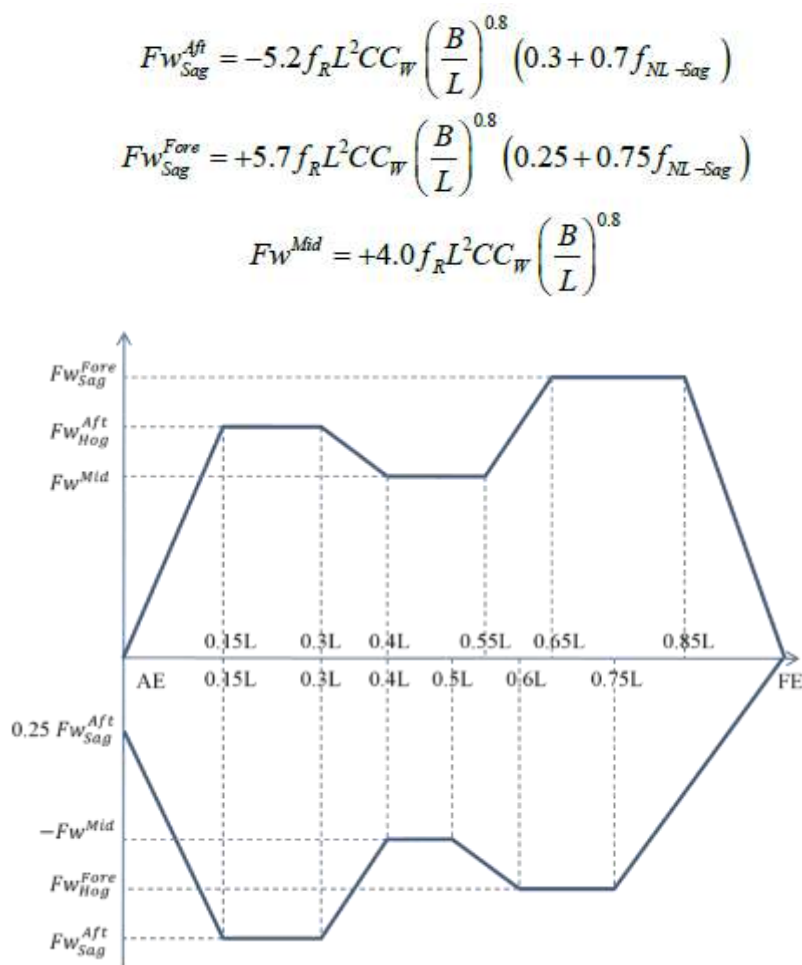


Figure 6.2.2.3(3) Distribution of vertical wave shear force FW along the ship length

6.2.2.4 Load cases

For the strength assessment, the maximum hogging and sagging load cases given in Table 7.2.2.4 are to be checked. For each load case the still water condition at each section as defined in 7.2.2.2 is to be combined with the wave condition as defined in 7.2.2.3, refer also to Figure 7.2.2.4.

Table 6.2.2.4 - Combination of still water and wave bending moments and shear forces

Load Case	Bending Moment		Shear Force	
	MS	MW	FS	FW
Hogging	MSmax	MWH	FSmax for $x \leq 0.5L$	FWmax for $x \leq 0.5L$
			FSmin for $x > 0.5L$	FWmin for $x > 0.5L$
Sagging	MSmin	MWS	FSmin for $x \leq 0.5L$	FWmin for $x \leq 0.5L$
			FSmax for $x > 0.5L$	FWmax for $x > 0.5L$

Notes:

MWH: Wave bending moment in *hogging* at the cross section under consideration, to be taken as the positive value of *MW* as defined in Figure 7.2.2.3(2).

MWS: Wave bending moment in *sagging* at the cross section under consideration, to be taken as the negative value of *MW* as defined in Figure 7.2.2.3(2).

FWmax: Maximum value of the wave shear force at the cross section under consideration, to be taken as the positive value of *FW* as defined in Figure 7.2.2.3(3).

FWmin: Minimum value of the wave shear force at the cross section under consideration, to be taken as the negative value of *FW* as defined in Figure 7.2.2.3(3).

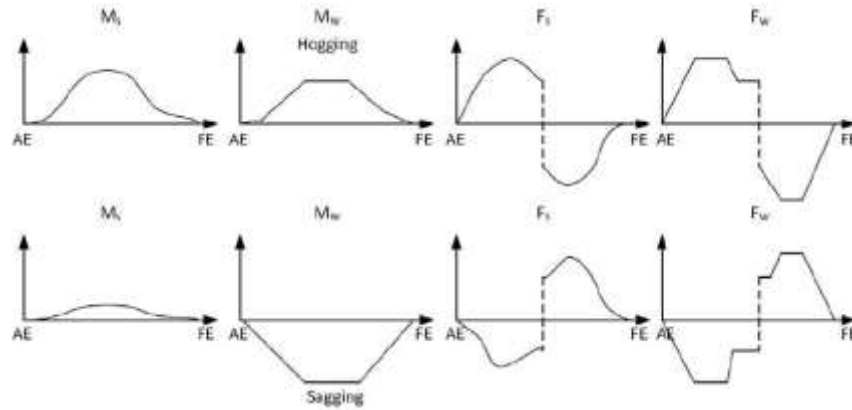


Figure 6.2.2.4 Load combination to determine the maximum hogging and sagging load cases as given in Table 6.2.2.4

6.2.2.5 Hull girder stress

The hull girder stresses, in N/mm², are to be determined at the load calculation point under consideration, for the “hogging” and “sagging” load cases defined in 7.2.2.4 as follows:

Bending stress:

$$\tau_{HG} = \frac{\gamma_S F_S + \gamma_W F_W}{t_{net} / q_v} 10^3$$

Shear stress:

$$\sigma_{HG} = \frac{\gamma_S M_S + \gamma_W M_W}{I_{net}} (z - z_n) 10^{-3}$$

where: γ_S, γ_W — partial safety factor, to be taken as:

$$\gamma_S = 1.0$$

$$\gamma_W = 1.0$$

6.2.3 Strength assessment

6.2.3.1 General requirements

Continuity of structure is to be maintained throughout the length of the ship. Where significant changes in structural arrangement occur adequate transitional structure is to be provided.

6.2.3.2 Stiffness criterion

The two load cases “hogging” and “sagging” as listed in 6.2.2.4 are to be checked.

The net moment of inertia, I_{net} , m⁴, is not to be less than:

$$I_{net} \geq 1.55L |M_S + M_W| 10^{-7}$$

6.2.3.3 Yield strength assessment

(1) General acceptance criteria

The yield strength assessment is to check, for each of the load cases “hogging” and “sagging” as defined in 6.2.2.4, that the equivalent hull girder stress σ_{eq} , in N/mm², is less than the permissible stress σ_{perm} , in N/mm², as follows:

$$\sigma_{eq} < \sigma_{perm}$$

where:

$$\sigma_{eq} = \sqrt{\sigma_x^2 + 3\tau^2}$$

$$\sigma_{perm} = \frac{R_{eH}}{\gamma_1 \gamma_2}$$

γ_1 — partial safety factor for material, to be taken as $\gamma_1 = K \frac{R_{eH}}{235}$;

γ_2 — partial safety factor for load combinations and permissible stress, to be taken as:

- $\gamma_2 = 1.24$, for bending strength assessment according to 7.2.3.3(2);
- $\gamma_2 = 1.13$, for shear stress assessment according to 7.2.3.3(3).

(2) Bending strength assessment

The assessment of the bending stresses is to be carried out according to 7.2.3.3(1) at the following locations of the cross section:

- at bottom;
- at deck;
- at top of hatch coaming;
- at any point where there is a change of steel yield strength.

The following combination of hull girder stress as defined in 7.2.2.5 is to be considered:

$$\sigma_x = \sigma_{HG}$$

$$\tau = 0$$

(3) Shear strength assessment

The assessment of shear stress is to be carried out according to 7.2.3.3(1) for all structural elements that contribute to the shear strength capability.

The following combination of hull girder stress as defined in 6.2.2.5 is to be considered:

$$\sigma_x = 0$$

$$\tau = \tau_{HG}$$

6.2.4 Buckling strength

6.2.4.1 Application

These requirements apply to plate panels and longitudinal stiffeners subject to hull girder positive bending and shear stresses. For the positive stress acted on plate panels and longitudinal stiffeners induced by hull girder bending, the buckling strength is to be taken into account only when the positive stress is the compression stress.

Definitions of symbols are given in Appendix 4 “Buckling Capacity”.

6.2.4.2 Buckling criteria

The acceptance criterion for the buckling assessment is defined as follows:

$$\eta_{act} \leq 1$$

where: η_{act} — maximum utilisation factor as defined in 6.2.4.3.

6.2.4.3 Buckling utilisation factor

The utilisation factor, η_{act} , is defined as the inverse of the stress multiplication factor at failure γ_c , see Figure 6.2.4.3

$$\eta_{act} = \frac{1}{\gamma_c}$$

Failure limit states are defined in:

- Appendix 4 of this Chapter, 2 for elementary plate panels;
- Appendix 4 of this Chapter, 3 for overall stiffened panels;
- Appendix 4 of this Chapter, 4 for longitudinal stiffeners.

Each failure limit state is defined by an equation, and γ_c is to be determined such that it satisfies the equation.

Figure 6.2.4.3 illustrates how the stress multiplication factor at failure γ_c , of a structural member is determined for any combination of longitudinal and shear stress, where:

σ_x, τ — applied stress combination for buckling given in 6.2.4.4(1);

σ_c, τ_c — critical buckling stresses to be obtained according to Appendix 4 of this Chapter for the stress combination for buckling σ_x and τ .

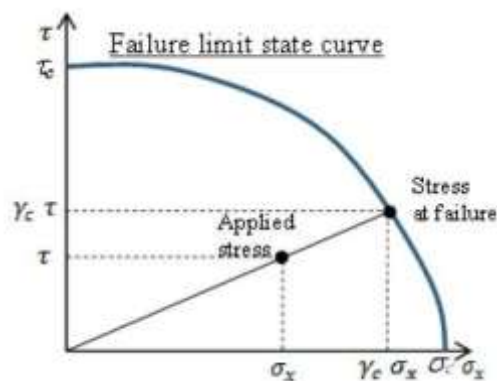


Figure 7.2.4.3 Example of failure limit state curve and stress multiplication factor at failure

6.2.4.4 Stress determination

(1) Stress combinations for buckling assessment

The following two stress combinations are to be considered for each of the load cases “hogging” and “sagging” as defined in 6.2.2.4. The stresses are to be derived at the load calculation points defined in 6.2.4.4(2).

(a) Longitudinal stiffening arrangement:

Stress combination 1 with:

$$\begin{aligned}\sigma_x &= -\sigma_{HG} \\ \sigma_y &= 0 \\ \tau &= 0.7\tau_{HG}\end{aligned}$$

Stress combination 2 with:

$$\begin{aligned}\sigma_x &= -0.7\sigma_{HG} \\ \sigma_y &= 0 \\ \tau &= \tau_{HG}\end{aligned}$$

(b) Transverse stiffening arrangement:

Stress combination 1 with:

$$\begin{aligned}\sigma_x &= 0 \\ \sigma_y &= -\sigma_{HG} \\ \tau &= 0.7\tau_{HG}\end{aligned}$$

Stress combination 2 with:

$$\begin{aligned}\sigma_x &= 0 \\ \sigma_y &= -0.7\sigma_{HG} \\ \tau &= \tau_{HG}\end{aligned}$$

(2) Load calculation points

The hull girder stresses for elementary plate panels (EPP) are to be calculated at the load calculation points defined in Table 7.2.4.4.

Table 6.2.4.4 - Load calculation points (LCP) coordinates for plate buckling assessment

LCP Coordinates	Hull Girder Bending Stress		Hull Girder Shear Stress
	Non horizontal plating	Horizontal plating	
x ordinate	Middle length of the EPP		
y coordinate	Both upper and lower ends of EPP (points A1 and A2 in Figure 7.2.4.4)	Outboard and inboard ends of EPP (points A1 and A2 in Figure 7.2.4.4)	Middle point of EPP (Point B in Figure 7.2.4.4)
z coordinate	Corresponding to x and y values		

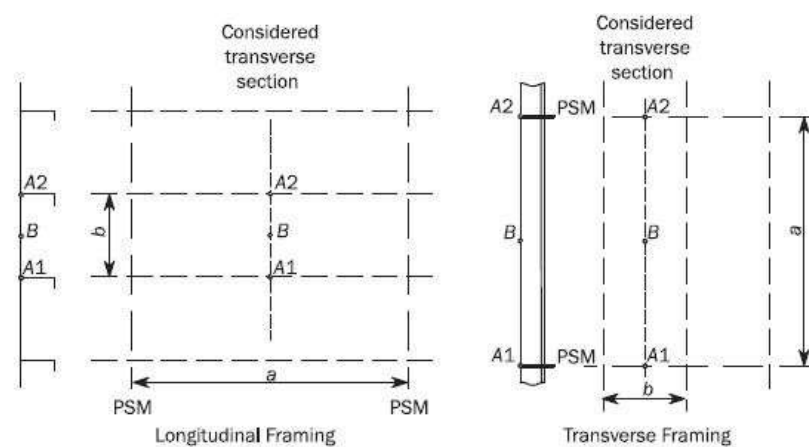


Figure 6.2.4.4 LCP for plate buckling assessment (PSM stands for primary supporting members)
The hull girder stresses for longitudinal stiffeners are to be calculated at the following load calculation point:

- at the mid length of the considered stiffener;
- at the intersection point between the stiffener and its attached plate.

6.2.5 Hull girder ultimate strength

6.2.5.1 General requirements

The hull girder ultimate strength is to be assessed for ships with length L equal to or greater than 150 m. The acceptance criteria, given in 6.2.5.4 are applicable to intact ship structures.

The hull girder ultimate bending capacity is to be checked for the load cases “hogging” and “sagging” as defined in 6.2.2.4.

6.2.5.2 Hull girder ultimate bending moments

The vertical hull girder bending moment, M in hogging and sagging conditions, to be considered in the ultimate strength check is to be taken as:

$$M = \gamma_S M_S + \gamma_W M_W$$

where: M_S — permissible still water bending moment, in kNm, defined in 7.2.2.2;

M_W — vertical wave bending moment, in kNm, defined in 7.2.2.3;

γ_S — partial safety factor for the still water bending moment, to be taken as: $\gamma_S = 1.0$;

γ_W — partial safety factor for the vertical wave bending moment, to be taken as: $\gamma_W = 1.2$.

6.2.5.3 Hull girder ultimate bending capacity

(1) General requirements

The hull girder ultimate bending moment capacity, M_U is defined as the maximum bending moment capacity of the hull girder beyond which the hull structure collapses.

(2) Determination of hull girder ultimate bending moment capacity

The ultimate bending moment capacities of a hull girder transverse section, in hogging and sagging conditions, are defined as the maximum values of the curve of bending moment M versus the curvature χ of the transverse section considered (M_{UH} for hogging condition and M_{US} for sagging condition, see Figure 6.2.5.3). The curvature χ is positive for hogging condition and negative for sagging condition.

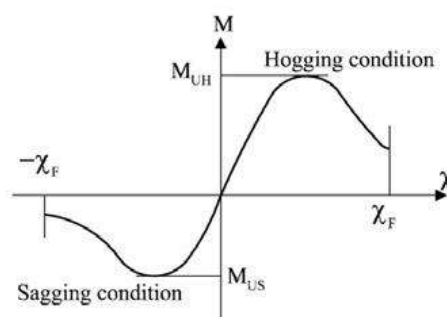


Figure 6.2.5.3 Bending moment M versus curvature χ

The hull girder ultimate bending moment capacity M_U is to be calculated using the incremental-iterative method as given in Appendix 5 of this Chapter or using an alternative method as indicated in Appendix 5.

6.2.5.4 Acceptance criteria

The hull girder ultimate bending capacity at any hull transverse section is to satisfy the following criteria:

$$M \leq \frac{M_U}{\gamma_M \gamma_{DB}}$$

where:	M — vertical bending moment, in kN·m, to be obtained as specified in 7.2.5.2
	M_U — hull girder ultimate bending capacity, in kN·m, to be obtained as specified in 7.2.5.3;

γ_M — partial safety factor for the hull girder ultimate bending capacity, covering material, geometric and strength prediction uncertainties, to be taken as:

$$\gamma_M = 1.05;$$

γ_{DB} — partial safety factor for the hull girder ultimate bending moment capacity, covering the effect of double bottom bending, to be taken as:

- for hogging condition: $\gamma_{DB} = 1.15$;
- for sagging condition: $\gamma_{DB} = 1.0$.

For cross sections where the double bottom breadth of the inner bottom is less than that at amidships or where the double bottom structure differs from that at amidships (e.g. engine room sections), the factor γ_{DB} for hogging condition may be reduced based upon agreement with ISC.

6.2.6 Additional requirements for large container ships

6.2.6.1 General requirements

The requirements of 6.2.6.2 and 6.2.6.3 are applicable, in addition to requirements of 6.2.3 to 6.2.5, to container ships with a breadth B greater than 32.26 m.

6.2.6.2 Yielding and buckling assessment

Yielding and buckling assessments are to be carried out taking into consideration additional hull girder loads (wave torsion, wave horizontal bending and static cargo torque), as well as local loads. All in-plane stress components (i.e. bi-axial and shear stresses) induced by hull girder loads and local loads are to be considered. See 3 of appendix 2 to this Chapter for detailed analysis methods.

6.2.6.3 Whipping

Hull girder ultimate strength assessment is to take into consideration the whipping contribution to the vertical bending moment. For detailed methods, see ISC Guidelines for Direct Calculation Assessment of Hull Structure Including Springing and Whipping.

SECTION 3 - DECK STRUCTURE

6.3.1 General requirements

6.3.1.1 In addition to the requirements of Sections 4 and 8, Chapter 2 of this PART, the scantlings of the deck structure are to comply with the requirements for the longitudinal strength in Section 2 of Chapter 2 of this PART and Section 2 of this Chapter.

6.3.1.2 The strength deck throughout the region of container holds is to be longitudinally framed and the scantlings of the structural members of the strength deck determined in accordance with the hull section modulus required in Section 2 of Chapter 2 of this PART and Section 2 of this Chapter are to be kept unchanged over the region of container holds.

6.3.1.3 In order to ensure the hull structural strength, particular attention is to be paid to continuity of the deck structure and abrupt changes of shape, section or plate thickness are to be avoided. Effective transition arrangements are to be fitted at both end structures of the deck opening length. Arrangement in way of hatch corners and openings are to be such as to minimize the creation of stress concentrations.

6.3.1.4 Where the difference between the thicknesses of plating inside and outside the line of strength deck openings exceeds 12 mm, a transition plate with a thickness equal to the mean of the adjacent plate thicknesses is to be fitted.

6.3.1.5 Where the lower deck acts as a primary support for the side framing, the deck plating thickness may be required to be suitably increased.

6.3.2 Cross deck strips

6.3.2.1 Where the cross deck strips of the strength deck form the top of a transverse bulkhead, their breadth b is not to be less than that obtained from the following formula:

$$b = 1000 + 1.5L \text{ mm}$$

where: L — length of ship, in m.

6.3.2.2 Where a transverse bulkhead top box is fitted, a reduced width of cross deck strips of the strength deck may be considered by calculation as appropriate.

6.3.2.3 In addition to complying with the requirement of 2.4.2.2, Chapter 2 of this PART, the thickness t of cross deck strips of the strength deck is not to be less than that obtained from the following formula:

$$t = 10 + 0.01L \text{ mm}$$

where: L — length of ship, in m.

6.3.2.4 The thickness t of cross deck strips of the second tier deck below the strength deck is not to be less than that obtained from the following formula, but not less than 8 mm:

$$t = 12s \text{ mm}$$

where: s — spacing of beams, in m, to be taken as not less than the standard spacing of beams.

6.3.2.5 The thickness of cross deck strips of other decks below the second tier deck may be 8 mm.

6.3.2.6 The cross deck strips are to be sufficiently stiffened in the transverse direction, and the thickness of the strips is to be increased locally in way of stress concentration.

6.3.2.7 The ends of cross deck strips are to be effectively connected to the torsion box structures.

6.3.3 Strength deck girders

6.3.3.1 Girders supporting the longitudinal coaming plating are to be fitted under the strength deck (except where torsion box structures are fitted).

6.3.3.2 The strength deck girders are to be continuous throughout the container hold area, including the engine room where this is situated between container holds.

6.3.3.3 The ends of strength deck girders are to be integrated into the structures outside the container hold area. Special consideration is to be given to the connection of the girders with the transverse box girders.

6.3.4 Deck openings

6.3.4.1 The corners of hatchway openings in the strength deck are to be rounded. The radius of hatch corners near the ship's sides is not to be less than $0.35 + 0.0005L$ m (L being the length of ship, in m), and the radius of hatch corners in way of the intersection of deck girders with cross deck strips is not to be less than 0.25 m. For rounded corners with negative radii, the designer is to provide technical reasons.

6.3.4.2 The radius of the hatch corners of the cargo hatchway openings adjacent to the engine room is to be made as large as practicable, with a radius of approximately $0.04B$ mm (B being the breadth of ship, in m).

6.3.4.3 Insert plates are required at the hatch corners and to have a thickness increased by 15% above that of the strength deck plating. For container holds adjacent to the engine room, such insert plates are to be increased in thickness by 25% above that of the strength deck plating but not less by 4 mm and not more than 7 mm, and they are to be made of the same material as the strength deck. If the thickness of the insert plate can not meet above requirements, direct calculation method covering yield, buckling and fatigue is to be adopted for verification. The extension of the insert plates is to comply with Figure 7.3.4.3 (R is the radius of hatch corner, e is not to be less than 760 mm and for longitudinal framing, not to be less than one longitudinal spacing).

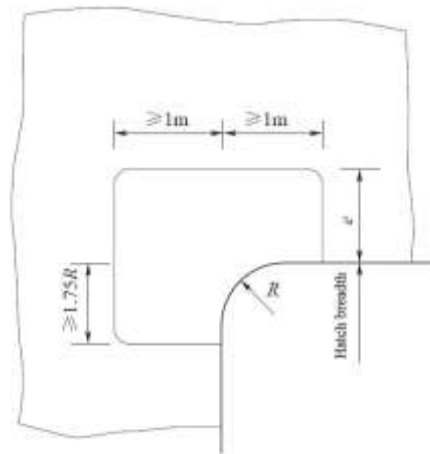


Figure 6.3.4.3

6.3.4.4 Openings are generally not to be arranged in the strength deck outside the line of hatch openings in the region of container holds.

6.3.5 Hatch coamings

6.3.5.1 Where the hatch coaming is to be continuous over the entire opening area, the ends of the coaming are to have an appropriate structural transition.

6.3.5.2 The structure of hatch coamings is to comply with the relevant requirements in Section 20 of Chapter 2 of this PART.

SECTION 4 - SHELL PLATING

6.4.1 Bottom plating and bilge strakes

6.4.1.1 In addition to the requirements of Section 3 of Chapter 2 of this PART, the thickness of bottom plating is to comply with the requirements for longitudinal strength in Section 2 of Chapter 2 of this PART and Section 2 of this Chapter. 6.4.1.2 For transversely framed bottom plating and bilge strakes, special attention is to be paid to their buckling strength.

6.4.2 Sheer strake and side shell plating

6.4.2.1 In addition to the relevant requirements of Section 3 of Chapter 2 of this PART, the thickness of sheer strake and side shell plating is to comply with the requirements for longitudinal strength in Section 2 of Chapter 2 of this PART and Section 2 of this Chapter. At positions where high forces are present and at positions of the side shell plating where the double side skin structures terminate, local increases in thickness may be required.

6.4.2.2 The difference in thickness between the sheer strake and the shell plating below is not to exceed 1/2 of the thickness of sheer strake.

SECTION 5 - SIDE FRAMING

6.5.1 Single side skin framing

6.5.1.1 The arrangement and the scantlings of side framing are to comply with the requirements of Section 7, Chapter 2 of this PART. ISC may require that direct calculation be carried out for checking the strength of the primary supporting members.

6.5.1.2 Where longitudinal side framing is adopted, the web frames are to be arranged in line with the solid floors in the double bottom and the transverse frames in the torsion box to form a ring system so as to ensure the transverse strength of the ship.

6.5.2 Double side skin framing

6.5.2.1 The minimum plate thickness t of transverse frames and horizontal flats (including perforated flats) within the double side skin construction is not to be less than that obtained from the following formula, but need not be greater than 9 mm:

$$t = 7.5 + 0.015L \text{ mm}$$

where: L — length of ship, in m.

6.5.2.2 Transverse frames and horizontal flats are to be fitted with stiffening members and their thickness is to be increased locally where high shear forces are present.

SECTION 6 - DOUBLE BOTTOM

6.6.1 General requirements

6.6.1.1 Unless otherwise stated by this Section, the scantlings of structural members of double bottom are to comply with the relevant provisions of Section 6, Chapter 2 of this PART, but local stiffening is to be required under container corner seatings. Where the double bottom is interconnected with side tanks or deep cofferdams, the watertight floors and watertight girders are to comply with the requirements for deep tanks in Section 13 of Chapter 2 of this PART.

6.6.1.2 The requirements of 2.6.9.2(2), Section 6, Chapter 2 of this PART do not apply to the cargo holds carrying containers only.

6.6.1.3 For container ships of 150 m and over in length, the double bottom structure may comply with the requirements of 7.9.10 of this Chapter, except 6.9.10.12.

6.6.2 Girders and floors

6.6.2.1 Side girders are to be arranged under container corner seatings.

6.6.2.2 Vertical or horizontal stiffeners are to be fitted for girders in region of container holds, the height of stiffener is normally not less than 150 mm. When the length of ship is less than 150 m, the height of stiffener is not to be less than L (mm) but not less than 50 mm.

6.6.2.3 For double bottoms longitudinally framed, solid floors are to be fitted under transverse bulkheads and below mid-hold or quarter-length-of-hold supporting structures.

6.6.2.4 The thickness of solid floors in region of container holds is to comply with the following requirements:

(1) The thickness t of solid floor is not to be less than the value obtained from the following formula, but need not be greater than 12 mm:

$$t = 0.6\sqrt{LK} + 2.5 \text{ mm}$$

where: L — length of ship;

K — material factor.

(2) In addition to complying with the requirements of (1) of this paragraph, the thickness t of watertight floors is not to be less than that obtained from the following formula:

$$t = 0.02L\sqrt{K} + 7 \text{ mm}$$

where: L and K are defined in (1) of this paragraph.

6.6.2.5 For longitudinally framed containership, the thickness t of the centre girders in region of container holds is not to be less than:

$$t = f_{db} (0.0077h_0 + 4)\sqrt{K} \text{ mm}$$

The thickness t of side girder in region of container holds is not to be less than the value obtained from the following formula:

$$t = f_{db} (0.0077h_0 + 1)\sqrt{K} \text{ mm}$$

where: f_{db} — correction factor of height of double bottom;

$f_{db} = 1$ when $L < 150\text{m}$;

$f_{db} = h_0/h_a$ when $L \geq 150\text{m}$, but not to be less than 0.9; Where the longitudinal girder complies with the requirements for direct calculation of global strength of ship in Appendix 2, $f_{db} =$

h_0/h_a but not to be less than 0.85.

h_0 — considered height of double bottom, in mm, see Section 6 of Chapter 2;

h_a — actual height of double bottom, in mm;

K — material factor.

6.6.2.6 Where container holds are fitted between engine room and aft peak tank, the primary members at bottom are to comply with relevant requirements in Section 6, Chapter 2 of this PART.

6.6.2.7 For double bottom framed longitudinally and fitted with center girders, brackets leading to adjacent longitudinals are to be fitted respectively at both sides of the center girder between the solid floors.

6.6.2.8 Where torsion box center girder is used for double bottom framed longitudinally, the arrangement and the section modulus of web frame ring are to comply with relevant requirements

of 6.9.10.6 of Section 9 of this Chapter.

6.6.3 Supporting structure of double bottom

6.6.3.1 Where mid-hold or quarter-length-of-hold supports for the double bottom structure are arranged, these are to take the form of an efficiently stiffened transverse box or other equivalent structures.

SECTION 7 – BULKHEADS

6.7.1 Inner skin longitudinal bulkheads

6.7.1.1 In addition to the relevant requirements of Sections 12 and 13 of Chapter 2 of this PART, the scantlings of inner skin longitudinal bulkheads are to comply with the requirements for longitudinal strength in Section 2 of Chapter 2 of this PART and Section 2 of this Chapter.

6.7.1.2 The longitudinal members of inner skin longitudinal bulkheads are to be continuous throughout the container hold area and maintained continuous in way of the machinery space where this is situated between container holds.

6.7.1.3 Where the inner skin bulkheads are stepped, the scarfing arrangements in way of the steps are to be sufficient to ensure an efficient overlap having a length of not less than 3 frame spacings for transition.

6.7.1.4 Adequate transition arrangements are to be fitted at both ends of the inner skin longitudinal bulkhead.

6.7.1.5 The difference in thickness between the top strake and the bulkhead plating below (at the torsion box) is not to exceed 25 mm.

6.7.2 Watertight transverse bulkheads

6.7.2.1 In general, a transverse box structure is to be arranged at the top and bottom of watertight transverse bulkheads. In addition, vertical webs and horizontal girders are to be fitted on the bulkheads to support bulkhead stiffeners. The upper and lower ends of vertical webs are to be aligned with strength deck girders and double bottom side girders respectively. Where the depth to breadth ratio of the bulkhead is large, the scantlings of such vertical webs are to be determined by direct calculation.

SECTION 8 - BOW SIDE STRUCTURE STRENGTHENING

6.8.1 General requirements

6.8.1.1 The bow (including forecastle) side structure is to be strengthened within $0.1L$ aft of the fore perpendicular above the summer load line. Where the maximum flare angle α at $0.15L$ from forward perpendicular (see Figure 6.8.1.3(1)) is greater than 40 degrees, the strengthened longitudinal extent is to be extended to $0.15L$ from forward perpendicular. The scantlings of side

members in the strengthened area are to comply with the requirements of this Section.

6.8.1.2 In addition to the requirements of this Section, the bow side structure is to comply with the other relevant requirements in this PART.

6.8.1.3 The bow slamming head h_s under consideration is to be obtained from the following formula:

$$h_s = C_s (0.22 + 0.15 \tan \alpha) (0.4V \sin \beta + 0.6\sqrt{L})^2 \quad \text{m}$$

where: $C_s = 0.144 (C - 0.5h_1)$, and not to be greater than 0.8;

where: h_1 — vertical distance between summer load line and the point under consideration, in m, see Figure 7.8.1.3(1). For shell plating, the point is to be taken at centre of plate panel; for members, the point is to be taken at mid-span;

C — coefficient of wave, see 2.2.3.1 of this PART;

α — flare angle at the point under consideration, defined as angle ($^\circ$) between vertical line and shell plating tangent in the cross section, see Figure 7.8.1.3(1);

β — entrance angle at the point under consideration, defined as angle ($^\circ$) between centreline and shell plating tangent in the horizontal plane, see Figure 7.8.1.3(2);

V — maximum service speed, in kn;

L — length of ship, in m, but need not be taken as greater than 250 m.

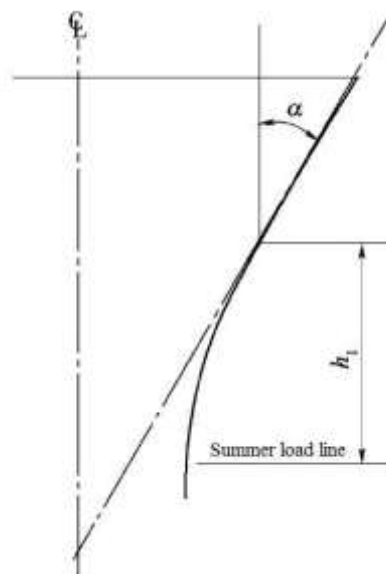


Figure 6.8.1.3(1)

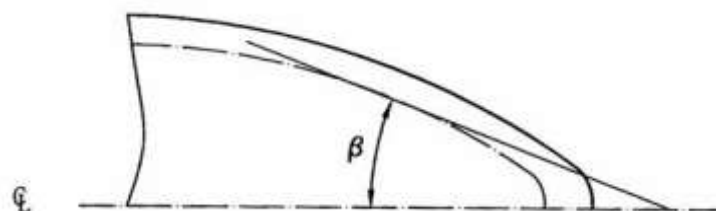


Figure 6.8.1.3(2)

6.8.2 Shell plating

6.8.2.1 The thickness t of shell plating is not to be less than that obtained from the following formula:

$$t = 3.2 b_{r1} s \sqrt{h_s K} + 1.5 \text{ mm}$$

where: b_{r1} — coefficient, to be taken from the following, and not to be less than 0.72:

$$b_{r1} = 1.0 \quad \frac{s}{l} \leq 0.4$$

$$b_{r1} = 1.187 - 0.467 \frac{s}{l} \quad \frac{s}{l} > 0.4$$

where: s — spacing of secondary members, in m;

l — span of secondary member, in m;

h_s — bow slamming head under consideration, see 7.8.1.3 of this Section;

K — material factor.

6.8.3 Secondary members

6.8.3.1 The section modulus W and the web sectional area A of secondary members such as side longitudinals or side frames are not to be less than those obtained from the following formulae:

$$W = 2.7 s h_s l^2 K \text{ cm}^3$$

$$A = 0.38 b_{r2} l s h_s K \text{ cm}^2$$

$$b_{r2} = 1 - \frac{s}{2l};$$

where:

s — spacing of secondary members, in m;

h_s — bow slamming head under consideration, see 7.8.1.3 of this Section;

l — span of secondary member, in m;

K — material factor.

6.8.3.2 Where the angle between web plating and shell plating of secondary members such as side longitudinals or side frames is less than 70°, tripping brackets are to be provided at mid-span of the members to improve the transverse stability of plate panels.

6.8.4 Primary members

6.8.4.1 The section modulus W and the web sectional area A of primary members such as side horizontal girders or vertical webs are not to be less than those obtained from the following formulae:

$$W = 2.1 S h_s l^2 K \text{ cm}^3$$

$$A = 0.265 S h_s l K \text{ cm}^2$$

where: S — spacing of girders or webs, in m;

h_s — bow slamming head under consideration, see 7.8.1.3 of this Section;

l — span of girder or web, in m;

K — material factor.

SECTION 9 - ADDITIONAL REQUIREMENTS FOR CONTAINER SHIPS OF GREATER THAN 250 M IN LENGTH

6.9.1 General requirements

6.9.1.1 This Section applies to large full container ships of more than 250 m in length.

6.9.1.2 Those not covered in this Section are to comply with the relevant requirements of Chapters 1 and 2 of this PART.

6.9.1.3 The bow (including forecastle) side structure strengthening is to comply with the requirements of Section 8 of this Chapter.

6.9.2 Longitudinal strength

6.9.2.1 The longitudinal strength is to comply with the requirements of Section 2 of this Chapter.

6.9.3 Deck structure

6.9.3.1 The deck structure is to comply with the relevant requirements of Sections 4 and 8, Chapter 2 of this PART.

6.9.3.2 The primary members of the deck structures in the region of container holds are to be verified by direct calculations.

6.9.3.3 The minimum thickness $t_{\min}$ of strength deck is to be calculated by the following formula:

$$t_{\min} = (0.02L + 5.5)\sqrt{K} \quad \text{mm}$$

where: L — length of ship, in m;

K — material factor.

6.9.3.4 Where the difference between the thicknesses of plating inside and outside the line of strength deck openings is large, two intermediate transition plates are at least to be fitted inside the line of opening.

The difference between the thicknesses of adjacent plates, in general not exceeding 1/2 of the thickness of the thicker plate, is to be gradually reduced towards the inside of the line of opening. In general the higher edge of the thicker plate is tapered in way of connections with a ratio not more than 1:4.

6.9.4 Box cross deck structure

6.9.4.1 The box cross deck structure means the transverse box girder structure at the top of transverse bulkheads of container holds.

6.9.4.2 The width and structural scantling of box cross deck structure are to be verified by direct calculations.

6.9.4.3 During the initial design, the width of box cross deck structure may be calculated by the following formula:

$$b = \max (32.5B+400, 1000) \text{ mm}$$

where: B — breadth of ship, in m.

6.9.4.4 In the strength deck plane, the minimum deck thickness of box cross deck structure is to be calculated by the following formula:

$$t = (10 + 0.01L)\sqrt{K} \text{ mm, but not to be less than 12 mm}$$

where: L — length of ship, in m, L need not be taken as greater than 300 m in calculation;

K — material factor.

6.9.4.5 The minimum thickness of bottom plating of box cross deck structure is to be calculated by the following formula:

$$t = 10s\sqrt{K} \text{ mm, but not less than 8 mm}$$

where: s — spacing of stiffeners, in m, to be taken not less than 0.95 m in calculation;

K — material factor.

6.9.4.6 The side plating of box cross deck structure (see Figure 7.9.4.6) is to comply with the following requirements:

(1) The thickness t_1 of side plating is not to be less than that obtained from the following formula:

$$t_1 = 12s \text{ mm, but not less than 10.5 mm}$$

where: s — spacing of stiffeners of side plating, in m.

(2) The thickness t_2 of the end insert plate is not to be less than that obtained from the following formula:

$$t_2 = 12s \text{ mm, but not less than 14.5 mm}$$

where: s — spacing of stiffeners of side plating, in m.

(3) The minimum scope of end insert plate is calculated by the following formulae:

$$a_1 = 1.75R \text{ m}$$

$$a_2 = 0.5b_s \text{ m}$$

where: R — radius of the hatch corners of the cargo hatchway opening in the strength deck plane, in m;

b_s — width of double side skin, in m.

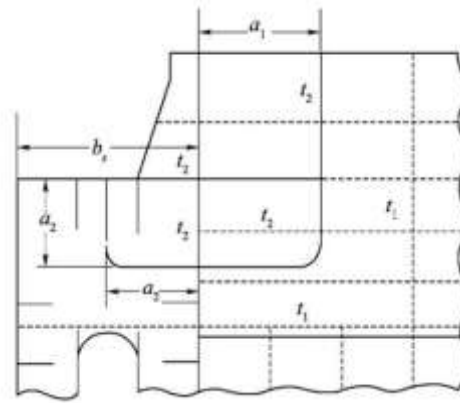


Figure 6.9.4.6

6.9.5 Strength deck openings

6.9.5.1 The corners of hatchway opening in the strength deck are to be rounded or rounded corners with negative radii. The design of hatch corners is to be verified by direct calculations.

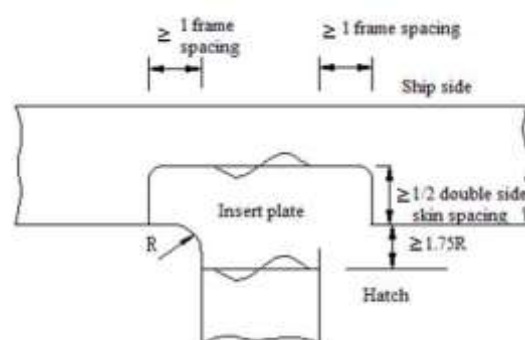
6.9.5.2 For rounded corners near the ship's sides, their radius is not to be less than that obtained from the following formula:

$$R = 0.35 + 0.0005L \text{ m}$$

where: L — length of ship, in m.

6.9.5.3 The radius of rounded corners in way of the intersection of deck girders with box cross deck structures is not to be less than 0.25 m.

6.9.5.4 For strength deck, insert plates are required at the hatch corners, generally extending to the extent not less than the requirements of Figure 7.9.5.4. The thickness of insert plates is to be greater than or equal to that of adjacent strength deck. The strengthening of the strength deck at the hatch corners is to be verified by means of fatigue assessment.



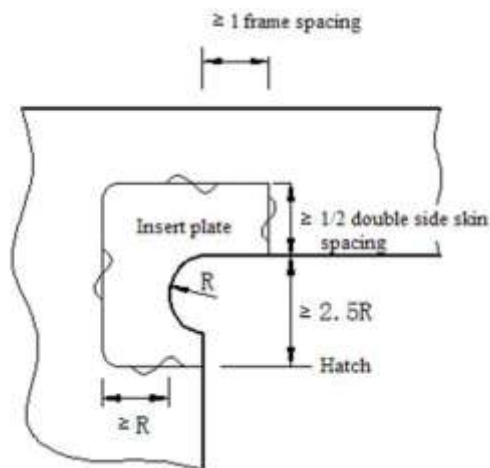


Figure 7.9.5.4

6.9.5.5 Large access openings are generally not to be arranged in the strength deck outside the line of hatch openings in the region of container holds.

6.9.5.6 Small openings, such as those for ventilation pipes or scuppers, are to be kept clear of hatch corners, ends of longitudinal hatch coamings, ends of box cross deck structures and other locations of stress concentration.

6.9.6 Hatch coamings of container hold

6.9.6.1 The hatch coaming is to be continuous over the entire opening area except for the engine room area. The ends of the coaming are to have an appropriate structural transition.

6.9.6.2 The structure of coaming is to comply with relevant requirements of Section 20 of Chapter 2 of this PART.

6.9.6.3 Hatch coamings are to be provided with brackets spaced not more than 3.15 m apart, and they are also to be provided with face plates. However, the spacing between brackets is not to exceed 6.3 m upon direct strength calculation. The brackets of hatch coamings are to be capable of effectively supporting the face plates. The toe ends of brackets are to terminate at the strength deck longitudinals. Brackets of hatch coamings in way of box cross deck structures are also to comply with 7.9.4.6 of this Section.

6.9.6.4 For face plates of hatch coamings, insert plates are required at the hatch corners, and the scope is shown in Figure 7.9.6.4. The thickness of insert plates is to be greater than or equal to that of adjacent face plates of hatch coamings. The strengthening of face plates of hatch coamings at hatch corners is to be verified by means of fatigue assessment.

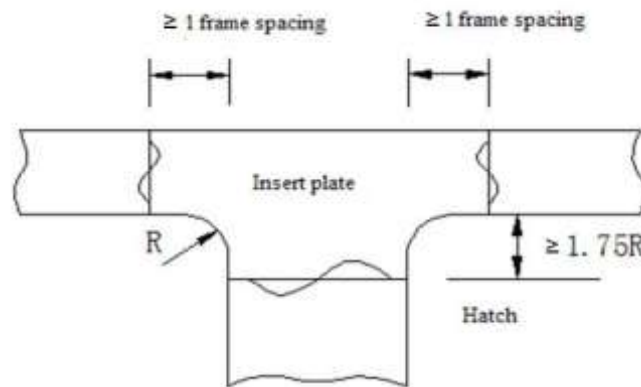


Figure 7.9.6.4

6.9.7 Shell plating

6.9.7.1 Except where stated by this Section, the shell plating is to comply with relevant requirements of Section 3, Chapter 2 of this PART.

6.9.7.2 In addition to 7.9.7.1 of this Section, the thickness of shell plating is not to be less than that obtained from the following formula:

$$t = \sqrt{LK} \text{ mm, but need not be greater than 16 mm}$$

where: L — length of ship, in m;

K — material factor.

6.9.7.3 The difference in thickness between the sheer strake and the adjacent shell plating is in general not to exceed 1/2 of the thickness of the thicker plate. In general the higher edge of the thicker plate is tapered in way of connections with a ratio not more than 1:4.

6.9.8 Structural arrangement of double side skin construction

6.9.8.1 Double side skins are to be fitted throughout the container hold area. The inner skin structure is to extend as far forward and aft as possible and effectively connected with the structures in way with adequate transition arrangements. The supporting members of inner skin are to be fitted in the double side skin, instead of in the container hold.

6.9.8.2 The inner skin is to be of continuous construction, and also maintained continuous in way of the engine room area. The inner skin may be stepped along the ship's length, considering the change of lines and arrangement of container bays. The scarfing arrangements in way of the steps are to be sufficient to ensure an efficient overlap of inner skin bulkheads having a length of not less than 3 frame spacings for transition.

6.9.8.3 Considering the change of lines and arrangement of container bays, the inner skin may be stepped horizontally in the vertical direction.

6.9.8.4 A transverse ring structure or vertical web is to be provided in line with the transverse watertight bulkheads of container holds in the double side skin. Watertight vertical webs are to be provided as far as practicable below the freeboard deck. Wash bulkheads are to be provided for ballast tanks.

6.9.8.5 A transverse ring structure or vertical web is to be provided in line with the transverse non-watertight pillar bulkheads of container holds in the double side skin.

6.9.8.6 A transverse ring structure or vertical web in the double side skin is to be provided in line with the floors in the double bottom.

6.9.8.7 Manholes are to be provided in vertical webs and horizontal girders. The manholes may either be round or elliptical. The long axis of elliptical manholes is to be vertical or along the length of the ship.

Except for access openings, the holes on upper and lower adjacent horizontal girders are not to be on the same vertical line. The edge around the holes is to be strengthened.

6.9.9 Scantling of double side skin construction

6.9.9.1 The primary members of double side skin construction include side shell platings, vertical transverse webs, horizontal flats, inner skin longitudinal bulkhead platings. The scantling of primary members is to be verified by direct calculations.

6.9.9.2 The inner skin plating is to comply with the following requirements:

(1) The minimum thickness t of inner skin plating is to be calculated by the following formula:

$$t = 7 + 0.02L\sqrt{K} \quad \text{mm}$$

where: L — length of ship, in m, L need not be taken as greater than 300 m in calculation;
 K — material factor.

(2) The inner skin plating is to comply with the requirements of 7.9.11.4 of this Section.

(3) The thickness t of inner skin plating forming boundary of tanks within $0.4 L$ amidships is, in addition to complying with the requirement of (4), not to be less than:

$$t = \left(4 + 0.6 \frac{z - z_n}{D - z_n}\right) s \sqrt{hK} + 2.5 \quad \text{mm, below the horizontal neutral axis}$$

$$t = \left(4 + 0.2 \frac{z_n - z}{z_n}\right) s \sqrt{F_b hK} + 2.5 \quad \text{mm, above the horizontal neutral axis}$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, measured from a third of the height from the lower edge of the plate in a strake to the top of the tank, or half the distance to the top of overflow, whichever is the greater;

D — moulded depth, in m;

Z_n — the height of horizontal neutral axis, from base line, of hull cross section, in m;
 Z — the height of calculation point from base line, in m;
 F_b — reduction factor, see 2.2.5.6, Chapter 2 of this PART;
 K — material factor.

- (4) The thickness t of inner skin plating forming boundary of tanks is not to be less than:

$$t = 4s\sqrt{hK} + 2.5 \quad \text{mm}$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, measured from a third of the height from the lower edge of the plate in a strake to the top of the tank, or half the distance to the top of overflow, whichever is the greater;

K — material factor.

- (5) The difference in thickness between the top strake of inner skin and the strake below is in general not to exceed 25 mm, and the maximum difference in thickness is not to exceed 35 mm. In general the higher edge of the thicker plate is tapered in way of connections with a ratio not more than 1:4.

6.9.9.3 Longitudinals (ship's side, inner skin) are to comply with relevant requirements of Chapter 2 of this PART. The minimum thickness of webs of longitudinals is 10 mm. Longitudinals are to penetrate continuously vertical transverse webs. Where side longitudinals are determined according to 2.7.5.1, Chapter 2 of this PART, the calculated pressure head h is to be obtained from following formulae:

$$\begin{aligned}
 h &= 0.26C + d - \frac{Z}{D_F}d \quad \text{m, if } Z < D_F \\
 h &= 0.2C + 0.06C \frac{D - Z}{D - D_F} \quad \text{m, if } Z \geq D_F
 \end{aligned}$$

where: D — moulded depth, in m;

D_F — minimum moulded depth, in m, in the middle of ship length, vertical distance from upper edge of flat keel to upper edge of side freeboard deck beam;

d — draught, in m;

C — coefficient, see 2.2.3.1, Chapter 2 of this PART;

Z — height of longitudinal to baseline, in m.

6.9.9.4 The thickness t of vertical transverse webs and horizontal flats forming boundary of tank is not to be less than:

$$t = 4s\sqrt{hK} + 2.5 \quad \text{mm}$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, measured from a third of the height from the lower edge of the plate in a strake to the top of the tank, or half the distance to the top of overflow, whichever is the greater;

K — material factor.

The minimum thickness of vertical transverse webs and horizontal flats is to be 10 mm. The minimum thickness of watertight flats is 11 mm.

6.9.10 Double bottom

6.9.10.1 Except where stated by this Section, the double bottom structure is to comply with the relevant requirements of Section 6, Chapter 2 of this PART.

6.9.10.2 The primary members of double bottom include inner bottom platings, solid floors, girders and bottom platings. The scantlings and arrangements of primary members are to be verified by direct calculations.

6.9.10.3 Where mid-hold or quarter-length-of-hold supports for the double bottom structure are arranged, these are to take the form of an efficiently stiffened transverse box or open section structure.

6.9.10.4 The side plates of the duct keel are in general not to be spaced more than 2 m apart; However, where the direct strength assessment has been carried out, the maximum spacing between the side plates are not to be greater than 3 m.

6.9.10.5 Bottom and inner bottom longitudinals are to be fitted within the region of duct keels. The longitudinals are to be maintained continuous. The bottom longitudinals at the center line of the ship are to be suitably increased in scantling.

6.9.10.6 A strength frame ring is to be provided to the duct keel in the plane of solid floors and the middle of spacing of solid floors. For transverse girders of inner bottom in the strength frame ring, their section modulus is not to be less than 85% of those of ship's bottom. The section modulus W of transverse girders of ship's bottom is not to be less than that obtained from the following formula:

$$W = 10.6 S d l^2 K \text{ cm}^3$$

where: S — spacing of the strength frame ring, in m;

d — draught, in m, to be taken not less than 0.66 times the vertical distance from the ship's bottom to the freeboard deck;

l — span, in m, to be taken as the spacing between two side plates;

K — material factor.

6.9.10.7 At least three side girders spaced apart generally not more than 3.5 m are to be fitted on each side of the centreline. Forward of $0.2L$ from the F.P., the spacing of side girders is not to be greater than 4 longitudinal spaces. Side girders are to be equally spaced and extend forward and aft as far as practicable.

6.9.10.8 Side girders are to be arranged and local stiffening is to be required under container corner seatings.

6.9.10.9 Solid floors in the region of container holds are to comply with the following requirements:

(1) Solid floors are to be fitted under transverse watertight bulkheads, transverse non-watertight pillar bulkheads/mid-hold supports, under container corners at hold quarter length locations and at other locations. Solid floors are in general to be spaced not more than 3.6 m apart.

(2) The thickness t of solid floors is to comply with relevant requirements of Section 6 of this Chapter and not to be less than that obtained from the following formula:

$$t = 10s \sqrt{\frac{R_{eH}}{235}} + 2.5 \quad \text{mm}$$

where: s — spacing of stiffeners, in m;

R_{eH} — yield stress of the material, in N/mm².

(3) In addition to complying with the requirements of (2) of this paragraph, the thickness t of watertight floors is to comply with relevant requirements of Section 6 of this Chapter.

6.9.10.10 The thickness t of inner bottom plating of container holds is not to be less than that obtained from the following formula:

$$t = 1.36(s + 0.66)^4 \sqrt{LdK^2} \quad \text{mm}$$

where: L — length of ship, in m;

d — draught, in m;

s — spacing of longitudinals, in m;

K — material factor.

The thickness t of inner bottom plating of container holds forming boundary of tanks is also to comply with the requirements for deep tanks in Section 13, Chapter 2 of this PART.

6.9.10.11 The section modulus W of inner bottom longitudinals of container holds is not to be less than that obtained from the following formula:

$$W = \frac{9.54ds l^2 K}{2.1 - F_b} \quad \text{cm}^3$$

where: s — spacing of longitudinals, in m;

l — span of longitudinals, in m;

d — draught, in m;

F_b — reduction factor at calculation point;

K — material factor.

6.9.10.12 Strengthening of bottom forward is to comply with the relevant requirements of 2.15.3 of Section 15, Chapter 2 of this PART. In the strengthening region, for the strengthening of double bottom framed longitudinally, 2.15.3.3(1) of Section 15, Chapter 2 of this PART may not be required, but the spacing of plate floors is not to exceed 3.2 m or 4 times the spacing of longitudinals (whichever is the greater).

6.9.10.13 The thickness of center girders and side girders in region of container holds and the arrangement of supporting bracket of center girders are to comply with relevant requirements of Section 6 of this Chapter.

6.9.11 Transverse bulkhead of container hold

6.9.11.1 The primary members of transverse bulkhead include bulkhead platings, vertical webs and horizontal girders. The scantling of primary members is to be verified by direct calculations.

6.9.11.2 The web thickness t of girders of transverse bulkhead is not to be less than that obtained from the following formula:

$$t = 10s \sqrt{\frac{R_e H}{235}} + 0.5 \quad \text{mm, and not less than 9 mm}$$

where: s — spacing of web stiffeners, in m;

$R_e H$ — yield stress of the material, in N/mm².

6.9.11.3 In general, a transverse box structure is to be arranged at the top and bottom of watertight transverse bulkheads. In addition, vertical webs and horizontal girders are to be fitted on the bulkheads to support bulkhead stiffeners. The upper and lower ends of vertical webs are to be aligned with strength deck girders and double bottom side girders respectively.

6.9.11.4 The scantlings of watertight transverse bulkhead platings and stiffeners are to be determined in accordance with the requirements of Section 12, Chapter 2 of this PART. The design head h is to be determined in accordance with the following requirements:

- (1) For watertight transverse bulkhead platings, the design head h is to be determined in accordance with the following requirements (whichever is the greatest):
 - ① vertical distance measured from the lower edge of the plate in a strake to the deepest equilibrium waterline obtained from the applicable damage stability calculations;
 - ② vertical distance measured from the lower edge of the plate in a strake to the freeboard deck;
 - ③ 2.5 m.
- (2) For stiffeners, the design head h is to be determined in accordance with the following requirements (whichever is the greatest):
 - ① vertical distance measured from the mid-span of stiffeners to the deepest equilibrium waterline obtained from the applicable damage stability calculations;
 - ② vertical distance measured from the mid-span of stiffeners to the freeboard deck;
 - ③ 2 m.

6.9.11.5 The minimum thickness of watertight transverse bulkhead platings is 8 mm.

6.9.11.6 One non-watertight transverse pillar bulkhead is to be fitted at every two 20 feet container bays along the ship's length in the container hold. The non-watertight transverse pillar bulkhead generally consists of vertical webs and horizontal girders.

6.9.12 Design verification

6.9.12.1 Except where otherwise stated, the design verification is not to lower the requirements for hull structures of this Section. The design verification of hull structures includes:

- (1) direct calculation of strength assessment;
- (2) fatigue strength assessment.

6.9.12.2 Direct calculations are to be carried out for strength assessment of the whole ship, primary structures of cargo holds and local structure of deck hatch corner under specified loads in accordance with Appendix 2 of this Chapter.

6.9.12.3 Fatigue strength assessment is to be carried out to the container hold structures in accordance with ISC Guidelines for Fatigue Strength of Ship Structure.

SECTION 10 - LONGITUDINAL STRENGTH OF COMBINED BENDING AND TORSIONAL MOMENTS FOR SHIPS WITH LARGE OPENINGS

6.10.1 General requirements

6.10.1.1 For ships with large openings on deck, the longitudinal strength of combined bending and torsional moments is to be checked by the following:

- (1) for length $L \leq 250$ m, the method defined in this Section or the method defined in (2);
- (2) for length $L > 250$ m, the direct strength calculation of whole ship defined in Appendix 2;

6.10.1.2 Stresses are to be calculated for at least seven transverse sections in the cargo area as follows:

- (1) at the forward end of the engine room;
- (2) at the forward end of the opening length, opening length being the distance from the aft end of the cargo hatch before the engine room to the forward end of the foremost cargo hatch;
- (3) at five intermediate sections within the opening length, at least three of which are to be within $0.4L$ amidships. The intermediate sections are to be arranged as far as possible in way of abrupt changes of longitudinal structures.

6.10.1.3 In addition, the stresses at transverse sections in way of abrupt changes of any other longitudinal structures beyond the requirements of 7.10.1.2 of this Section are to be calculated.

6.10.2 Wave bending moment

6.10.2.1 The vertical wave bending moment M_v is to be calculated by the following formula:

$$M_v = 9.81MKFL^2B(C_b + 0.7) \times 10^{-2} \quad \text{kN}\cdot\text{m}$$

where: L — length of ship, in m;

B — breadth of ship, in m;

M — distribution factor of bending moment, see 2.2.3.1 of Section 2, Chapter 2

of this PART;

C_b — block coefficient, taken as 0.6 for actual C_b less than 0.6;

$$K = 4.47 \left(\frac{L}{1000} - 0.230 \right)^2 + 0.817$$

F—factor, obtained from the following formulae:

$$F = 9.4 - 0.95 \left(\frac{300 - L}{100} \right)^{3/2}, \text{ for } L \leq 300 \text{ m};$$

$$F = 9.4, \text{ for } 300 < L < 350 \text{ m};$$

$$F = 9.4 - 0.45 \left(\frac{L - 350}{100} \right)^{3/2}, \text{ for } 350 \leq L \leq 500 \text{ m}.$$

6.10.2.2 The midship horizontal wave bending moment M_H is to be calculated by the following formula:

$$M_H = 0.431 L^2 B \quad \text{kN} \cdot \text{m}$$

where: L, B — see 7.10.2.1 of this Section.

M_H is equal to zero at ends, and the distribution of M_H along the length of the ship is to follow a straight line.

6.10.3 Torque

6.10.3.1 The hydrodynamic torque $MT(x)$ at any cross section along the length of the ship is to be calculated by the following formula:

$$M_T(x) = 9.81 e^{-0.00295L} \frac{LB^3 C_T}{20000} \left(1.75 + 1.5 \frac{\varepsilon}{D} \right) \left(1 - \cos \frac{2\pi}{L} x \right) \quad \text{kN} \cdot \text{m}$$

where: e — base of natural logarithms;

L — length of ship, in m;

B — breadth of ship, in m;

D — moulded depth, in m;

$$C_T = 13.2 - 43.4 C_W + 78.9 C_W^2;$$

where: C_W — the water plane area coefficient, need not be greater than $0.165 + 0.95 C_b$;

ε — the distance measured from the shear centre below the baseline of the ship to the baseline, in m;

x — distance from any one cross-section to A.P., in m;

C_b — block coefficient, see 7.10.2.1 of this Section.

6.10.3.2 Cargo torque is caused by the uneven transverse distribution of cargoes, consumables or ballast. Unless any other loading case is specified, the cargo torque M_{TC} amidships is to be calculated by the following formula:

$$M_{TC} = 15.7 B n_B n_t \quad \text{kN} \cdot \text{m}$$

where: B — breadth of ship, in m;

n_B — number of stacks of containers in cargo holds amidships along the breadth of ship;

n_t — number of tiers of containers in cargo holds amidships, excluding the containers on deck and on hatch covers.

MTC is equal to zero at ends and the distribution of MTC along the length of the ship is to follow a straight line.

6.10.4 Stress calculation and criteria

6.10.4.1 The still water bending stresses σ_s is to be calculated by the following formula:

$$\sigma_s = \frac{M_s}{W_v} \times 10^3 \quad \text{N/mm}^2$$

where:

M_s — permissible still water bending moment, in kN·m;

W_v — vertical bending section modulus at deck or bottom, in cm³, to be calculated in accordance with the relevant requirements of Section 2, Chapter 2 of this PART.

The permissible still water bending stress $[\sigma_s]$ at strength deck and keel is $88/K$, in N/mm², where K is material factor.

6.10.4.2 The combined vertical bending stress σ_c for ships under the heading wave condition is to be calculated by the following formula:

$$\sigma_c = \frac{M_s + M_v}{W_v} \times 10^3 \quad \text{N/mm}^2$$

where: M_s , W_v — same as defined in 6.10.4.1 of this Section;

M_v — vertical wave bending moment, in kN·m, see 7.10.2.1 of this Section.

The permissible combined vertical bending stress $[\sigma_c]$ is $157/K$ at the strength deck, in N/mm² and $150/K$ at the keel, in N/mm², where K is referred to 7.10.4.1.

6.10.4.3 The combined stress for ships under the oblique sea condition is to be the sum of the following stresses:

(1) The combined vertical bending stress σ_c is to be determined by the following formula:

$$\sigma_c = \frac{M_s + 0.6M_v}{W_v} \times 10^3 \quad \text{N/mm}^2$$

where: M_s , W_v — same as defined in 7.10.4.1 of this Section;

M_v — see 7.10.2.1 of this Section.

(2) The horizontal bending stress σ_H is to be determined by the following formula:

$$\sigma_H = \frac{yM_H}{I_H} \times 10^5 \quad \text{N/mm}^2$$

where: M_H — horizontal wave bending moment, in kN·m, see 7.10.2.2 of this Section;

y — horizontal distance from the point under consideration to centreline of the transverse section, in m;

I_H — horizontal moment of inertia, in cm⁴.

(3) The warping stress due to the hydrodynamic torque MT and cargo torque MTC .

The permissible combined stresses at strength deck and bottom is $157/K$, in N/mm^2 , where K is referred to 6.10.4.1.

APPENDIX 1 CONTAINER SECURING

1 General Requirements

1.1 Application

1.1.1 Container stowage and securing requirements in this Appendix are based on containers manufactured in compliance with ISO 1496-1:2013.

This Appendix sets forth the survey requirements for the initial installation of container securing systems aboard vessels classed by ISC. It is to be clearly understood that no representation is made as to the ability of any container to withstand the loads allowed. The allowable loads have been derived from successful usage over a number of years and may exceed the design loads set forth in ISO Standard. It is the responsibility of the shipowner, or operator to ascertain that the containers used in the system can withstand the loads applied to them.

1.1.2 External dimensions, rated weights and corner fitting locations for common freight containers are given in Table 1.1.2.

Table 1.1.2 - External Dimensions, Rated Weights and Corner Fitting Locations for Common Freight Containers^①

Nominal Size	Standard	Container Designation	Length (mm)	Width (mm)	Height (mm)	Dimensions Center to Center of Corner Fittings (longitudinal) (mm)	Dimensions Center to Center of Corner Fittings (transverse) (mm)	Rated Weight (kg)
20 ft	ISO 668	1CC	6058	2438	2591	5853	2259	30480 (24000) ^②
		1C	6058	2438	2591	5853	2259	30480
		1CX	6058	<2438	2591	5853	2259	30480
40 ft	ISO 668	1AAA	12192	2438	2896	11985	2259	30480
		1AA	12192	2591	2591	11985	2259	30480
		1A	12192	2438	2591	11985	2259	30480
		1AX	12192	<2438	2591	11985	2259	30480
45 ft	ISO 668	1EEE	13716	2438	2896	13509	2259	30480
		1EE	13716	2591	2591	13509	2259	30480
43 ft	—	—	13103	2438	2591	11985	2259	30480
48 ft	—	—	14630	2591	2908	14422	2259	30480
53 ft	—	—	16154	2591	2908	15947	2259	30480

Notes: ^① The statistics of containers of ISO standard in the Table are determined according to ISO 668:2013.

^② The rated weight for containers of 20 ft manufactured in accordance with the previous version of Amd 1:2005 of ISO 668:1995 is 24,000 kg. In the design of securing system, the recommended weights of empty containers are as follows:

20 ft container 2.5 t

40 ft container	3.5 t
43 ft and 45 ft container	4.0 t
48 ft and 53 ft container	4.5 t

1.2 Class notation

1.2.1 Ships other than container ships, fitted with container securing arrangements complying with the requirements of 1 to 5 of this Appendix, will be assigned the class notation “Equipped with Container Securing Arrangements”.

1.2.2 Where the ship has onboard container lashing program which has the ability to evaluate the safety of container stowage and lashing arrangement according to the requirements of 1 to 4 of this Appendix, and the lashing program is installed and maintained in accordance with the requirements of 6 of this Appendix, the notation CLC may be assigned upon application by the shipowner.

1.2.3 In addition to the requirements for CLC, the notation CLC(V) may be assigned, taking into account of the requirements for specific routes in 7.1 of this Appendix.

1.2.4 In addition to the requirements for CLC(V), the notation CLC(V,W) may be assigned, taking into account of the seasons and weather factors of specific routes in 7.2 of this Appendix.

1.3 Plans and documents

1.3.1 The following plans and documents are to be submitted for approval:

- (1) General arrangement plan showing the disposition and design weights of the containers;
- (2) Details of the cell guide structure, where fitted;
- (3) Plans of lashing bridges, where fitted;
- (4) Plans of stanchions on the deck, where fitted;
- (5) Plans of securing arrangements of containers not associated with cell guides, where fitted;
- (6) Details of securing devices (fixed and portable equipment, including safe working load);
- (7) Arrangement plan of fixed securing devices and plan of hull supporting structure;
- (8) Container securing manual/arrangement plan (container securing manual/arrangement plan approved by ISC is to be kept on board).

1.4 Limitation on ship handling

Improper ship handling related to course and speed or threshold phenomena like parametric rolling can create adverse loads acting on the ship and the cargo which are in excess of the loads determined on the basis of 4 of this Appendix. It is the responsibility of the master to apply good seamanship in order to mitigate excessive ship motions to reduce loads acting on the cargo stowage arrangements.

1.5 Definitions

1.5.1 **Bay:** An indication of the longitudinal position of a stack on ship. An athwartship block of containers associated with a hatch or hatch cover containing multiple stacks (or rows).

1.5.2 Cell Guides: A rigid securing system of vertical steel angles, spaced with some margin on container length and width that provides alignment and horizontal restraint for container stacks.

1.5.3 Container Block: A number of container stacks interconnected by double cones and/or bridge fittings.

1.5.4 Container Stack: A single vertical stack of containers which may be secured by lock fittings, lock fittings plus lashings, or cell guides.

1.5.5 Corner Fitting: A fixture, typically a casting, consisting of standard apertures and faces, which provide a common interface for handling and securing containers. It is an integral part of the container end frame structure and is generally in compliance with ISO Standard 1161. A similar fitting can also be found at intermediate posts located some distance from the end frame structure (such as at the 40-ft location on a 45-ft container).

1.5.6 Corner Post: Reinforced vertical structure between the corner fittings at the ends of containers designed to take the compressive and tensile forces exerted by lifting, stacking, and securing. Some containers also have intermediate 'corner' posts located some distance in from their ends at a nominal 40-ft spacing.

1.5.7 Design Breaking Load: The design breaking load of a component is determined by prototype testing. The design breaking load is not to be more than the last load recorded during the test prior to failure.

1.5.8 Design GM Value: The *GM* values used in the lashing calculations of containers are determined by the designer and specified in the container securing manual/arrangement plan. At least the minimum value and the maximum value are to be included. The minimum value is not to be less than the *GM* value in the condition where the maximum number of containers is loaded and the maximum value is not to be less than the maximum value of all expected container loading conditions. In the initial design, the minimum design *GM* value may be taken as $0.025B$, and the maximum design *GM* value may be taken as $0.075B$, where *B* is the breadth of the ship.

1.5.9 ISO Freight Container: Containers meeting the design dimensions and rated weights of ISO container standards such as:

ISO 1496-1 Series 1 freight containers ISO 668 External dimensions and ratings ISO 1161 Corner fittings and specifications

1.5.10 Lashing Assembly: A tension element made-up of a rod, wire rope or chain, a tensioning device, and a lashing point; used to secure a stack of containers.

1.5.11 Lashing Point: Fittings welded to the deck, hatch cover, stanchion, and lashing bridge, connecting lashing devices to the vessel structure or hatch covers. These include D-rings, lashing eyes plates, etc.

1.5.12 Lashing Bridge: An athwartship, elevated platform on deck from which container stacks on the hatch covers or deck may be secured with lashing assemblies.

1.5.13 Safe Working Load (SWL): The SWL of a securing device is the design breaking load divided by an appropriate safety factor. The maximum resultant load upon a component is not to exceed the SWL.

1.5.14 Proof Load: A test load applied to a container securing device during production testing. The minimum proof load is to be determined according to Table 2.2.1.

1.5.15 Row/Stack: An indication of the transverse position of a container in a stack.

1.5.16 Racking: Distortion of the container end or side due to horizontal forces.

1.5.17 Securing Devices: The general name of all fixed and portable devices used to secure and support containers.

1.5.18 Tier: An indication of the vertical position of a container in a stack. The first tier is the lowest position in the stack.

1.5.19 Turnbuckle: A specific type of Tensioning Device, used to connect the lashing rod and the lashing point.

1.5.20 Twist lock: A fitting inserted into corner fittings and used to secure containers stacked on top of each other in tension, compression, and shear.

1.6 Special Requirements

1.6.1 For containers not covered by ISO Standard 1496-1 as well as special ways of containers arrangement, the securing of such containers is to be considered according to the parameters and allowable loads as specified in 4.8 of this Appendix.

2 Materials and Testing

2.1 Materials

2.1.1 Steels used for the construction of the cell guides and the fixed securing devices attached to the hull are to comply with the relevant requirements of ISC Rules for Materials and Welding.

2.2 Prototype testing

2.2.1 Except for cell guides, prototype tests are to be carried out to determine the breaking loads of securing devices. The testing is to be carried out on at least two randomly selected samples of each item. The relationship between design breaking load and safe working load is to be as indicated in Table 2.2.1.

No permanent deformation (other than that due to initial embedding of component parts) is to be induced by test loads up to the proof load given in the Table.

Table 2.2.1 = Design Breaking Loads and Proof Loads

Item	Min. Design Breaking Load (kN)		Min. Proof Load (kN)	
	SWL ≤ 400	SWL > 400	SWL ≤ 400	SWL > 400
Lashings:				
Wire rope	3 × SWL		1.5 × SWL	
Rod (higher tensile steel)	2 × SWL			
Chain (mild steel)	3 × SWL			
Chain (higher tensile steel)	2.5 × SWL			
Other securing devices	2 × SWL	SWL + 400	1.5 × SWL	SWL + 200

Notes: ① The yield stress of higher tensile steel is not to be less than 315 N/mm².

② Breaking and proof loads for lashings of material other than steel will be specially considered.

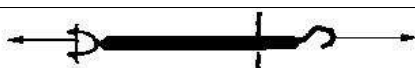
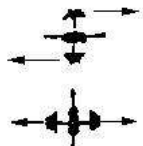
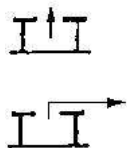
③ SWL means the safe working load, in kN.

2.2.2 Where one of the two test samples fails before the design breaking load is reached, an additional sample is to be tested. The prototype testing may be accepted provided that the following conditions are met:

- (1) The failure load is not less than 95% of the design breaking load;
- (2) An additional sample is tested satisfactorily;
- (3) The average failure load of the three samples, taking the additional sample into account, is not less than the design breaking load.

2.2.3 Securing devices may be tested in accordance with Table 2.2.3.

Table 2.2.3 - Test Mode

Securing Device	Test Mode	Recommended Minimum Value (kN)		
		SWL	Proof Load	Breaking Load
Lashing rod (higher tensile steel)		180	270	360
Lashing rod		250	375	500
Lashing chain (higher tensile steel)		80	—	200
Lashing chain		100	—	300
Lashing wire		120	—	360
Turnbuckle		250	375	500
Twist lock		200	300	400
		250	375	500
Cone		200	300	400
Embedded stacking device		250	375	500
Stacking device		250	375	500
		200	300	400
D-ring		250	375	500
Lashing eye plate		250	375	500
Buttress		SWL is to be the individual calculation result of the stowage arrangement and test load is to be determined according to Table 2.2.1.		

2.3 Product testing

2.3.1 For production by a manufacturer in batches according to the plans and documents of the securing devices which have been accepted in the prototype testing, such products are to be subjected to testing according to one of the following requirements.

- (1) Batch testing: For securing devices except for chain or wire rope lashings, one randomly selected sample from every 50 pieces, or from each batch if less than 50 pieces, is to be proof loaded to 1.5 times the safe working load. For chain or wire rope lashings, one randomly selected sample from every 50 pieces, or from each batch if less than 50 pieces, is to be tested to breaking.
- (2) Individual testing: Every securing device is to be proof loaded to the safe working load of the item. In addition, one randomly selected sample from every batch of chain or wire rope lashings is to be tested to breaking prior to delivery.

2.3.2 For production test carried out in accordance with 2.3.1(1) of this Appendix, permanent deformation will not be accepted within the range of loading up to:

- (1) $1.5 \times SWL$, where $SWL < 250 \text{ kN}$; (2) $SWL + 125$, where $SWL \geq 250 \text{ kN}$.

2.3.3 In the event of premature failure or serious plastic deformation occurring in a test sample, two further samples are to be selected for testing. In the event that these samples are found to be satisfactory, the associated batch may be accepted.

2.3.4 For production test carried out in accordance with 2.3.1(2) of this Appendix, permanent deformation will not be accepted.

3 Stowage and Securing of Containers

3.1 General requirements

3.1.1 Containers are to be secured by one, or a combination of the following systems: corner locking devices, lashings, cell guides, buttresses, shores or equivalent structural restraint.

3.1.2 The method of securing containers is to be determined by calculating the forces acting on the containers in accordance with 4 of this Appendix and is to be capable of ensuring the strength of containers and securing devices.

3.2 Arrangements for stowage and securing on exposed decks

3.2.1 The stowage of containers on exposed decks is to satisfy the following requirements.

- (1) The arrangements are to be such as to permit safe access for personnel in the necessary working of the ship, and to provide sufficient access for installation and inspection of the securing devices.
- (2) Containers stowed on deck or on hatch covers are generally to be aligned in the fore and after direction.
- (3) Containers are to be stowed so that they do not extend beyond the ship's side; adequate support is to be provided where they overhang hatch coamings or other deck structures.
- (4) Where containers are stowed on hatch covers, the covers are to be effectively restrained against sliding by approved type stoppers or equivalent.

3.2.2 The securing for containers stowed on the exposed deck is to comply with the following requirements:

- (1) Twist locks and/or lashing arrangements are to be used for securing containers.
- (2) In order to improve the lashing efficiency, the fixed lashing points can be arranged on the lashing bridge. In such case, the relative displacement between the structure of lashing bridge and the container stack is to be considered for calculating the lashing force.
- (3) Normally, the internal lashing type is to be used for securing, as shown in Figure 3.2.2(a). For the external lashing type as shown in Figure 3.2.2(b), when the corner fitting connected to the lashing rod is in tension, due to the clearance existing between the twist locks and the container corner fittings, the twist locks will not be subject to the pulling force until such clearance between the twist lock and corner fitting of container is closed. In such case, the lashing rod may be broken as a result of excessive pulling force. When the external lashing type is selected, this situation is to be considered in securing calculation. Where no actual data is available, 12 mm vertical clearance is to be considered for semi-automatic twist lock and 20 mm vertical clearance for automatic twist lock.

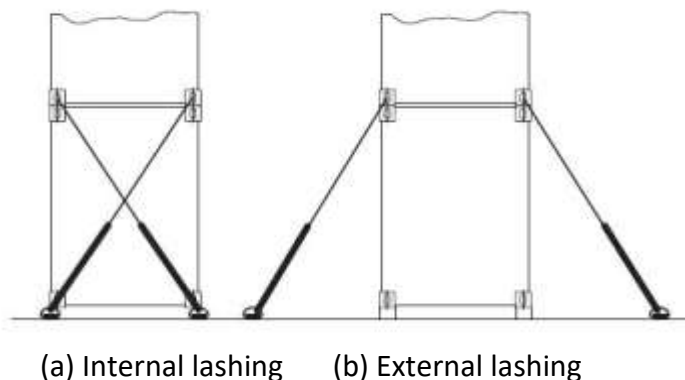


Figure 3.2.2 Internal lashing and external lashing

3.2.3 Cell guides may be used.

3.2.4 Up to a calculated remaining lifting force of 375 kN a vertical lashing can be applied for securing containers.

3.3 Arrangements for stowage and securing in holds

3.3.1 Without cell guides

- (1) Containers are generally to be stowed in holds and 'tween decks in the fore and after direction.
- (2) Containers may be secured by locking devices only or by a combination of locking devices, buttresses, shores or lashings, and the method of securing may be referred to 3.2 of this Appendix.
- (3) Where the calculations indicate that remaining lifting forces could occur at any particular level, twist locks are to be fitted at that level. Elsewhere, consideration will be given to the use of double stacking cones.
- (4) Where the calculations indicate that remaining lifting forces will not occur between containers at any level, consideration will be given to the use of double stacking cones in lieu of locking

devices throughout.

- (5) Buttresses are to be securely attached to the ship's structure. Where practicable, the attachment to the ship's structure is to include means for vertical adjustment of the buttresses to match container stacks of different heights.
- (6) Shores of the compression type only may be permanently attached to the ship's structure or they may be hinged or portable and the ship's structure in way is to be reinforced as necessary. The shores are to abut the container corner fittings with minimal clearance.
- (7) Adjacent stacks of containers are to be linked in line with buttresses or shores in order to transmit lateral loads, and the fittings used for these linkages are to be of adequate strength as buttresses or shores.
- (8) The ship's structure supporting shores and buttresses is to be reinforced as necessary.

3.3.2 Using cell guides

- (1) The cell guides are not to form an integral part of the ship's structure; the guide system is to be so designed as to keep it free from the main hull stresses.
- (2) Cell guides are to be of robust construction; they are to be designed to resist loads caused by loading and unloading of the containers, to prevent shifting of the containers and to transmit the loads caused by motions of the ship into the main hull structure. The thickness of guides is not to be less than 12 mm.

The allowable stresses of cell guides are to be as follows (ReH being the yield stress of the material, in N/mm²):

$$\text{Allowable shear stress: } [\tau] = 0.4ReH$$

$$\text{Allowable normal stress: } [\sigma] = 0.67ReH$$

- (3) Cell guides are generally to be fabricated from steel plate and rolled sections; the guides are to be adequately supported at their upper ends.
- (4) Athwartship cross ties are to be fitted between cell guides as a spacing determined from the loading on the guides but, generally, not more than 5 m apart. Wherever possible, cross ties are to be arranged in line with the corners of the containers as stowed and are to be supported against fore and after movement at a minimum of two points across the breadth of the hold. Where, however, the maximum fore and after deflection in the cross tie can be shown not to exceed 20 mm, then one support point may be accepted.
- (5) The intersection between cell guide and cross ties is to provide adequate torsional stability.
- (6) Intermediate brackets are to be fitted to vertical cell guides at suitable intervals.
- (7) Longitudinal tie bars may be required to be fitted where shown necessary by the force calculations for the structure. Where fitted, they are to comply with the requirements for spacing and deflection as specified in 3.3.2(4) of this Appendix.
- (8) Where, at the sides or ends of holds, the guide rails are fitted to transverse or longitudinal bulkheads, the bulkhead is to be locally reinforced to resist the additional loads.
- (9) The cell guides are to give a total clearance between the container and guide bars not exceeding 25 mm in the transverse direction and 40 mm in the longitudinal direction. Attention is to be given to the accuracy in fitting cell guides so as to ensure smooth loading and unloading of containers.
- (10) A device to pre-centre the container and direct it into the cell guides is to be of robust

construction, and is normally to be fitted at the top of the guide bars.

(11) Where containers of different height are stacked in the cargo holds, the horizontal force acting at the middle of each two cross ties needs to be considered for the strength of guides.

3.4 Mixed stacks of 20 ft and 40 ft containers

3.4.1 Where the cell guides are arranged for the carriage of 40 ft containers, provision may be made for the installation of temporary intermediate cell guides for 20 ft containers. The permanent structure is to be designed such that it is suitable for either loading pattern.

3.4.2 Alternatively, permanent means for the support of 20 ft containers at the mid-length of a cell arranged for 40 ft containers will be considered.

3.4.3 Where it is desired to stow 20 ft containers in the lower tiers without external support at the mid-bay location, the following requirements are to be complied with.

(1) Overall stacked container weights allowed for 20 ft containers stowed in cell guides with no 40 ft container overstowed can be derived from Tables 3.4.3(1) depending on the acceleration and the number of tiers in the stack.

(2) Overall stacked container weights allowed for 20 ft containers stowed in cell guides with at least one 40 ft container overstowed can be derived from Table 3.4.3(2) depending on the acceleration and the number of tiers in the stack.

(3) Racking forces acting on end walls of 20 ft containers stowed in the lowest tier at the mid-length of a cell arranged for 40 ft containers are not to exceed 185 kN. The orientation of the containers is to ensure as far as possible that all door ends or closed ends are facing in one direction. Weights listed in Table 3.4.3(1)

and Table 3.4.3(2) apply to 20 ft containers the maximum rated weight of which is 30,480 kg.

(4) Stacking cones are to be fitted between each tier of the 20 ft containers and between the 20 ft containers and bottom of the hold to prevent transverse sliding.

(5) Where fore and aft tension/pressure adapter cones are used to link two 20 ft containers to equate to a 40 ft container, the storage of 40 ft containers above is not required.

Table 3.4.3(1) - Stowage Weights of 20 ft Containers (t)

at (g) Tiers	0.3	0.31	0.32	0.33	0.34	0.35	0.36	0.37	0.38	0.39	0.4
12	168.0	163.5	158.4	153.6	149.1	144.9	140.8	137.0	133.4	129.9	126.7
11	168.8	163.4	158.2	153.5	148.9	144.0	140.7	136.9	133.3	129.8	126.0
10	168.4	163.0	157.9	153.1	148.6	144.3	140.3	136.5	133.0	129.5	126.3
9	167.4	162.0	156.9	152.2	147.7	143.5	139.5	135.7	132.1	128.8	125.5
8	166.7	161.3	156.3	151.5	147.1	142.9	138.9	135.1	131.6	128.2	125.0
7	166.4	161.0	156.0	151.3	146.8	142.6	138.7	134.9	131.4	128.0	124.8
6	164.0	159.5	154.5	149.8	145.4	141.2	137.3	133.6	130.1	126.7	123.6
5	152.5	152.5	152.5	149.3	144.9	140.8	136.9	133.2	129.7	126.4	123.0
4	122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0	121.5
3	91.5	91.5	91.5	91.0	91.5	91.5	91.5	91.5	91.5	91.5	91.5
2	61.0	51.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0

at (g) Tiers	0.41	0.42	0.43	0.44	0.45	0.46	0.47	0.48	0.49	0.5	0.51
12	123.0	120.7	117.9	115.2	112.6	110.2	107.8	105.6	103.4	101.4	99.4
11	123.5	120.6	117.8	115.1	112.5	110.1	107.7	105.5	103.3	101.3	99.3
10	123.2	120.5	117.5	114.8	112.3	109.8	107.5	105.3	103.1	101.0	99.0
9	122.5	119.6	116.8	114.1	111.6	109.2	106.8	104.6	102.5	100.4	98.5
8	122.0	119.1	116.3	113.6	111.1	108.7	106.4	104.2	102.0	100.0	98.0
7	121.8	118.9	116.1	113.5	110.9	108.5	106.2	104.0	101.9	99.8	97.9
6	120.6	117.7	115.0	112.3	109.8	107.5	105.2	103.0	100.9	98.9	96.9
5	120.2	117.3	114.6	112.0	109.5	107.1	104.8	102.7	100.6	98.6	96.6
4	118.5	115.7	113.0	110.4	108.0	105.6	103.4	101.2	99.2	97.2	95.3
3	91.5	91.5	91.5	91.0	91.5	91.5	91.5	91.5	91.5	91.5	91.5
2	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0

at (g) Tiers	0.63	0.64	0.65	0.66	0.67	0.68	0.69	0.7	0.71	0.72	0.73
12	80.4	79.2	78	76.8	75.6	74.5	73.4	72.4	71.4	70.4	69.4
11	80.4	79.1	77.9	76.7	75.6	74.5	73.4	72.3	71.3	70.3	69.4
10	80.2	78.9	77.7	76.5	75.4	74.3	73.2	72.2	71.2	70.2	69.2
9	79.7	78.5	77.3	76.1	74.9	73.8	72.8	71.7	70.7	69.7	68.8
8	79.4	78.1	76.9	75.8	74.6	73.5	72.5	71.4	70.4	69.4	68.5
7	79.2	78.0	76.8	75.6	74.5	73.4	72.3	71.3	70.3	69.3	68.4
6	78.5	77.2	76.0	74.9	73.8	72.7	71.6	70.6	69.6	68.7	67.7
5	78.2	77.0	75.8	74.7	73.5	72.5	71.4	70.4	69.4	68.4	67.5
4	77.1	75.9	74.8	73.6	72.5	71.5	70.4	69.4	68.4	67.5	66.6
3	75.6	74.4	73.2	72.1	71.1	70.0	69.0	68.0	67.1	66.1	65.2
2	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0

at (g) Tiers	0.74	0.75	0.76	0.77	0.78	0.79	0.8	0.81	0.82	0.83	0.84
12	68.5	67.6	66.7	65.8	65	64.1	63.3	62.6	61.8	61.1	60.3
11	68.4	67.5	66.6	65.8	64.9	64.1	63.3	62.5	61.8	61	60.3
10	68.3	67.4	66.5	65.6	64.8	64	63.2	62.4	61.6	60.9	60.1
9	67.9	67	66.1	65.2	64.4	63.6	62.8	62	61.2	60.5	59.8
8	67.6	66.7	65.8	64.9	64.1	63.3	62.5	61.7	61	60.2	59.5
7	67.5	66.6	65.7	64.8	64	63.2	62.4	61.6	60.9	60.1	59.4
6	66.8	65.9	65	64.2	63.4	62.6	61.8	61	60.3	59.6	58.8
5	66.6	65.7	64.8	64	63.2	62.4	61.6	60.8	60.1	59.4	58.7
4	65.7	64.8	63.9	63.1	62.3	61.5	60.7	60	59.3	58.5	57.8
3	64.3	63.5	62.6	61.8	61	60.3	59.5	58.8	58.1	57.4	56.7
2	61.0	61.0	60.3	59.5	58.7	58	57.2	56.5	55.8	55.2	54.5

Note: In the above table, “tiers” is the number of tiers of 20 ft containers and “*at*” the transverse acceleration of the stack in the intermediate tier. For example, where 7 tiers of 20 ft containers are stacked with no 40 ft containers overstowed, if the transverse acceleration of the stack in the intermediate tier *at* is 0.45g, then the overall weight of the stack is not to exceed 110.9 t, but the weight of container of each tier of stack may be different.

Table 3.4.3(2) - At least One Tier of 40 ft Containers Stowed above 20 ft Containers (t)

at (g) Tiers	0.3	0.31	0.32	0.33	0.34	0.35	0.36	0.37	0.38	0.39	0.4
12	210.8	209.9	209.2	208.4	207.6	206.8	205.9	205.3	204.5	203.6	203.5
11	218.4	217.6	216.8	216.1	215.3	214.6	213.9	213.0	209.8	204.5	200.4
10	227.4	226.7	225.9	225.3	224.7	223.5	217.4	211.5	206.0	200.8	197.0
9	238.6	237.9	237.2	232.1	225.3	218.9	212.8	207.1	201.7	196.5	193.1
8	244.0	243.1	235.5	228.4	221.7	215.3	209.3	203.7	198.3	193.2	188.4
7	213.5	213.5	213.5	213.5	213.5	209.1	203.3	197.8	192.6	187.7	183.0
6	183.0	183.0	183.0	183.0	183.0	183.0	183.0	183.0	183.0	181.4	176.8
5	152.5	152.5	152.5	152.5	152.5	152.5	152.5	152.5	152.5	152.5	152.5
4	122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0
3	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5
2	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0

at (g) Tiers	0.41	0.42	0.43	0.44	0.45	0.46	0.47	0.48	0.49	0.5	0.51
12	198.5	193.8	189.3	185.0	180.9	177.0	173.2	169.6	166.1	162.8	159.6
11	195.5	190.8	186.4	182.1	178.1	174.2	170.5	167.0	163.6	160.3	157.1
10	192.2	187.6	183.2	179.1	175.1	171.3	167.6	164.1	160.8	157.6	154.5
9	188.3	183.9	179.6	175.5	171.6	167.9	164.3	160.9	157.6	154.4	151.4
8	183.8	179.4	175.3	171.3	167.5	163.8	160.4	157.0	153.8	150.7	147.8
7	178.5	174.3	170.2	166.4	162.7	159.1	155.7	152.5	149.4	146.4	143.5
6	172.5	168.4	164.5	160.8	157.2	153.8	150.5	147.4	144.4	141.5	138.7
5	152.5	152.5	152.5	152.5	150.5	147.3	144.1	141.1	138.2	135.5	132.8
4	122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0	122.0
3	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5
2	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0

at (g) Tiers	0.52	0.53	0.54	0.55	0.56	0.57	0.58	0.59	0.6	0.61	0.62
12	156.5	153.6	150.7	148.0	145.4	142.8	140.3	138.0	135.7	133.4	131.3
11	154.1	151.2	148.4	145.7	143.1	140.6	138.2	135.8	133.6	131.4	129.3
10	151.5	148.6	145.9	143.2	140.7	138.2	135.8	133.5	131.3	129.2	127.1
9	148.5	145.7	143.0	140.4	137.9	135.5	133.1	130.9	128.7	126.6	124.6
8	144.9	142.2	139.6	137.0	134.6	132.2	129.9	127.7	125.6	123.5	121.6
7	140.8	138.1	135.6	133.1	130.7	128.4	126.2	124.1	122.0	120.0	118.1
6	136.0	133.5	131.0	128.6	126.3	124.1	122.0	119.9	117.9	116.0	114.1
5	130.3	127.8	125.4	123.2	121.0	118.8	116.8	114.8	112.9	111.0	109.3
4	122.0	121.1	118.9	116.7	114.6	112.6	110.7	108.8	107.0	105.2	103.5
3	91.5	91.0	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5	91.5
2	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	1.0	61.0

at (g) Tiers	0.63	0.64	0.65	0.66	0.67	0.68	0.69	0.7	0.71	0.72	0.73
12	129.2	127.2	125.2	123.3	121.5	119.7	118.0	116.3	114.6	113.1	111.5
11	127.2	125.2	123.3	121.4	119.6	117.9	116.1	114.5	112.9	111.3	109.8
10	125.1	123.1	121.2	119.4	117.6	115.9	114.2	112.5	111.0	109.4	107.9
9	122.6	120.7	118.8	117.0	115.3	113.6	111.9	110.3	108.8	107.3	105.8
8	119.6	117.8	115.9	114.2	112.5	110.8	109.2	107.7	106.1	104.7	103.2
7	116.2	114.4	112.6	110.9	109.3	107.6	106.1	104.6	103.1	101.7	100.3
6	112.3	110.5	108.8	107.2	105.6	104.0	102.5	101.1	99.6	98.2	96.9
5	107.5	105.8	104.2	102.6	101.1	99.6	98.2	96.8	95.4	94.1	92.8
4	101.9	100.3	98.8	97.3	95.8	94.4	93.0	91.7	90.4	89.2	87.9
3	91.5	91.5	91.5	90.4	89.0	87.7	86.4	85.2	84.0	82.8	81.7
2	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0

at (g) Tiers	0.74	0.75	0.76	0.77	0.78	0.79	0.8	0.81	0.82	0.83	0.84
12	110.0	108.5	107.1	105.7	104.4	103.0	101.8	100.5	99.3	98.1	96.9
11	108.3	106.9	105.4	104.1	102.7	101.4	100.2	98.9	97.7	96.6	95.4
10	106.5	105.0	103.7	102.3	101.0	99.7	98.5	97.3	96.1	94.9	93.8
9	104.4	103.0	101.6	100.3	99.0	97.8	96.5	95.3	94.2	93.0	91.9
8	101.8	100.5	99.2	97.9	96.6	95.4	94.2	93.0	91.9	90.8	89.7
7	98.9	97.6	96.3	95.1	93.8	92.7	91.5	90.4	89.3	88.2	87.1
6	95.6	94.3	93.1	91.9	90.7	89.5	88.4	87.3	86.3	85.2	84.2
5	91.5	90.3	89.1	88.0	86.8	85.7	84.7	83.6	82.6	81.6	80.6
4	86.7	85.6	84.5	83.4	82.3	81.3	80.2	79.3	78.3	77.3	76.4
3	80.6	79.5	78.5	77.5	76.5	75.5	74.5	73.6	72.7	71.9	71.0
2	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0

Note: In the above table, “tiers” is the number of tiers of 20 ft containers, excluding the number of 40 ft containers stacked on the top, and “ a_t ” the transverse acceleration of the stack in the intermediate tier. For example, where 7 tiers of 20 ft containers are stacked with at least a tier of 40 ft containers overstowed, if the transverse acceleration of the stack in the intermediate tier a_t is 0.45g, then the overall weight of the stack is not to exceed 162.7 t, excluding the number of 40 ft containers stacked on the top, but the weight of container of each tier of stack may be different.

4 Determination of Forces Acting on Containers and Strength of Securing Arrangements

4.1 General requirements

4.1.1 The forces acting on the containers are to be determined according to loading conditions and associated motions of the ship. The following forces are to be taken into account: inertial forces of the containers generated by accelerations due to roll, pitch and heave motions of the ship, static gravity forces, wind forces, forces imposed by the securing arrangements and wave impact forces.

4.1.2 The resultant force acting on the containers can be divided into three components as F_x , F_y and F_z , as shown in Figure 4.1.2, where ox is the central axis of roll and F_x , F_y and F_z act on the centre of the container, which means that the centre of gravity of the container is assumed to be at the centre of the container. In securing calculation, it may be accepted that the centre of

gravity of the container is at 45% of container height.

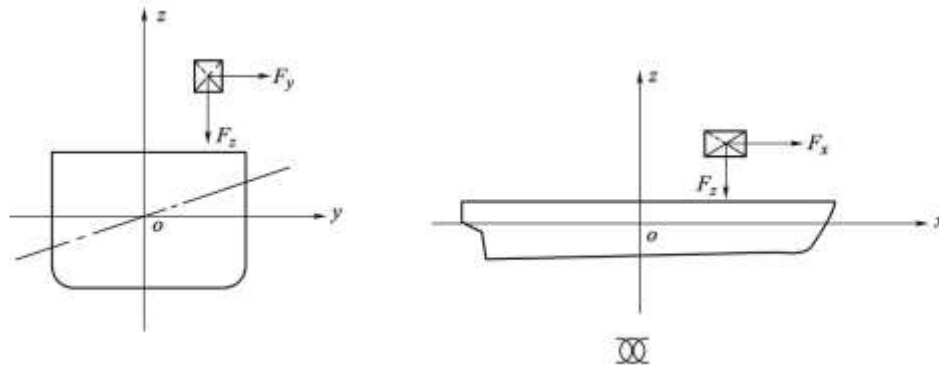


Figure 4.1.2 Forces Acting on Containers

4.2 Container securing acceleration

4.2.1 The transverse acceleration a_t for container securing calculation is calculated as follows:

$$a_t = (g + b_v) \cdot \sin \phi_m + b_h \cdot \cos \phi_m + \left(\frac{2\pi}{T_R}\right)^2 \cdot \phi_m \cdot (z - z_{ROLL}) \text{ m/s}^2$$

where: g —gravity acceleration, to be taken as 9.81 m/s^2 ;

b_v —acceleration of vertical motion due to pitch and heaving, in m/s^2 ;

b_h —acceleration of transverse motion due to yawing and swaying, in m/s^2 ;

ϕ_m —rolling angle of ship, in rad;

T_R —rolling period of ship, in s;

z —height from container gravity center position to baseline, in m;

z_{ROLL} —height from ship rolling centerline to baseline, in m.

In above calculation formula of transverse acceleration, b_v and b_h are determined by main dimension, block coefficient and speed of ship, and rolling angle and rolling period are determined by main dimension and metacentric height of ship. Transverse acceleration a_t may be determined through ISC ship calculation system.

4.2.2 The vertical acceleration a_v for container securing calculation is calculated as follows:

$$a_v = 0.866 k_x g \text{ m/s}^2$$

where: g —gravity acceleration, to be taken as 9.81 m/s^2 ;

k_x —longitudinal distribution coefficient which can be determined through ISC ship calculation systems.

4.2.3 The longitudinal acceleration a_l for container securing calculation is calculated as follows:

$$a_l = g (0.4 - 0.001 L_{BP}), \text{ but need not be less than } 1.5 \text{ m/s}^2$$

where: g —gravity acceleration, to be taken as 9.81 m/s^2 ;

L_{BP} —length between perpendiculars, in m.

4.3 Forces acting on containers

4.3.1 The transverse force component F_y parallel to deck is to be calculated as follows:

$$F_y = G a_t + Q \text{ kN}$$

where: G —gross weight of the container, in t;

a_t —transverse acceleration, in m/s^2 , see 4.2.1 of this Appendix;

$Q = qA$, in kN, where q is the wind pressure, to be taken as 0.95 kPa for outermost containers at side (for containers at bottom, a splash force of 0.95 kPa is also to be taken into consideration), and as zero for others; A is the projected side area of containers bearing the wind pressure, in m^2 . If the distance between adjacent container stacks is not more than 1 m, the wind load at containers inside can be omitted. If the distance between adjacent container stacks is 5 m or over, the wind load at containers inside is to be included in its entirety. If the distance is between 1 m and 5 m, linear interpolation is needed. If the exposed area is less than 1/3 of the side area, the wind load can be omitted.

4.3.2 The vertical force component F_z normal to deck is to be calculated as follows: When checking the strength of the vertical supporting structure of containers:

$$F_z = Ga_v \text{ kN}$$

where: G — see 4.3.1 of this Appendix;

a_v — see 4.2.2 of this Appendix.

4.3.3 The longitudinal force component F_x parallel to deck is to be calculated as follows:

$$F_x = Ga_l \text{ kN}$$

where: G — see 4.3.1 of this Appendix;

a_l — see 4.2.3 of this Appendix.

4.4 Distribution and combination of forces acting on containers

4.4.1 The forces acting on each container are distributed as follows.

(1) The transverse component F_y of force is transmitted to the supporting point x from fore and after end walls of the container. The transverse force H_i transmitted from each end wall of the no. i container is to be obtained from the following formula:

$$H_i = F_{yi}/2 \text{ kN}$$

The distribution of force H_i : if the center of gravity of the container is assumed to be the center of the container, $H_i/2$ acting on top of end wall and $H_i/2$ on bottom of end wall of the container; if the center of gravity of the container is assumed to be 45% height of the container, 0.45 H_i acting on top of end wall and 0.55 H_i on bottom of end wall of the container.

where: F_{yi} — transverse component of force, see 4.3.1 of this Appendix.

(2) The vertical component F_z of force is transmitted to the supporting structure from the four lower corners of the container. The vertical force V_i at each lower corner of the no. i container is to be obtained from the following formula:

$$V_i = F_{zi}/4 \text{ kN}$$

where: F_{zi} — vertical component of force of the no. i container, see 4.3.2 of this Appendix.

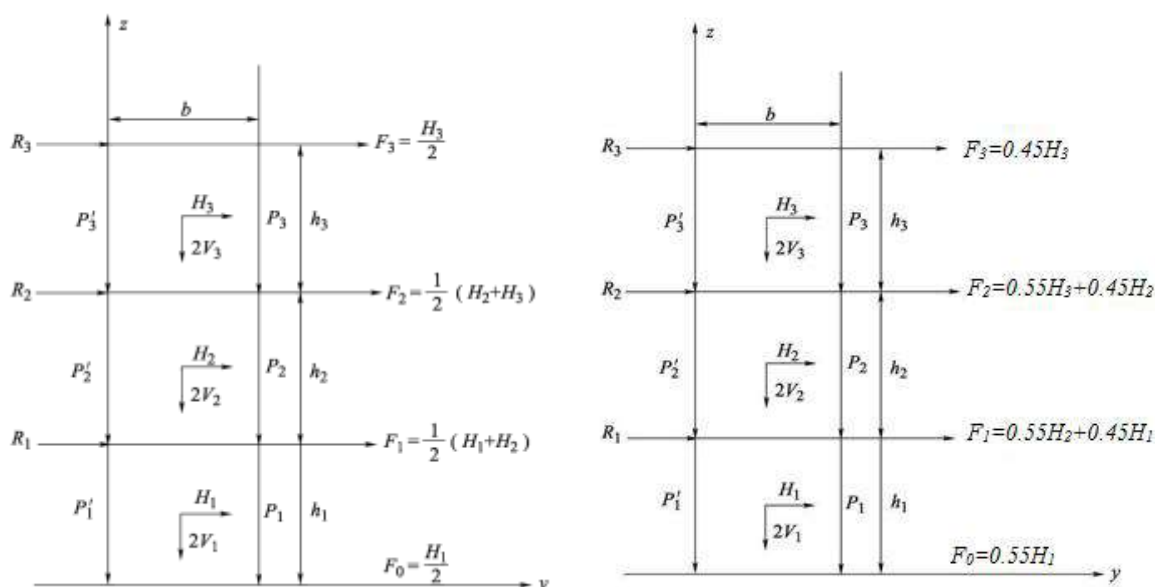
(3) The longitudinal component of force is transmitted to the supporting point x from both side

walls of the container. The longitudinal component force L_i transmitted from each side wall of the no. i container is to be obtained from the following formula:

$$L_i = F_{xi}/2 \text{ kN}$$

where: F_{xi} — longitudinal component of force of the no. i container, see 4.3.3 of this Appendix.

4.4.2 For containers in a three tier stack, the distribution of force at closed ends is given in Figure 4.4.2 and Table 4.4.2. The distribution of force on side walls may be treated in the same way.



(a) Gravity center at container center

(b) Gravity center at 45% height of container

Figure 4.4.2 Distribution of Force at Closed Ends of Containers

Table 4.4.2 - Distribution of Force at Closed Ends of Containers of Each Tier

Tier Force	1st tier	2nd tier	3rd tier
Transverse racking force R_i per container end	$F_3 + F_2 + F_1$	$F_3 + F_2$	F_3
Maximum vertical pressure P_i per bottom corner	$V_3 + \frac{F_3}{b} (h_3 + h_2 + h_1) + V_2 + \frac{F_2}{b} (h_2 + h_1) + V_1 + \frac{F_1}{b} h_1$	$V_3 + \frac{F_3}{b} (h_3 + h_2 + h_1) + V_2 + \frac{F_2}{b} (h_2 + h_1) + V_1 + \frac{F_1}{b} h_1$	$V_3 + \frac{F_3}{b} h_3$
Minimum vertical pressure P_i per bottom corner	$V_3 - \frac{F_3}{b} (h_3 + h_2 + h_1) + V_2 - \frac{F_2}{b} (h_2 + h_1) + V_1 - \frac{F_1}{b} h_1$	$V_3 - \frac{F_3}{b} (h_3 + h_2) + V_2 - \frac{F_2}{b} h_2$	$V_3 - \frac{F_3}{b} h_3$
Shear force S_i per bottom corner	$0.55(H_3 + H_2 + H_1)$	$0.55(H_3 + H_2 + H_1)$	$0.55 H_3$

Note: Where P_1 indicates a negative value, it is a lifting force.

4.5 Calculation for lashings

4.5.1 Wire ropes, steel rods or steel chains may be adopted for lashings, the safe working load of which may be determined according to the breaking loads listed in Table 2.2.1 of this Appendix.

4.5.2 Figure 4.5.2 shows a two-tier stack of containers, in which internal lashing is arranged to the second tier. If the center of gravity of the container is assumed to be the center of the container, for the selection of the effective sectional area A of the lashing, the residual racking force T (T being as required in 4.7.2 (2) of this Appendix) acting on the containers may be calculated in accordance with the following formula:

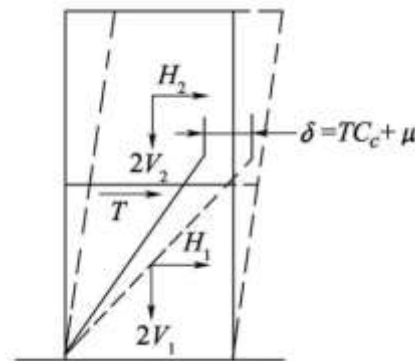


Figure 4.5.2 Two-Tier Stack

$$T = \frac{\frac{1}{2}H_1 + H_2 - \frac{AEI_y^2}{l^3}\mu}{\frac{AEI_y^2}{l^3}C_c + 1} \quad \text{kN}$$

where:

H_1, H_2 — see 4.4.1 (1) of this Appendix;

l — overall length of lashing assembly, which is to include torsion element, turnbuckle and eye plate. l can be obtained as follows: $l = \sqrt{l_x^2 + l_z^2}$

l_x — longitudinal length component of lashing assembly, in mm;

l_y — transverse length component of assembly, in mm;

l_z — vertical length component of lashing assembly, in mm;

E — elastic modulus of lashings, to be taken as 10,000 kN/cm² for steel wire rope, 4,000 kN/cm² for steel chain based on its nominal diameter, 14,000 kN/cm² for steel rod (lashed to top of 1st tier containers or bottom of 2nd tier containers), or 17,500 kN/cm² for steel rod (lashed to top of 2nd tier containers or bottom of 3rd tier containers) or 19,000 kN/cm² for steel rod (lashed to top of 3rd tier containers or bottom of 4th tier containers);

A — effective sectional area of lashings, in cm²;

μ — sliding at lower corners of container, in mm, to be taken as 4 mm for 1st and 2nd tier of container door end and 0 for closed end;

C_c — spring constant for container transverse frame, if no actual information available,

0.27 mm/kN for door end, 0.06 mm/kN for closed end and 0.168 mm/kN for side wall.

4.5.3 The lashing forces generated by the lashings are not to exceed the allowable loads as required in 4.7.2 (1) of this Appendix on container corner fittings.

4.6 Shoring forces

4.6.1 Where rigid shoring is used for the stowage of containers in holds without cell guide systems, the shoring forces may be determined by the following calculation.

The shoring forces Q_3 and Q_5 as shown in Figure 4.6.1 are to be calculated as follows:

$$Q_3 = \frac{1}{h_1} [H_4(h_1 - Z_4) + H_5(h_1 - Z_5)] + \frac{1}{h_2} [H_1Z_1 + H_2Z_2 + H_3Z_3] \quad \text{kN}$$

$$Q_5 = \frac{1}{h_1} (H_4Z_4 + H_5Z_5) \quad \text{kN}$$

where: for H_1, H_2, H_3, H_4 and H_5 , see 4.4.1(1) of this Appendix.

Q_i is the shoring force for a stack of containers. Where there are n stacks of containers arranged in the transverse direction and the number n does not exceed 4, the shoring force is to be nQ_i ; where n exceeds 4, the shoring force Q_i (n) may be calculated as follows:

$$\text{If } n-m \leq 4, \quad Q_i(n) = Q_i \left[1 - \frac{(n-4)^2}{2n-m} \right]$$

$$\text{If } n-m > 4, \quad Q_i(n) = Q_i \left(\frac{8+m}{2n} \right)$$

where: n —number of stacks using the same transverse support;

m —maximum tiers of all container stacks.

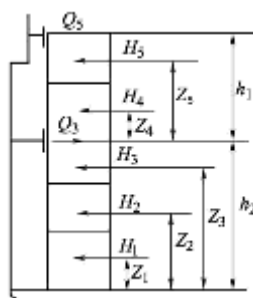


Figure 4.6.1 Rigid Shoring Forces

4.6.2 Where elastic shoring is used for the stowage of containers in holds, the shoring forces may be determined by the following calculation:

As shown in Figure 4.6.2, there are three elastic shoring points in one stack of containers, i.e. i, j and k ; and the shoring forces are expressed as Q_i, Q_j and Q_k respectively. The shoring forces may be obtained according to the principle that the displacement of the elastic shoring points is equal to the total displacement of containers, with consideration being given to the mutual influence between the shoring forces. The shoring forces Q_i, Q_j and Q_k may be obtained as follows:

$$Q_k(C_{ik} + kC_c) + (kQ_i + kQ_j)C_c + \delta_k = C_c[(H_{k+1} + H_{k+2} + H_{k+3} + H_{k+4})k + \sum_{r=1}^k H_r(r - \frac{1}{2})]$$

$$Q_j(C_{ij} + jC_c) + jQ_iC_c + \delta_j = C_c[(H_{j+1} + H_{j+2})j + \sum_{r=1}^j H_r(r - \frac{1}{2})]$$

$$Q_i(C_{ii} + iC_c) + \delta_i = C_c[H_{i+1}i + \sum_{r=1}^i H_r(r - \frac{1}{2})]$$

where: C_{si} , C_{sj} , C_{sk} — spring constants of shoring points i , j , k respectively, in mm/kN;

δ_i , δ_j , δ_k — initial gaps at shoring points i , j , k respectively;

C_c — see Table 4.5.2.

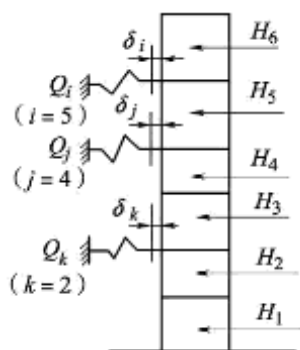


Figure 4.6.2 Elastic Shoring Forces

4.7 Allowable loads on containers

4.7.1 Forces acting on containers are not to exceed the allowable loads on containers irrespective of the methods of securing arrangements for containers.

4.7.2 As shown in Figure 4.7.2, the allowable loads on freight containers of ISO Standard Series 1 are as follows:

(1) lashing forces acting on the corner fittings:

the horizontal component of force on each end or side wall is not to exceed 150 kN or 225kN, the criteria value depends on the direction of horizontal component, see Figure 4.7.2a) for details;

the vertical component of force on each end or side wall is not exceed 300 kN;

in no case is the resultant of horizontal and vertical components of force to exceed 300 kN.

(2) Racking forces acting on end or side walls:

the transverse racking force on each end or side wall is not to exceed 150 kN;

the vertical racking force on each end or side wall is not to exceed 100 kN.

(3) Vertical tensile and compressive forces acting on the corner fittings:

the vertical tensile force acting at each top corner is not to exceed 250 kN;

the vertical tensile force acting at each bottom corner is not to exceed 250 kN;

the compressive force at each corner post is not to exceed 848 kN.

(4) Transverse compressive and tensile forces acting on the corner fittings:

the transverse compressive (tensile force) at each top corner of 20 ft containers is not to exceed 225 kN;

the transverse compressive (tensile force) at each top corner of 40 ft containers is not to exceed 340 kN;

the transverse compressive (tensile force) at each bottom corner of 20 ft containers is not to exceed 350 kN; The transverse compressive (tensile force) at each bottom corner of 40 ft containers is not to exceed 500 kN.

Where a buttress supports the stack at an intermediate level, the total transverse compressive (tensile) force acting at the level is not to exceed 575 kN for 20 ft containers and 840 kN for 40 ft containers.

- (5) For 45 ft containers, vertical compressive forces acting on the corner fittings:
 if the container is stacked at 45 ft position and supported in 45 ft position, the compressive force at bottom corner post is not to exceed 942 kN;
 if the container is stacked at 40 ft position and supported in 40 ft position, the compressive force at bottom corner fitting is not to exceed 404 kN.
 For 45 ft containers, other allowable loads are the same as those for 40 ft containers.
- (6) For containers with special dimensions (e.g. 43 ft, 48 ft and 53 ft), test results need to be submitted.

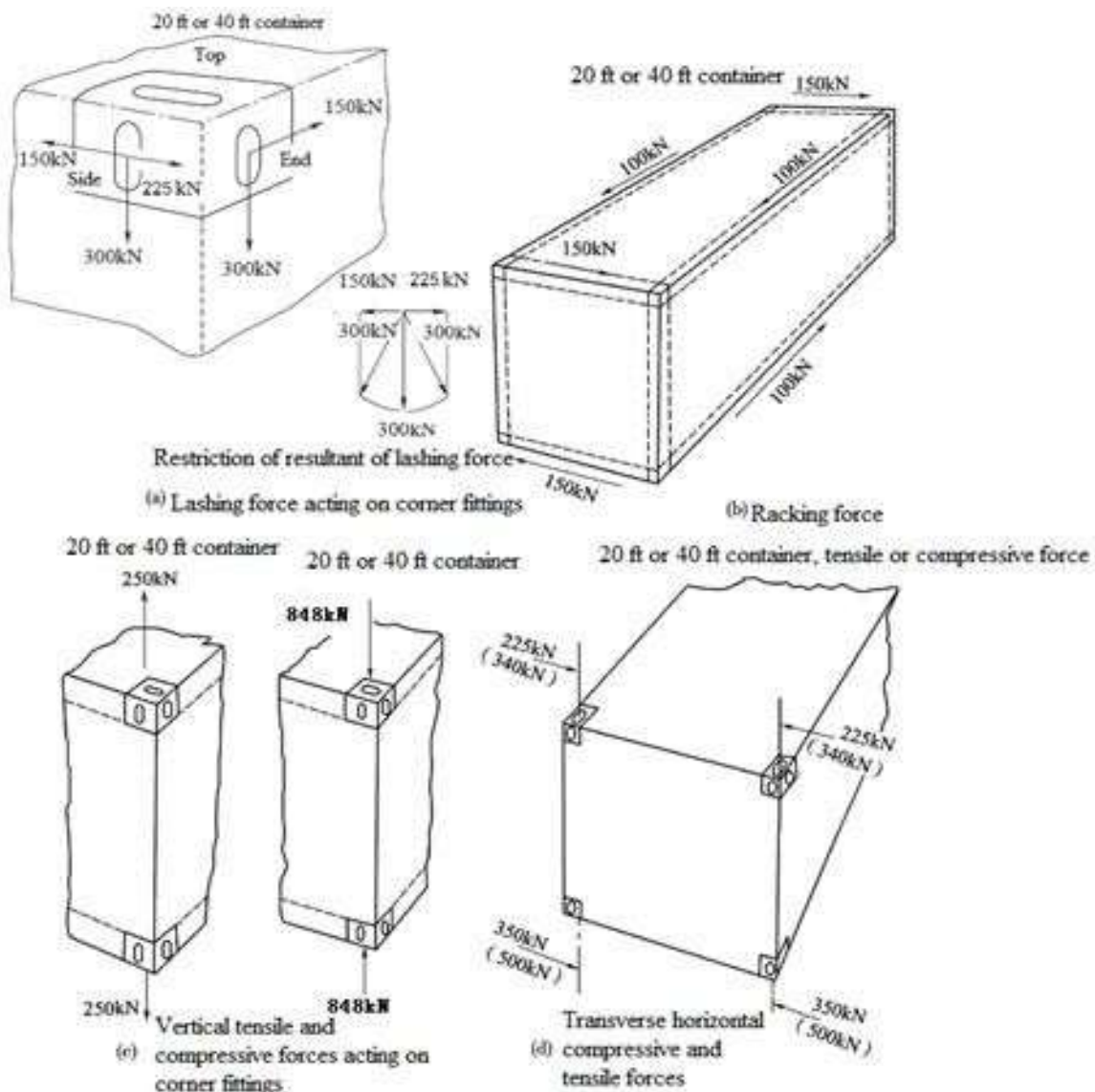


Figure 4.7.2 Allowable Loads on 20/40 ft Containers

4.8 Direct calculation of container securing

4.8.1 General requirements

4.8.1.1 2-dimensional beam model may be used to model containers and calculate the strength of containers and their lashings.

4.8.1.2 Each stack may be analysed separately unless there are connections between the stacks such as double cones or similar.

4.8.1.3 The flange thickness of twist locks or cones are to be included in clearances between container stacks.

4.8.2 Modelling of geometry

4.8.2.1 Beam elements are used to model container frames according to the dimension of containers.

4.8.2.2 The spring constant of the door end and of closed end are to be obtained respectively by adjusting the cross sectional area of the corner post as indicated by Figure 4.8.2.2:

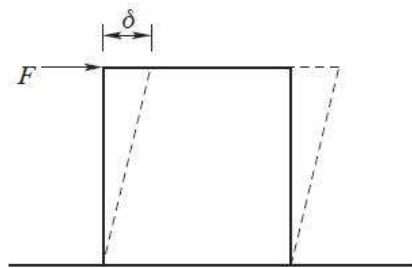


Figure 4.8.2.2 Spring Constant of Door End and of Closed End

For example: If the spring constant of the door end of the container is 0.291 mm/kN, when $F=1,000$ kN, the deflection of the frame is 291 mm.

4.8.2.3 Twist locks between two tiers of containers are to be modeled as rigid elements, with a hinge at one end to avoid transfer of bending moments.

4.8.2.4 Cones between two tiers of containers are to be modeled as non-linear elements capable of taking compression but not tension.

4.8.2.5 Lashing rods are to be modeled according to actual elastic modulus and cross sectional area.

4.8.3 Boundary conditions and loading

4.8.3.1 Elements attached to the ship structure are to be restricted from translation.

4.8.3.2 Loads should be applied as point loads in the corners of the containers. The transverse forces are applied to the top and bottom corners while vertical forces are only applied to the

bottom corners of the container.

4.8.4 Calculation results

4.8.4.1 Results are to be extracted from the model to check whether the containers comply with the allowable loads of containers specified in 4.7 of this Appendix and whether the loads on the securing devices exceed their SWL.

5 Strength Evaluation of Container Securing Structure

5.1 General requirements

5.1.1 These requirements apply to the lashing bridge and stanchion structure and supporting structure of fixed securing devices (lashing eye plate, deck ring, etc.) on the deck of container ships.

5.2 Lashing bridge

5.2.1 The SWL of lashing rods (50% of the breaking load) is theoretically the maximum load to check the strength of lashing bridges.

5.2.2 To check the strength of a lashing bridge, loads are to be applied according to the condition where the maximum lashing force may occur in the container securing manual/arrangement plan, and the lashing force is to be obtained by calculating according to the container securing manual/arrangement plan. The lashing force is to be applied in line with the lashing rods and can be decomposed into force components in longitudinal, transverse and vertical direction. The lashing force is applied to the securing eye plate of the lashing bridge. In calculating lashing forces, the relative displacement between the lashing bridge and the container stacks are to be taken into account, which is not to exceed the values given in Table 5.2.2.

Table 5.2.2 - Relative displacement between lashing bridge and container stacks

Lashing bridge of 1-tier container height	Lashing bridge of 1-tier container height	Lashing bridge of 1-tier container height
10 mm	25 mm	35 mm

5.2.3 In the initial design, forces may be applied according to the condition where the maximum lashing force may occur in reality. The lashing force is to be taken as 60% safe working load of each lashing rod (or other securing devices).

5.2.4 When checking the strength of lashing bridges, conditions where lashing forces are applied to forward and aft part lashing bridges together as well as respectively are to be calculated.

5.2.5 To better describe the force distribution of each structural part in each direction, strength checking of lashing bridge is to adopt 3-dimensional finite element structural analysis. The extent of the model, the elements and the boundary conditions are based on the following principles:

(1) The finite element model is to include all lashing bridges above the deck or hatch cover. The boundary conditions are to restrict all translations between elements and deck or hatch cover.

(2) The mesh size of the plate element is generally 100 mm × 100 mm, and triangle elements are to be avoided as far as possible in high stress areas and high stress changing areas.

5.3 Deck stanchion

5.3.1 In design of deck stanchion, the most critical conditions are to be taken into account, as well as the transverse load and vertical load acting on the stanchion.

5.3.2 Where lashing points are arranged on the stanchion, the horizontal and vertical components of lashing forces are also to be taken into account.

5.4 Fixed securing device

5.4.1 SWL of the connected securing device is to be used as the design load of supporting structure of fixed securing device.

5.5 Strength criteria

5.5.1 Allowable stresses for lashing bridge structures, deck stanchion structures and supporting structures of fixed cargo securing devices under various conditions are as follows:

Allowable shear stress: $[\tau] = 0.4 ReH$

Allowable equivalent stress: $[\sigma] = 0.88 ReH$

where ReH is the yield stress of the material, in N/mm².

6 Lashing Software

6.1 General requirements

6.1.1 All seagoing dedicated container ships are to be provided with lashing software complying with the requirements of this section.

6.1.2 Lashing software is an electronic data processing tool for onboard analysis of forces in container stacks and thereby reflects the parameters of the lashing system as described in the Cargo Securing Manual.

6.1.3 An approved lashing software is not a substitute for the approved Cargo Securing Manual. It is considered as a supplement to the approved Cargo Securing Manual.

6.1.4 The lashing software is a ship specific tool, and the results of the calculations are only applicable to the ship for which it has been approved.

6.2 Operation manual

6.2.1 An operation manual is to be provided for the lashing software and be kept on board, which is to be approved by ISC.

6.2.2 The language of the operation manual is to be the same as the language of the approved

Cargo Securing Manual. A translation into another language considered appropriate may be required.

6.2.3 The operation manual is to contain descriptions and instructions, as appropriate, as per the following list:

- (1) a general description of the lashing software;
- (2) installation;
- (3) function keys;
- (4) menu displays;
- (5) input and output data;
- (6) required minimum hardware to operate the software;
- (7) instruction on testing the lashing software with the test loading condition;
- (8) a list of all terms, definitions, error messages and warnings likely to be encountered by the user; and
- (9) in the case of error messages and warnings, there are to be unambiguous user instructions for subsequent action to be taken in each case.

6.3 Functional requirements

6.3.1 The lashing software is to be capable of calculating forces on containers and container securing equipment for any loading conditions for each container stack.

6.3.2 It is also to be capable of indicating the respective permissible values in order to assist the master in his/her judgement on whether the ship is loaded within the approved limits. The following parameters are to be presented:

- (1) summary of ship particulars such as IMO No., length, and breadth;
- (2) summary of loading conditions showing relevant input parameters such as draught and GM;
- (3) stack and container positions;
- (4) actual stack weights verified against permissible stack weights;
- (5) relevant properties of securing devices, including permissible loads;
- (6) accelerations and other external forces such as wind containers are exposed to;
- (7) listing of all calculated forces on containers and container securing equipment, and evaluation of compliance of the calculated forces with the corresponding allowable values.

6.3.3 The container and lashing arrangements in each bay on deck and in holds are to be shown graphically.

6.3.4 The data are to be presented on screen and in hard copy printout in a clear and unambiguous manner.

6.3.5 A clear warning is to be given on screen and in hard copy printout if any of the allowable forces are exceeded.

6.3.6 In addition to the printout content, each page of the printout is to contain ship's identification, lashing software name and version number, date and time of the printout, and the title of the loading condition. The printout is to be paginated sequentially, and the total number of printout pages are to be shown.

6.3.7 Units of measurement are to be clearly identified and used consistently.

6.3.8 Incorrect data input by the users, such as negative draught values, are to be prohibited. An error message is to be prompted on screen and in hard copy printout in a clear and unambiguous manner.

6.4 Test Loading Conditions

6.4.1 The lashing software is to be delivered with test loading conditions for selected stacks and bays covering applicable stowage patterns for containers of different dimensions contained in the Cargo Securing Manual. It is generally to cover the container stacking of the ship's bow, amidships and stern bay, including at least one lashing calculation for the conditions listed in the Cargo Securing Manual. For ships assigned the CLC(V) or CLC(V,W) notation, the corresponding additional conditions are to be supplemented.

6.4.2 The test loading conditions and their results are to be permanently stored in the computer where the lashing software is installed and be protected against unintentional or unauthorized modifications and access.

6.5 Approval of Lashing Software

6.5.1 The lashing software is subject to approval and is to include:

- (1) verification of type approval, if any;
- (2) verification that the latest ship data has been used;
- (3) verification and approval of the test loading conditions and their results;
- (4) verification if requirements of 6.3 are satisfied;
- (5) checking of proper installation, and verification of the instrument on board in accordance with the approved test loading conditions;
- (6) checking the availability of the operation manual on board.

6.5.2 In case of modifications implying changes in the ship's design or container securing arrangement, the software is to be modified accordingly and re-approved.

6.5.3 Any changes in software version related to the container securing calculations are to be reported and be approved.

6.5.4 Upon installation, the lashing software is to be verified with the approved test loading conditions in the presence of surveyor. It is to be checked that the operation manual for the lashing software is available on board.

6.5.5 Verification does not absolve the shipowner of responsibility for ensuring that the information supplied into the lashing software is consistent with the current condition of the ship and approved Cargo Securing Manual.

6.6 Acceptable Tolerances

6.6.1 The results of the lashing software are compared with those of the ISC plan approval software. The tolerance of the accuracy of the results from the lashing software is to be below 1.0% of the allowable values. However, deviations may be accepted provided that there is a satisfactory explanation for the deviation and that there will be no adverse effects on the safety of the ship.

6.7 Annual and Special Survey

6.7.1 At each annual and special survey, it is to be checked that the operation manual is available on board.

6.7.2 The lashing software is to be checked for accuracy annually by the ship's Master by applying the test loading conditions. If the surveyor is not present for lashing software check, a copy of the test loading condition results obtained by this check is to be retained on board as documentation of satisfactory testing for the surveyor's verification at the next scheduled survey.

6.7.3 At each special survey this checking is to be done in the presence of surveyor.

7 Specific Route and Season

7.1 Transverse acceleration for specific route

7.1.1 For container securing of specific route, transverse acceleration a_{vt} is to be calculated as follows:

$$a_{vt} = a_t \cdot f_{route} \text{ m/s}^2$$

where: a_t — transverse acceleration calculated according to 4.2.1 of this Appendix, in m/s^2 ;

f_{route} — specific route factor.

7.1.2 For each specific route, ISC will determine route factor f_{route} by statistical calculation of ship motion. ISC will develop specific wave scatter diagram based on acceptable wave statistical data to obtain f_{route} . For each specific route, latitude and longitude coordinates of a series of points along the route is to be provided by the shipowner or the information on sea areas passed by the route is to be provided. Division of sea areas and statistical data of wave in sea area are to be agreed by ISC. For each passed sea area, at least one point is to be given. If possible, time percentage for each passed sea area is to be provided.

7.1.3 For container securing of short voyage (port to port, navigation time within 72 hours), the specific route factor may be calculated as follows:

$$f_{route} = 1 - (H_S - 13)^2 / 240$$

where: H_S — the maximum expected significant wave height on the route during the navigation time, in m.

7.2 Transverse acceleration for specific season

7.2.1 For container securing of specific season, transverse acceleration a_{wt} is to be calculated as follows:

$$a_{wt} = a_{vt} f_{season} \text{ m/s}^2$$

where: a_{vt} — transverse acceleration of specific route which is calculated in accordance with 7.1.1 of this Appendix, in m/s^2 ;
 f_{season} —specific season factor.

7.2.2 Specific season factor f_{season} is the ratio of transverse acceleration calculated in accordance with the wave statistical data of a specific route in different seasons to transverse acceleration calculated in accordance with the wave statistical data throughout the year.

8 Approval and Certification of Container Securing Systems

8.1 General requirements

8.1.1 All seagoing dedicated container ships are to comply with the requirements of this section.

8.1.2 It is important for the safety of the ship and the protection of the cargo and personnel that the cargo is secured properly especially accounting for strength of the supporting structures and securing fittings. Hereto, a scope containing the following for approval and/or certification of container securing systems is defined:

- (1) fixed and portable container securing fittings;
- (2) arrangement plan of fixed container securing fittings;
- (3) drawings of container supporting structures (container stanchions, hatch covers, lashing bridges, and cell guides, if any);
- (4) cargo safe access plan;
- (5) container stowage and securing plan; (6) lashing software.

8.2 Fixed and Portable Container Securing Fittings

8.2.1 Fixed container securing fittings are used to secure and support containers and are permanently welded to the ship structure.

8.2.2 Portable container securing fittings are used to secure containers and are not categorised as fixed container securing fittings.

8.2.3 Minimum Breaking Load corresponds to the minimum load at which the first crack appears in the tested representative samples.

8.2.4 Minimum Proof Load corresponds to the test load below which visible permanent deformation is not allowed.

8.2.5 Drawings of fixed and portable container securing fittings are to show dimensions, materials, design loads, and manufacturer's markings.

8.2.6 Each fixed and portable container securing fitting type is subject to prototype testing to determine the minimum breaking loads. The minimum breaking load obtained from prototype testing is to be equal to or exceed the design minimum breaking load. Requirements for prototype testing are given in 2.2 of this Appendix.

8.2.7 Fixed and portable container securing fittings are subject to production testing prior to delivery or installation. A number of samples from a batch of the container securing fittings is to be loaded to minimum proof load of the fittings. The production testing approval documents of delivered container securing fittings are to be kept on board and may be included in the approved Cargo Securing Manual. Requirements for production testing are given in 2.3 of this Appendix.

8.2.8 The plan detailing the arrangement of the fixed container securing fittings is to be approved. The arrangement plan is to include the following for all areas where the fittings are installed:

- (1) The type of fixed container securing fittings such as container foundations and lashing eye plates;
- (2) Unambiguous location of installed fittings such as their location relative to clearly described locations of the ship structures.

8.3 Drawings of Container Supporting Structures

8.3.1 The drawings of the structures necessary for conducting container stowage and securing are subject to approval. The drawings are to be detailed enough to allow their model generation for structural analyses.

A plan is to be provided showing all relevant design loads for structural assessment of the container supporting structures and their foundations.

8.3.2 Structures involved in container stowage and securing include hatch covers, container stanchions, lashing bridges and cell guides.

8.4 Cargo Safe Access Plan

8.4.1 The cargo safe access plan is to be examined for its compliance with the requirements prescribed in MSC.1/Circ.1353/Rev.2 (refer to ISC Guidelines for the Preparation of the Cargo Securing Manual).

8.5 Container Stowage and Securing Plan

8.5.1 If the stowage and securing plan, as referred to in MSC.1/Circ.1353/Rev.2 4.2.1 and 4.2.2 (refer to ISC Guidelines for the Preparation of the Cargo Securing Manual), is required by the

Administration, the plan is subject to approval in accordance with 8.5.2 and 8.5.3.

8.5.2 The container stowage plan is to include at least the following information for each container type the ship is designed for:

- (1) longitudinal and athwartship views of under deck and on deck stowage locations of containers including reefers as appropriate;
- (2) alternative stowage patterns for containers of different dimensions; (3) maximum stack masses;
- (4) maximum stack heights with respect to approved sight lines; and
- (5) maximum nominal container capacity.

8.5.3 The container securing arrangement plan is to contain all information necessary to prepare lashing calculations. The container securing arrangement plan is to include at least the following information:

- (1) summary of ship particulars such as IMO No., length and breadth;
- (2) summary of loading conditions showing relevant input parameters such as draught and GM;
- (3) longitudinal views of under deck and on deck stowage locations of containers as appropriate showing nominal capacity;
- (4) maximum stack masses;
- (5) relevant properties of securing fittings, including permissible loads;
- (6) graphical presentation of container and lashing arrangements in each bay on deck and in holds for sample loading conditions for each container type the ship is allowed to carry;
- (7) stack total mass and the sequence of masses in a stack;
- (8) minimum quantity of fittings required to secure containers for the presented sample loading conditions.

8.6 Lashing Software

8.6.1 If the ship is provided with lashing software on board, the approval is to follow the requirements of Section 6 of this Appendix.

APPENDIX 2

DIRECT STRENGTH CALCULATION OF CONTAINER SHIPS

1 General

1.1 Application

1.1.1 This Appendix applies to direct strength calculations of container ships as required by this Chapter.

1.1.2 For those not covered in this Appendix, the relevant requirements of Section 5, Chapter 1 of this PART are to be complied with.

2 DIRECT CALCULATIONS OF STRENGTH OF PRIMARY STRUCTURES OF CARGO AREA

2.1 General requirements

2.1.1 The direct strength calculations for cargo holds are applicable to the evaluation of the strength of the following primary structures within cargo area in typical loading conditions:

- (1) double bottom structure (bottom plating, inner bottom plating, girders, floors);
- (2) double side structure (side shell plating, inner hull plating, longitudinal stringers and transverse web frames);
- (3) Transverse bulkhead structure (transverse bulkhead plating, bulkhead webs);
- (4) Deck structure (deck, torsion box).

2.1.2 Where fuel oil tanks are arranged between cargo holds amidships, strength evaluation is to be carried out for fuel oil tank area in accordance with 2.8 of this Appendix.

2.2 Structural modeling

2.2.1 Unless stipulated otherwise in this Appendix, see Section 5, Chapter 1 of this PART for requirements for structural modeling.

2.2.2 Normally, the longitudinal extent is to cover the length of 1/2 hold + 1 hold + 1/2 hold within the cargo area amidships, namely the length of one 40 ft bay + two 40 ft bays + one 40 ft bay. The vertical extent is to be taken up to the hatch coaming. A full-breadth model is to be required for transverse extent.

2.2.3 The model is generally to cover transverse watertight bulkheads and transverse support bulkheads. The transverse support bulkheads are at both ends and the middle of the model, and typical finite element models are shown in Figures 2.2.3(1) to (3).

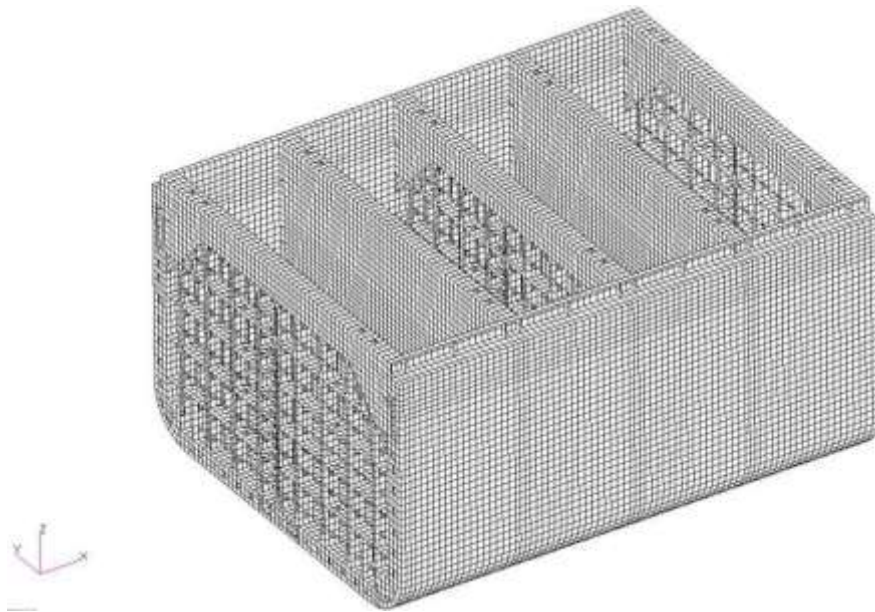


Figure 2.2.3(1) Typical finite element model

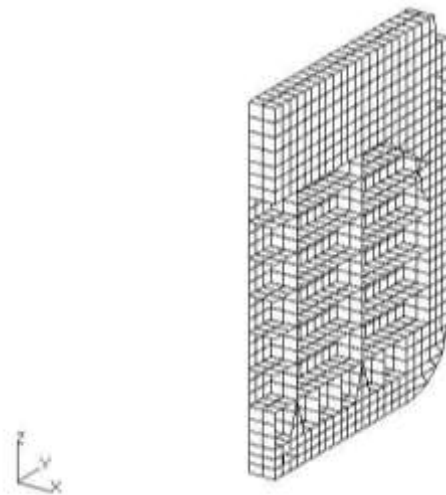


Figure 2.2.3(2) Typical finite element model of watertight transverse bulkhead (half-breadth)

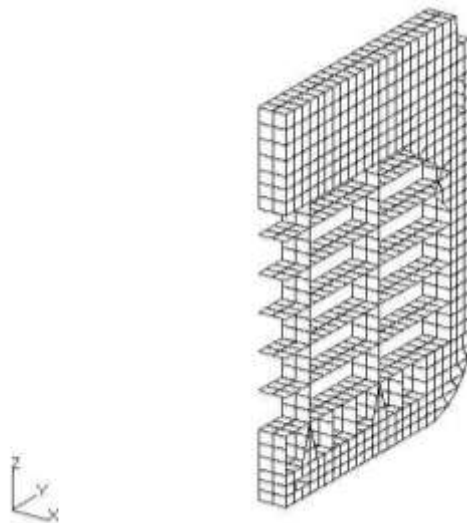


Figure 2.2.3(3) Typical finite element model of transverse support bulkhead (half-breadth)

2.3 Design loads

2.3.1 Unless stipulated otherwise in this Appendix, see Section 5, Chapter 1 of this PART for design loads.

2.3.2 The global loads include still water bending moment and wave bending moment. The still waterbending moment M_S is to be taken as the permissible hogging moment $\overline{M}_{S-Hog}$ and permissible sagging moment $\overline{M}_{S-Sag}$ provided by the designer. Vertical wave bending moment M_W includes hogging wave bending moment M_{W-Hog} and sagging wave bending moment M_{W-Sag} , is to be calculated in accordance with 7.2.2.3 of Section 2 of this Chapter.

2.3.3 Local loads include:

- (1) hydrostatic pressure;
- (2) hydrodynamic wave pressure;
- (3) self-weights of hull structure and containers;
- (4) dynamic loads of hull structure and container induced by the ship's motions, see 2.3.5 for the acceleration of ship's motions.

2.3.4 External hydrodynamic wave pressure is an additional pressure induced by local wave loads, consisting of hydrodynamic wave crest pressure and hydrodynamic wave trough pressure. See 1.5.3.3(4) and (5) of Chapter 1 of this PART for hydrodynamic wave crest pressure p_{hd} . The hydrodynamic wave trough pressure p_{hd1} is to be calculated as follows, the distribution is shown in Figure 2.3.4.

$$p_{hd1} = \max \left(-p_{hd}, \rho_w g (z - d_1) \right) \quad \text{KN/m}^2$$

where:

p_{hd} — to be taken in accordance with 1.5.3.3(4) of Chapter 1 of this PART;

ρ_w — density of seawater, taken as 1.025 t/m³;

g — acceleration due to gravity, $g = 9.81 \text{ m/s}^2$;

z — vertical distance from calculation point to baseline, in m;

d_1 — draught in the considered load condition, in m.

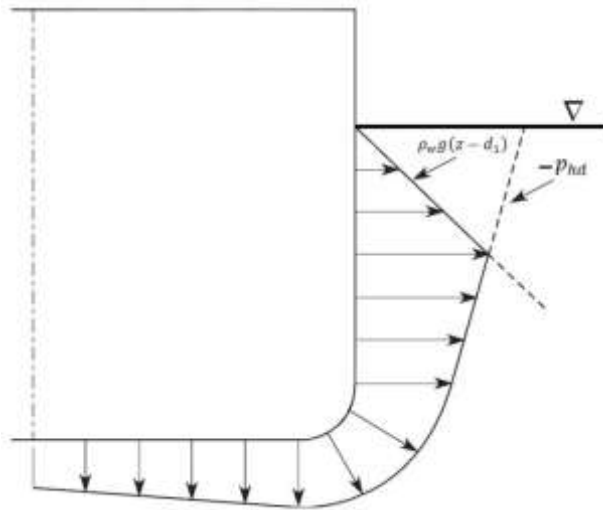


Figure 2.3.4 Distribution of hydrodynamic wave trough pressure on transverse section of the hull

2.3.5 The vertical acceleration a_v induced by the ship's motions is to be calculated as follows, positive downwards:

$$a_v = f_{LC} (C_{ZH} a_z - C_{ZP} a_p (x - 0.45L)) \quad \text{m/s}^2$$

where:

f_{LC} — coefficient, to be taken as follows:

= -1.0 where the considered load condition is sagging condition;

= 1.0 where the considered load condition is hogging condition; C_{ZH} — load combination factor of heave acceleration,

$$C_{ZH} = 0.15 - 0.5f_T, \quad f_T = d_1/d;$$

a_z — to be calculated in accordance with 1.5.2.1(3) of Chapter 1 of this PART;

C_{ZP} — load combination factor of pitch acceleration, taken as 0.7;

a_p — to be calculated in accordance with 1.5.2.1(5) of Chapter 1 of this PART;

x — X coordinate of the calculation point, in m;

L — length of the ship, in m.

The longitudinal acceleration a_l induced by the ship's motions is to be calculated in accordance with 1.5.2.2(7) of Section 5, Chapter 1 of this PART and the speed is to be taken as half of the maximum service speed.

2.4 Loading conditions

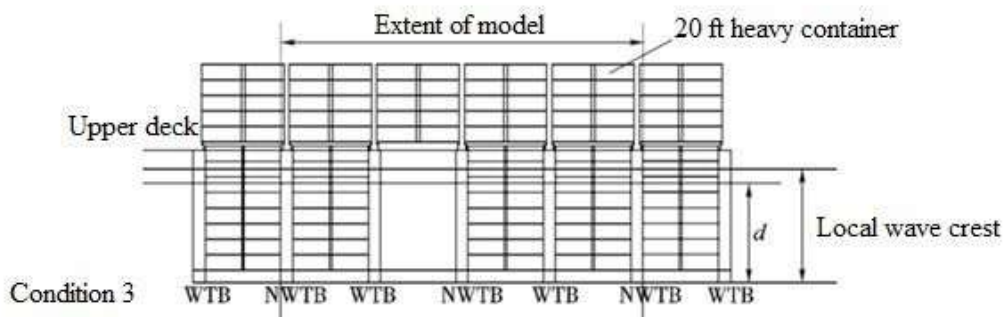
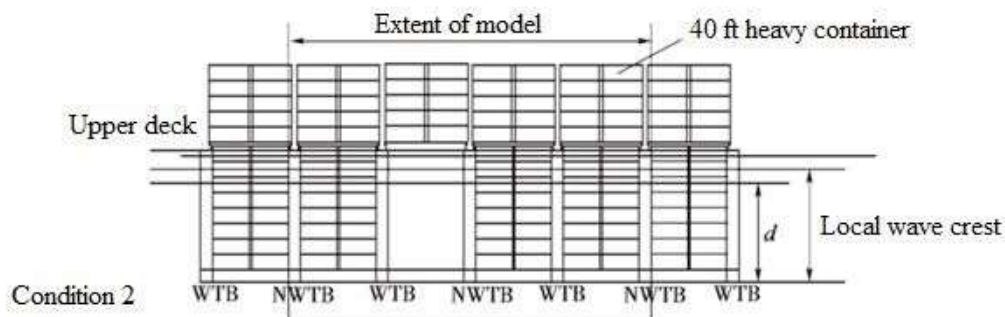
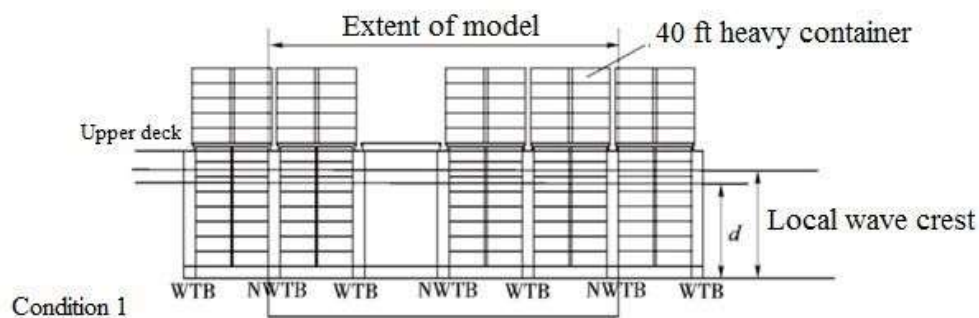
2.4.1 The applicable loading conditions are to be checked according to Table 2.4.1. For more severe loading conditions in the loading manual not covered by the Table, direct strength calculation is to be carried out. Figure 2.4.1 shows various loading conditions.

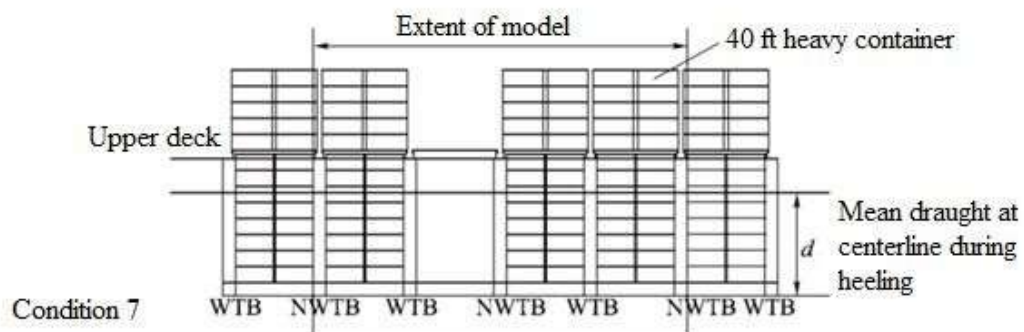
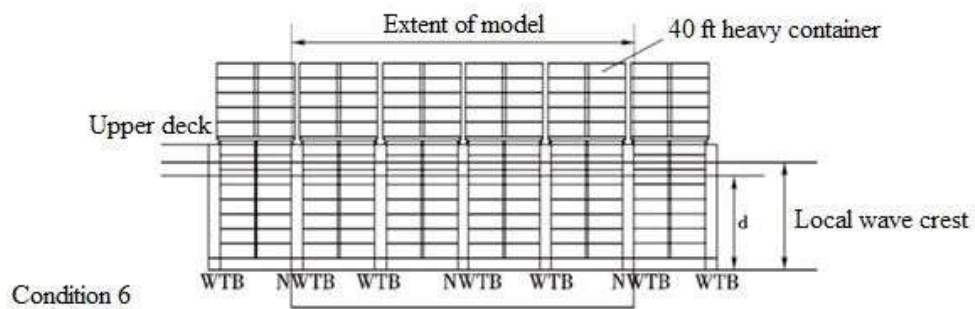
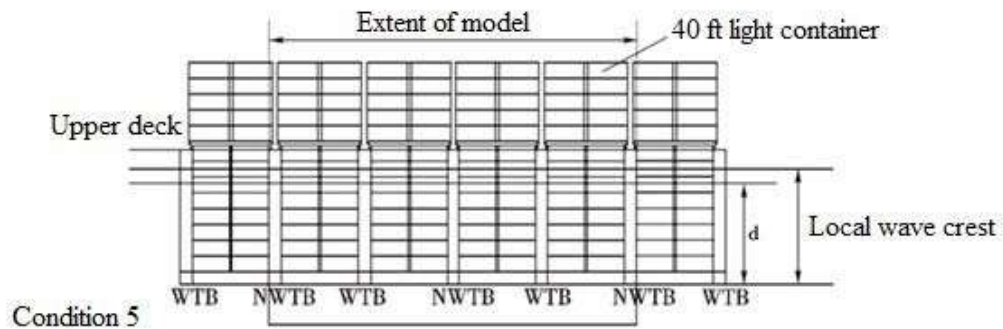
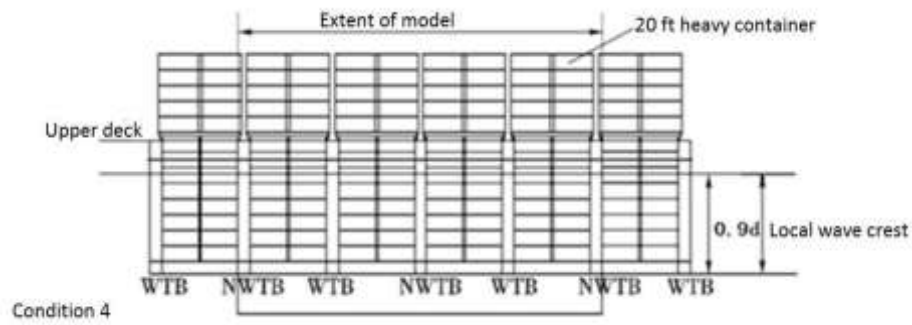
Table 2.4.1 - Loading Conditions

Loading Condition	Condition Description	Still Water Bending Moment	Wave Bending Moment	Draught	Hydrodynamic Wave Pressure	Container Weight	Dynamic Acceleration of Hull Structure and Containers
1	Empty within one 40 ft bay and hatch covers over the bay; full within other bays and hatch covers	$\overline{M}_{s-Hog}$	M_{w-Hog}	d	p_{rd}	40 ft heavy container	a_v
2	Empty within one 40 ft bay and full on hatch covers over the bay; full within other bays and hatch covers	$\overline{M}_{s-Hog}$	M_{w-Hog}	d	p_{rd}	40 ft heavy container	a_v
3	Empty within one 40 ft bay and full on hatch covers over the bay; full within other bays and hatch covers	$\overline{M}_{s-Hog}$	M_{w-Hog}	d	p_{rd}	20 ft heavy container	a_v
4	Full within hold of all holds and on all hatch covers	$\overline{M}_{s-Hog}$	M_{w-Sag}	$0.9d$	p_{rd}	20 ft heavy container	a_v
5	Full within hold of all holds and on all hatch covers	$\overline{M}_{s-Hog}$	M_{w-Hog}	d	p_{rd}	40 ft light container	a_v
6	Full within hold of all holds and on all hatch covers	$\overline{M}_{s-Hog}$	M_{w-Hog}	d	p_{rd}	40 ft heavy container	a_v
7	Empty within one 40 ft bay and hatch covers over the bay; full within other bays and hatch covers (heeling of ship)	—	—	d	—	40 ft heavy container	—
8	Full within hold of all holds and on all hatch covers (heeling of ship)	—	—	d	—	20 ft heavy container	—
9	Full within hold of all holds and on all hatch covers (longitudinal motions of ship)	$\overline{M}_{s-Sag}$	M_{w-Sag}	d	p_{rd}	40 ft heavy container within holds, 20 ft heavy container on hatch covers	a_l, a_v
10	Damage (heeling of ship)	$\overline{M}_{s-Sag}$	—	d_{dam}	—	40 ft heavy container (except the damaged tank in the middle)	—

Notes:

- (1) d — draught, in m;
- (2) Heavy container — the weight of a container is to be taken as permissible stack weight divided by the maximum number of tiers;
- (3) Light container — the weight of a container is not to be greater than the values taken as follows: In hold: 55% of the weight of heavy container;
- On hatch covers: to be taken as 90% of the permissible stack weight divided by the maximum number of tiers or 17 tons, whichever is the lesser;
- (4) for condition 7 and 8, the heeling angle is to be calculated in accordance with Section 5, Chapter 1 of this PART; Where the direct calculation of wave load is available, the heeling angle predicted by direct calculation may be accepted, but not to be less than 18° ;
- (5) for condition 9, loads within hold and on hatch covers to be determined as specified in 2.4.3 and 2.4.4;
- (6) where a hold consists of two or more 40 ft bays, then each bay is to be considered as entirely empty;
- (7) definition for d_{dam} is defined in 2.4.5 of this appendix.





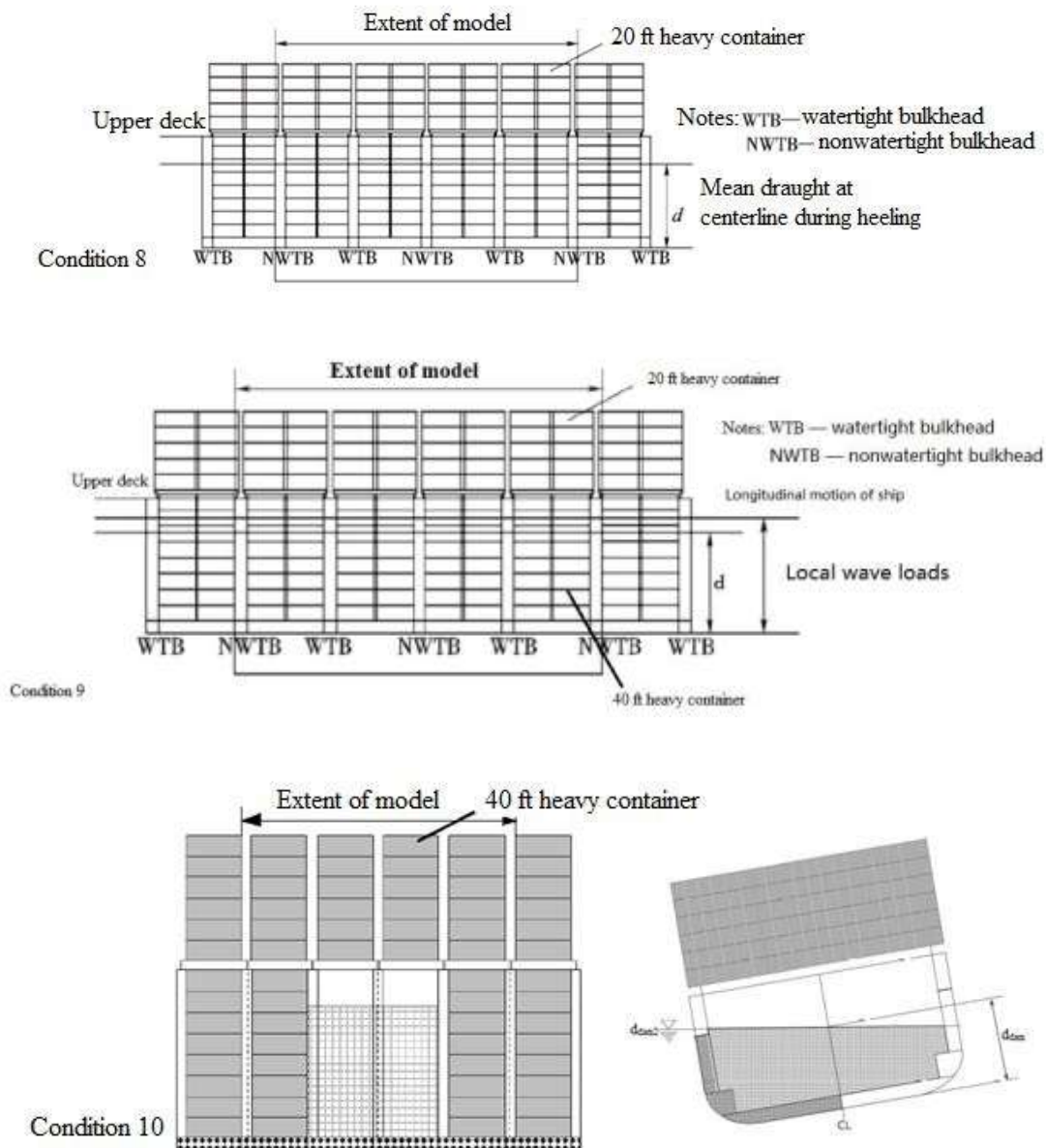


Figure 2.4.1 Loading conditions

2.4.2 For heeling conditions (conditions 7 and 8), the load components are to be calculated assuming that the ship heels to maximum heeling angle. The transverse load components of containers in holds are to act as a group of concentrated forces on transverse bulkheads, with the locations of container corners corresponding to transverse bulkheads as acting points. The load components from containers on deck are to act as a group of horizontally distributed shear forces on nodes of top elements of the transverse coaming.

2.4.3 Where deck is fitted with torsion box girders and the span of the cross deck box is not greater than 13.0 m, the condition 9 need not be considered.

2.4.4 For surging condition (condition 9), the forces arising from acceleration of the longitudinal motion of each container within hold is to be distributed from corresponding corners of the

container to primary members of the transverse bulkhead (or the transverse support bulkhead) in way of cell guides. Determination of loads due to containers on hatch covers is as follows:

- (1) The longitudinal forces from containers on each hatch cover are to be calculated at mid-height of the stack. The moment about the stack base caused by longitudinal forces may be ignored.
- (2) The number of tiers of containers is the maximum one of loaded containers, and the maximum stack weight and the number of tiers are to be those permitted in the loading manual or the cargo handling manual.
- (3) The longitudinal forces from containers sited between the ship's side and the longitudinal hatch coamings may be ignored.
- (4) 15% of the total longitudinal force acting on hatch covers is to be distributed on nodes at top of longitudinal and transverse hatch coamings to simulate the friction force to which the bearing pads at hatch coamings are subjected due to longitudinal motion.
- (5) The remaining 85% of the longitudinal forces on hatch covers are to act on nodes corresponding to the longitudinal stopper positions at one end of the hatch cover (top of the transverse hatch coaming). If the stopper positions are unknown, they are assumed to be located at the mid-breadth of the aft end of the hatch cover. Three covers are to be assumed if the number of hatch covers is unknown.

2.4.5 For damage condition (condition 10), it is assumed that any cargo hold of ship is flooded to the deepest equilibrium waterline. Only the damage of middle hold and the ballast tank on the same side is considered in the FE model. The loads are applied to the container in the same way of that specified in 2.4.2. The maximum height of damage point $ddam2$ and $ddam$ in way of longitudinal centerline is to be determined by the deepest equilibrium waterline.

2.5 Boundary conditions

2.5.1 Boundary conditions for local loads

2.5.1.1 For symmetric loading cases (conditions 1, 2, 3, 4, 5, 6, 9, 10), see Table 2.5.1.1(1) for boundary conditions; for asymmetric loading cases (conditions 7 and 8), see Table 2.5.1.1(2) for boundary conditions; nodes, intersection lines and end planes in the Table are shown in Figure 2.5.1.1.

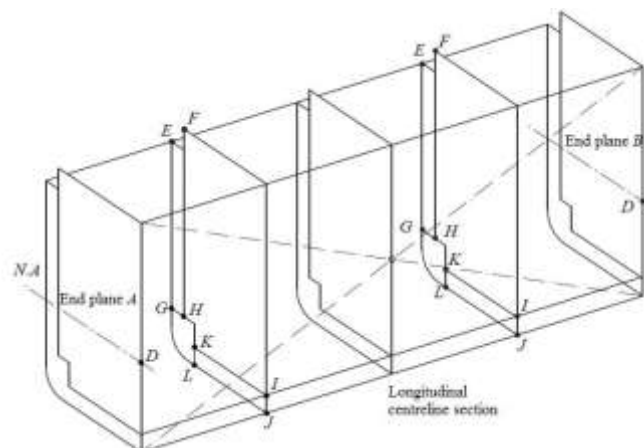


Figure 2.5.1.1 Boundary Conditions

2.5.1.2 For symmetric loading cases, vertical spring elements are to be provided at nodes on intersections of shell plating and inner hull plating with forward and aft transverse bulkheads. For asymmetric loading cases, Horizontal spring elements are to be provided at nodes on intersections of bottom plating and inner bottom plating with forward and aft transverse bulkheads in addition that vertical spring elements are to be provided at nodes on intersections of shell plating and inner hull plating with forward and aft transverse bulkheads. The coefficient of elasticity of spring elements is to be distributed evenly and calculated by the following formula:

$$K = \frac{5GA}{6l_H n} \quad \text{N/mm}$$

where: G — shear modulus of elasticity of material, $G = 0.792 \times 10^5$ N/mm² for steel;

A — shearing area of shell plating, inner hull plating, bottom plating and inner bottom plating in way of forward and aft bulkheads, in mm²;

l_H — length of midship hold, in mm;

n — number of nodes on vertical intersections of shell plating and inner hull plating or number of nodes on horizontal intersections of bottom plating and inner bottom plating.

Table 2.5.1.1(1) - Boundary Conditions for Symmetric Loading Cases

Position	Displacement constraint			Rotation constraint		
	δx	δy	δz	θx	θy	θz
Node J	—	Constraint	—	—	—	—
End planes A, B	Constraint	—	—	—	Constraint	Constraint
Intersection lines EG, FH	—	—	Spring	—	—	—

Table 2.5.1.1(2) - Boundary Conditions for Asymmetric Loading Cases

Position	Displacement constraint			Rotation constraint		
	δx	δy	δz	θx	θy	θz
End planes A, B	Constraint	—	—	—	Constraint	Constraint
Intersection lines EG, FH	—	—	Spring	—	—	—
Intersection lines IK, JL	—	Spring	—	—	—	—

2.5.2 Boundary conditions for global loads

2.5.2.1 See Table 2.5.2.1 for boundary conditions for global loads. The boundary conditions apply to the calculation of hull girder bending moments for Table 2.4.1 only.

2.5.2.2 An independent point D (see Figure 2.5.1.1) is to be set in way of intersection of the neutral axis with the longitudinal centerline section within end planes A and B , the overall longitudinal bending moment is to be applied on the point D , and the degree of freedom δ_x , δ_y , δ_z of each member node for end planes is linked to the independent point.

2.5.2.3 The displacements of the independent point D within end planes A and B in transverse direction, vertical direction, and the rotation around longitudinal axes are restrained, i.e.: δ_y

$=\delta_z=\theta_x=0$; the displacement of the independent point *D* within end plane *A* in longitudinal direction is restrained, i.e.: $\delta_x=0$

Table 2.5.2.1 - Boundary conditions for global loads

Position	Displacement constraint			Rotation constraint		
	δx	δy	δz	θx	θy	θz
Node J	—	Constraint	—	—	—	—
End planes A, B	Link	Link	Link	—	—	—
Independent point D (End plane A)	Constraint	Constraint	Constraint	Constraint	Bending moment	—
Independent point D (End plane B)	—	Constraint	Constraint	Constraint	Bending moment	—

2.6 Strength evaluation

2.6.1 Evaluation area

2.6.1.1 Evaluation is to be carried out for middle hold and the primary members with the scope of a transverse framing extending forward and afterward.

2.6.2 Yield strength evaluation

2.6.2.1 The strength check is to be carried out after the stresses due to local load case and global load case are combined. The in-plane stress of the element is to be taken for stress of plate element.

2.6.2.2 In all conditions, permissible stresses of primary members are shown in Table 2.6.2.2.

Table 2.6.2.2 - Permissible Stresses

Structural Member	Loading Condition	Permissible Stress (N/mm ²)	
		[σ]	[τ]
Deck plating	LC1, 2, 3, 4, 5, 6, 9	225/K	—
Bottom plate, inner bottom plate	LC1, 2, 3, 4, 5, 6, 9	225/K	—
Shell plating, longitudinal bulkhead	LC1, 2, 3, 4, 5, 6, 9	225/K	115/K
Bottom girders	LC1, 2, 3, 4, 5, 6, 9	235/K	115/K
Double bottom floors	LC1, 2, 3, 4, 5, 6, 7, 8, 9	175/K	90/K
Transverse web frames	LC1, 2, 3, 4, 5, 6, 7, 8, 9	195/K	95/K
Longitudinal stringers	LC1, 2, 3, 4, 5, 6, 9	225/K	—
	LC7, 8	175/K	90/K
Transverse bulkhead plating	LC1, 2, 3, 4, 5, 6, 9	180/K	100/K
	LC10	235/K	—
Transverse bulkhead webs	LC1, 2, 3, 4, 5, 6, 7, 8, 9	175/K	—
	LC10	235/K	—
Connection of the double bottom and side platform to the watertight transverse bulkhead structure	LC10	235/K	—
Cross-deck torsion box	LC7, 8	175/K	90/K
	LC9	175/K	—

	LC10	235/K	—
Bracket toe end with local stress concentration	LC1, 2, 3, 4, 5, 6, 7, 8, 9, 10	220/K	—

Notes:

(1) K — material factor;

(2) The elements at king-pin area of hatch coaming are directly subjected to the load resulting from hatch cover under loading condition 9, so the permissible equivalent stress is $[\sigma_e]=195/K \text{ N/mm}^2$.

2.6.3 Buckling strength evaluation

2.6.3.1 Finite element buckling strength evaluation is to be carried out for members such as shell plating, inner bottom plating, deck, bulkhead plating of hull structure of containership, web plates and pillars of primary and local supporting members, horizontal/vertical girders of supporting bulkhead.

2.6.3.2 See 2.6.1 for evaluation area.

2.6.3.3 In addition to the requirements of 2.6.3.4 to 2.6.3.8, buckling strength evaluation is to be carried out in accordance with the requirements for finite element buckling as specified in Chapter 8 of PART 9-1 of the Rules.

2.6.3.4 In buckling strength evaluation, the calculation of the buckling capacity of all panels and stiffeners is to be carried out based on the size after deduction of the standard thickness deduction t_r . The standard thickness deduction t_r is shown in Table 2.6.3.4.

Table 2.6.3.4 - Standard Thickness Deduction

Position	Standard Thickness Deduction (mm)
Deck, wing space plating (e.g. second deck, etc.)	1
Longitudinal bulkhead (inner hull plating)	1
Shell plating (including bottom plating), inner bottom	1
Inner structure (girder, floor) of double bottom and wing space	1
Transverse bulkhead structure (watertight, non-watertight)	0
Cross-deck torsion box	0

Note: If other thickness deduction method is used for buckling strength evaluation (e.g. based on corrosion allowance), the permissible utilization factor is to be considered otherwise.

2.6.3.5 For stresses obtained by calculation of finite element model (including stress components of direct stress and shear stress), if stress component is local stress or including components of local stress, the correction of stress is to be carried out for the stress calculation according to the following formula:

$$\sigma_A = \frac{\sigma t}{t - t_r} \quad \text{N/mm}^2$$

where: σ_A — corrected buckling working stress (including components of axial compressive stress and shear stress), in N/mm^2 ;

σ — stress obtained by finite element calculation ((including components of axial

compressive

stress and shear stress), in N/mm²;

t— plate thickness for finite element calculation, in mm;

t_r—standard thickness deduction, in mm, see Table 2.6.3.4.

2.6.3.6 For permissible buckling utilization factor η_{all} used for buckling strength evaluation η_{all} , see Table 2.6.3.6

Table 2.6.3.6 - Permissible buckling utilization factor, η_{all}

Structural Component	Permissible Buckling Utilization Factor (η_{all})
— Plating (including web plates in way of openings)	1
— Stiffener	1
— Stiffened panel	1
— Strut, pillar	0.75
— Horizontal/vertical girder of supporting bulkhead checked by strut buckling mode	0.75
— Collision bulkhead (where necessary)	0.9

2.6.3.7 Definition of method for evaluating the stiffened/unstiffened panels of hull panel of containership is shown in Table 2.6.3.7 and Figures 2.6.3.7(1) to 2.6.3.7(6).

Table 2.6.3.7 - Types of panels and corresponding evaluation methods

Structural Element	Evaluation Method	Definition for Regular Panel
Longitudinal structure (see Figures 2.6.3.7(1), (4), (6))		
External shell plate (bottom plating, side shell plating)	SP-A	Length: between web frames Width: between primary supporting members (PSM)
Inner bottom plating	SP-A	Length: between web frames Width: between PSM
Inner hull / longitudinal bulkhead plating	SP-A	Length: between web frames Width: between PSM
Horizontal and longitudinal stringer of hopper tank and vertical side plating	SP-A	Length: between web frames Width: between PSM
Hatch coaming side plating	SP-A or UP-A	Length: between web frames Width: between PSM
Upper deck	SP-B [5]	Length: between web frames Width: between PSM
Double bottom longitudinal girders	SP-B [5]	Length: between web frames Width: height of the whole web plate
Transverse structure (see Figure 2.6.3.8(2))		
Transverse framing of deck / web plate of cross-deck torsion box, including bracket of regular mesh shape	SP-A [6]	Local stiffener / between face plate / PSM
Transverse framing of deck / web plate of cross-deck torsion box, including bracket of irregular mesh shape	SP-B [5]	Local stiffener / between face plate / PSM
Transverse webs of double hull wing tank	SP-B [5]	Length: height of the whole web plate Width: between PSM

Transverse webs of double hull wing tank (independent arrangement)	SP-B	Length: height of the whole web plateWidth: between PSM
Irregular stiffened panel (e.g. web plate panel in hopper tank and at bilge – continuous alignment)	UP-A	Local stiffener / between face plate / PSM
Irregular stiffened panel (e.g. web plate panel in hopper tank and at bilge – discontinuous alignment)	UP-B [5]	Local stiffener / between face plate / PSM
Double bottom floors	SP-A [6]	Length: height of the whole web plateWidth: between PSM
Watertight transverse bulkhead and transverse supporting bulkhead (see Figures 2.6.3.8(3), (4), (5))		
All regular bulkhead stiffened panels (including secondary buckling stiffeners vertical to the regular stiffeners, e.g. carling)	SP-A	Length: between PSMWidth: between PSM
All irregular bulkhead stiffened panels (e.g. web plate panels in hopper tank and at bilge)	UP-A	Local stiffener / between face plates
Bulkhead horizontal web plate, including bracket of regular mesh shape (three arrangements of panel and over)	SP-B [5]	Local stiffener / between face plates
Bulkhead horizontal web plate, including bracket of regular mesh shape (two arrangements of panel and less)	SP-B [5]	Local stiffener / between face plates
Bulkhead horizontal web plate, including bracket of irregular mesh shape	UP-B	Local stiffener / between face plates
Bulkhead vertical web plate, including bracket of regular mesh shape	SP-B [5]	Local stiffener / between face plates
Bulkhead vertical web plate, including bracket of irregular mesh shape	UP-B	Local stiffener / between face plates
Cross deck (see Figure 2.6.3.8(6))		
Longitudinal deck strips between hatchways	SP-B [5]	Local stiffener / between PSM
Cross deck strips between hatchways	SP-B	Local stiffener / between PSM

Notes:

1. SP means stiffened panel.
2. UP means unstiffened panel.
3. A means Method A.
4. B means Method B.
5. For a long side of the web plate panel of a primary supporting member:
If alongside the face plate or an attached plate without “in-line support” (e.g. pull-in property), Method B (SP-B or UP-B) shall be selected.
For other situations, Method A (SP-A or UP-A) shall be selected.
6. In the typical case where the short edge and sheathing (flange of attached plate) are connected, Method A (SP-A or UP-A) shall be selected. However, if a long side of the panel lacks “in-line support” and may be pulled in, Method B (SP-B or UP-B) shall be selected.
7. In-line support means an edge of a panel is always subject to the structural support or restraint of an adjacent panel and/or edge stiffener.
8. Pull-in means an edge of a panel may be pulled freely toward the center of the plate.
In this table, “in-line support” and “pull-in” represent opposite mechanical properties.

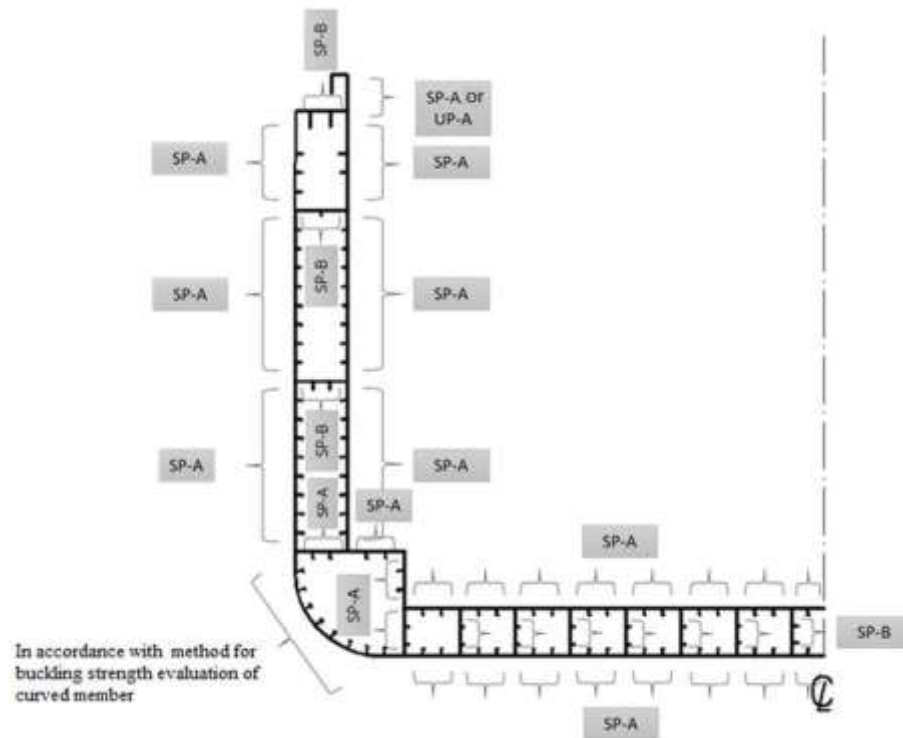


Figure 2.6.3.7(1) Typical longitudinal panels of containership

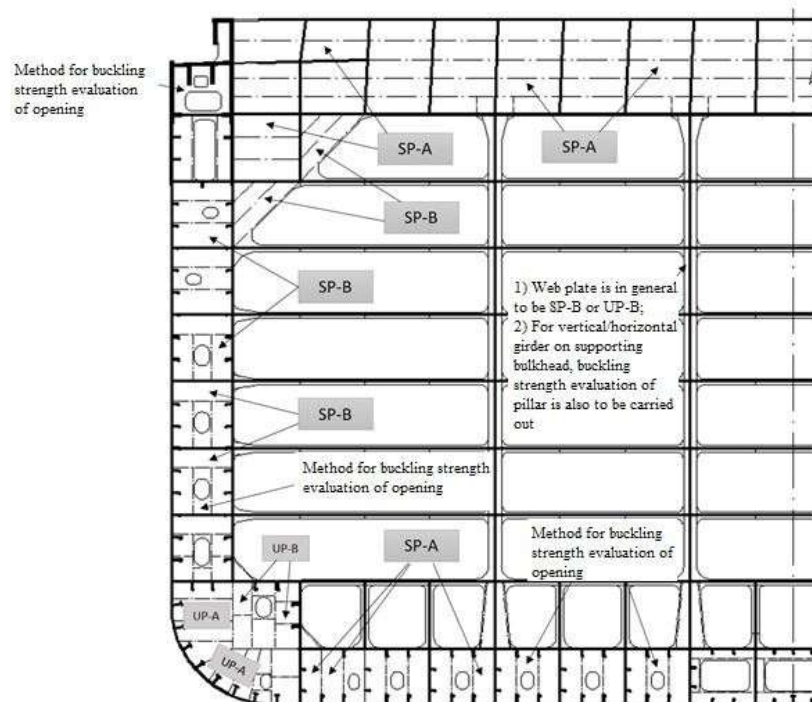


Figure 2.6.3.7(2) Typical transverse member in way of bulkhead (supporting) of containership

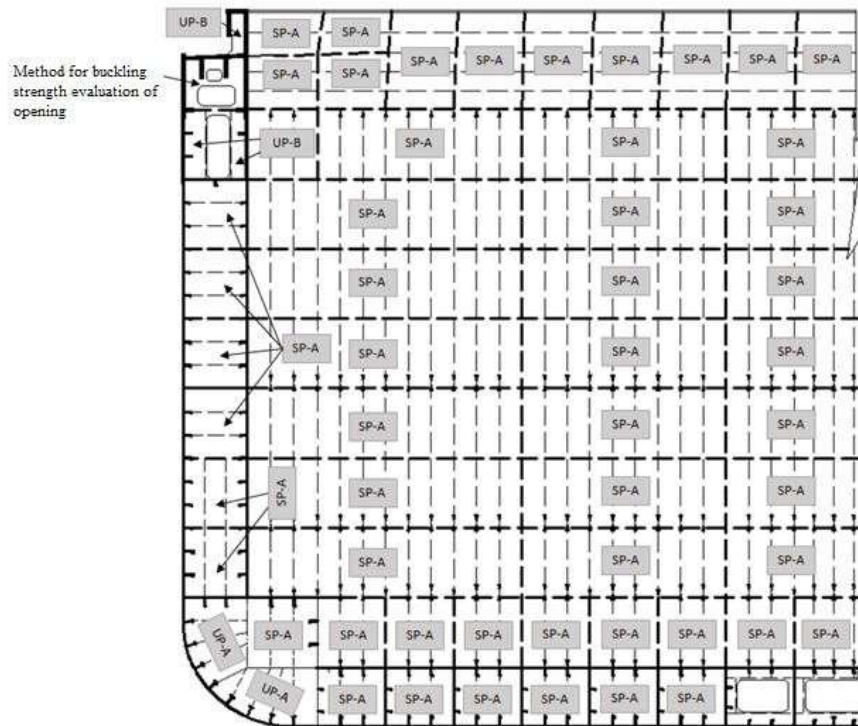


Figure 2.6.3.7(3) Typical watertight transverse bulkhead of containership

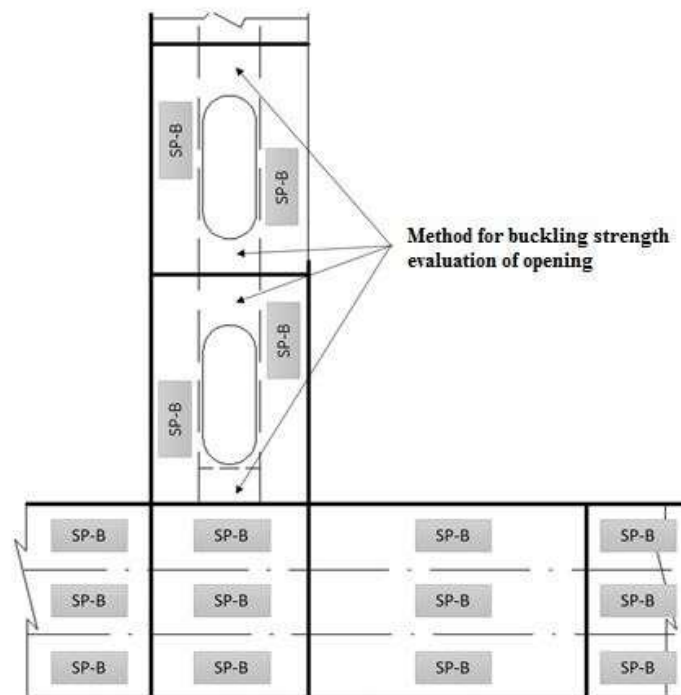


Figure 2.6.3.7(4) Transverse bulkhead vertical girder and double bottom girders

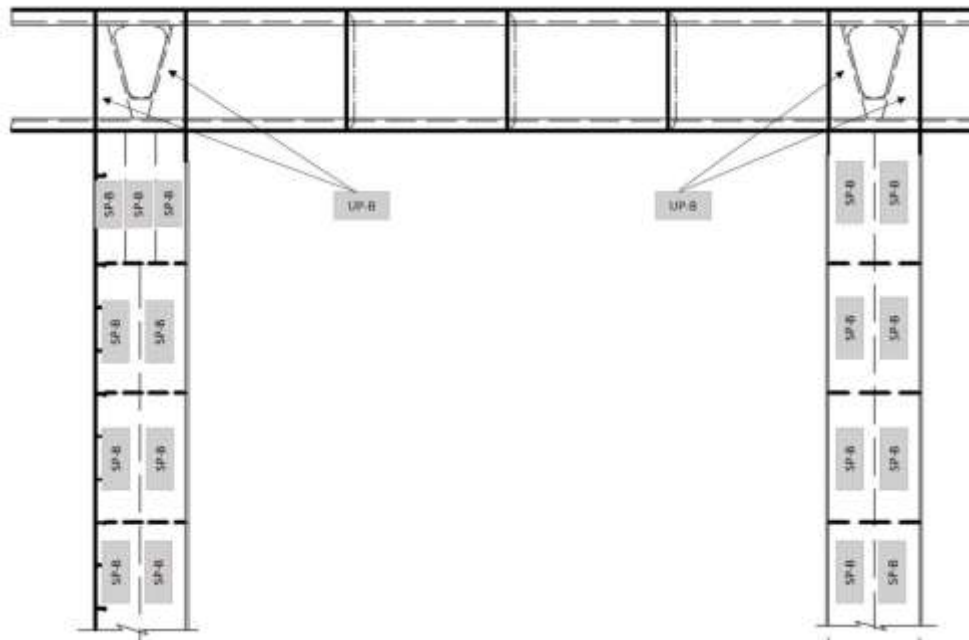


Figure 2.6.3.7(5) Horizontal girder of transverse bulkhead

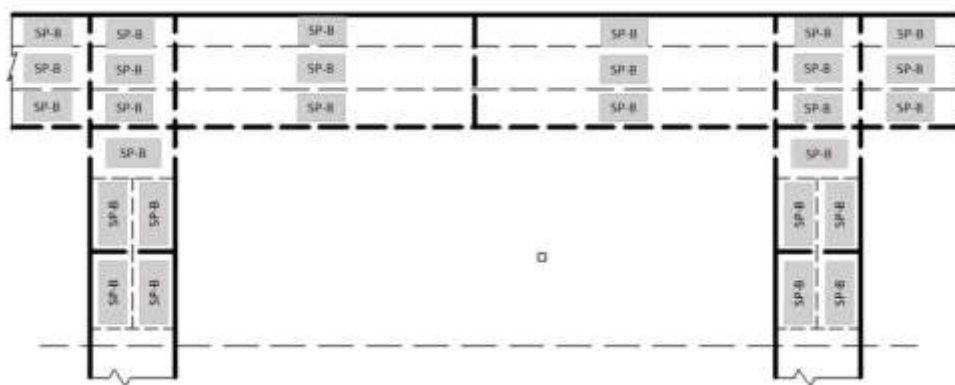


Figure 2.6.3.7(6) Deck strips between hatchways

2.6.3.8 For vertical and horizontal webs of supporting bulkhead, see Figure 2.6.3.8, the buckling utilization factor of its members is to be taken as the greater of the maximum buckling utilization factor of web plate panel (stiffened/unstiffened panel) and the maximum buckling utilization factor of pillars of web.

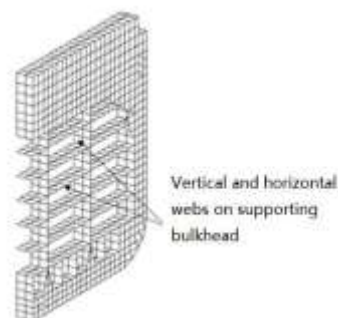


Figure 2.6.3.8 Vertical and horizontal webs on supporting bulkhead

2.7 Fine mesh analysis

2.7.1 In order to evaluate more accurately the stress level and distribution in way of the concentration of local structural stresses, fine mesh analysis and strength evaluation are at least to be carried out to the following critical parts in the evaluation area required by 2.6.1:

(1) in way of the steps of transverse web frames in the middle of supporting bulkhead and watertight transverse bulkhead (for cargo hold with two supporting transverse bulkheads, the location is the middle of the two supporting transverse bulkheads), see Figure 2.7.1(1).

(2) connection of bottom girder to inner bottom plate and bottom plating in watertight transverse bulkhead area, see Figure 2.7.1(2).

(3) large bracket toe near steps of the supporting bulkhead, see Figure 2.7.1(3).

Fine mesh analysis is also to be carried out if the stress in other critical areas exceeds the permissible criteria.

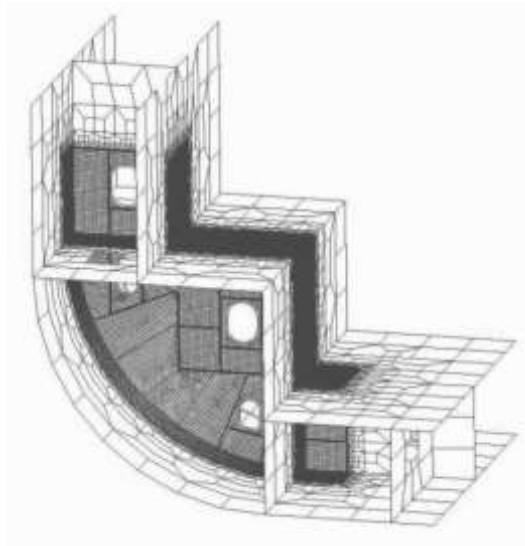


Figure 2.7.1(1) Refined transverse web frame

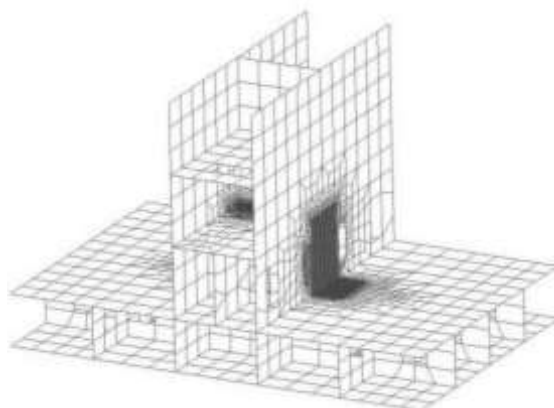


Figure 2.7.1(2) Refined structural connection of girder to inner bottom plating and bottom plating

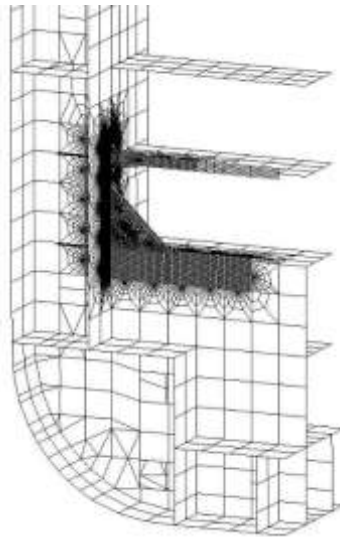


Figure 2.7.1(3) Refined large bracket toe of supporting bulkhead

2.7.2 The fine mesh analysis may be conducted by sub-modeling method and embedding method. The individual local finite element model in fine mesh areas is to be used for sub-modeling method, of which the boundary conditions and loads may be obtained from the finite element model of cargo hold blocks.

The embedding method is to carry out analysis by embedding the fine mesh model into the finite element model of cargo hold block.

2.7.3 Where the local finite element model is used, its range is to be such that the stress of critical locations is not significantly affected by boundary conditions and applied loads. The boundaries of refined model are to be in consistent with the main support members (e.g. girders and floors) of finite element model o cargo hold blocks.

2.7.4 The mesh size of fine mesh area is not to be greater than 50 mm ×50 mm. In general, the range of fine mesh area is not to be less than 10 elements in all directions of critical positions.

2.7.5 Plate element simulation is to be used for all plating and stiffeners within fine mesh areas. The transition of mesh density is to be maintained stable. The aspect ratio of elements within fine mesh area is to be close to 1 as far as possible so as to avoid the change of mesh density and use of triangular element, as well as the distortion element of which the angle is less than 60° or greater than 120°. In any case, the aspect ratio of element is not to exceed 3. The stiffeners beyond the fine mesh area may be simulated by beam element.

2.7.6 For the transverse web frames, if finite element sub-model method is used, the longitudinal range of model is at least to be of the spacing of “1+1” web frames, i.e., one web frame spacing is extended both before and after the checked transverse web frames, and the web frames at forward and after ends may not be modeled. In addition, the model is to include the full molded breadth and full molded depth of ship.

2.7.7 The fine mesh analysis is to be carried out in accordance with the design conditions specified in this Appendix.

2.7.8 Where sub-model method is used for fine mesh analysis, node displacement obtained from finite element model calculation for cargo hold block is to be applied to the corresponding boundary node of individual local finite element model as a given displacement.

2.7.9 The stress criteria and check method for fine mesh analysis are shown in Table 2.7.9.

Table 2.7.9 - Maximum permissible membrane stress of fine mesh analysis

Element Stress	Yield Utilization Factor (<i>Applicable to all conditions</i>)
Element not adjacent to welds	$\lambda_y \leq 1.7$
Element adjacent to welds	$\lambda_y \leq 1.5$

where: (1) λ_y — yield utilization factor;

$$\lambda_y = \frac{\sigma_e}{[\sigma_e]}$$

(2) In the block finite element model, if the Von Mises stress of element located in the fine mesh check area exceeds the permissible values given in Table 2.7.9, the mean value of Von Mises stress calculation results obtained from fine mesh analysis with the area equivalent to the mesh size of block finite element model is not to exceed the permissible value specified in Table 2.7.9.

(3) The maximum permissible stress is to be based on the mesh size of 50 mm × 50 mm. If smaller size is used, the element mean Von Mises stress on the equivalent areas of above-mentioned mesh size may be compared with the permissible stress. The mean stress is to be calculated only when all the boundaries of element are within the range of above-mentioned mesh size.

Von Mises mean stress is to be weighted based on element area:

$$\sigma_{e-av} = \frac{\sum_{i=1}^n A_i \sigma_{e-i}}{\sum_{i=1}^n A_i}$$

Where:

σ_{e-av} — Von Mises mean stress;

σ_{e-i} — Von Mises stress of the i^{th} plate element within the area to be considered ;

A_i — area of the i^{th} plate element within the area to be considered;

n — number of elements within the area to be considered.

Note 1: The mean stress calculation is to be based on the stress at centroid of the element, and the value is not to be obtained by interpolation and/or extrapolation.

Note 2: Stress averaging method is not allowed to be used for evaluation in way of structural discontinuities and abutting members.

2.8 Strength evaluation of fuel oil tank areas

2.8.1 Where fuel oil tanks are provided within the cargo hold areas of container ships, structural strength evaluation is to be carried out for the primary members in the fuel oil tank areas:

- (1) boundary structures of fuel oil tanks;
- (2) deck and cross deck within fuel oil tank areas;
- (3) internal grillage structures of fuel oil tanks, i.e., girders and web frame structures;
- (4) double bottom structures below fuel oil tanks (bottom plating, inner bottom plating, girders and floors);
- (5) side structures in way of fuel oil tank (side shell plating, inner shell plating, longitudinal stringers, side web frames).

2.8.2 Structural modeling

2.8.2.1 The longitudinal extent of block model is generally to cover the complete structures within the fuel oil tank area, with a cargo hold structure of 40 ft container bay extended both forward and afterward, i.e., “one 40 ft container bay + fuel oil tank + one 40 ft container bay”. The typical finite element model is shown in Figure 2.8.2.1.

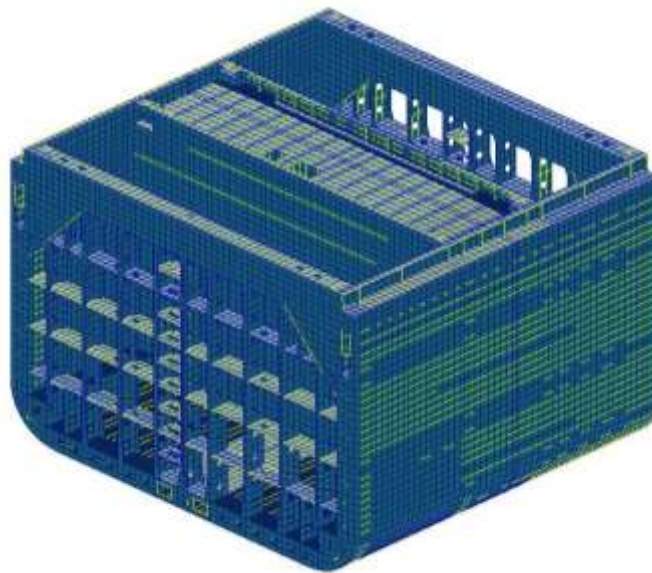


Figure 2.8.2.1 Finite Element Model of Fuel oil tank

2.8.2.2 Except the above-mentioned modelling requirements, the other structural modeling requirements are listed in 2.2 of this Appendix.

2.8.3 Design loads

2.8.3.1 Except the liquid pressure of tanks, the other loads are given in 2.3 of this Appendix.

2.8.3.2 Pressures of liquid in tank

The pressures of liquid in tank include the pressure in static load condition and the pressure in dynamic load condition.

- (1) The pressure of ballast tanks under dynamic load condition p_{blast1} and the pressure of fuel oil

tank under dynamic load condition ρ_{HD1} are to be calculated by:

$$p_{blast1} = \rho_w(a_v + g)h_1 + 10p_v \quad \text{kN/m}^2$$

$$p_{HD1} = \rho_f(a_v + g)h_1 + 10p_v \quad \text{kN/m}^2$$

where:

h_1 — distance from the load point to the top of tank, in m;

ρ_w — density of sea water, in 1.025 t/m³;

ρ_f — density of oil fuel, in 1.0 t/m³;

p_v — dynamic load coefficient, to be taken not less than 0, is to be calculated by:

$$p_v = \Delta z - 1.5$$

where: Δz — distance between the top of tank and the top of overflow pipe, in m.

(2) The pressure of ballast tanks under static load condition p_{blast} and the pressure of fuel oil tanks under static load condition p_{HO} are to be calculated by:

$$p_{blast} = \rho_w g h_2 \quad \text{kN/m}^2$$

$$p_{HO} = \rho_f g h_2 \quad \text{kN/m}^2$$

Where: h_2 — distance from the load point to the top of overflow pipe, in m.

$\rho_w \cdot \rho_f$ — the same as 2.8.3.2(1).

2.8.4 Loading conditions

2.8.4.1 In order to fully evaluate the structures of fuel oil tanks, the loading conditions are to be determined according to the arrangement type of fuel oil tanks. The basic principle is that strength analysis is to be carried out for the structures within fuel oil tank area based on full load of fuel oil tank, alternate load and light ship conditions respectively. Figure 2.8.4.1 gives several typical arrangement types of fuel oil tanks, and the loading conditions of various typical fuel oil tank arrangement types are shown in Table 2.8.4.1(1) to Table 2.8.4.1(3).

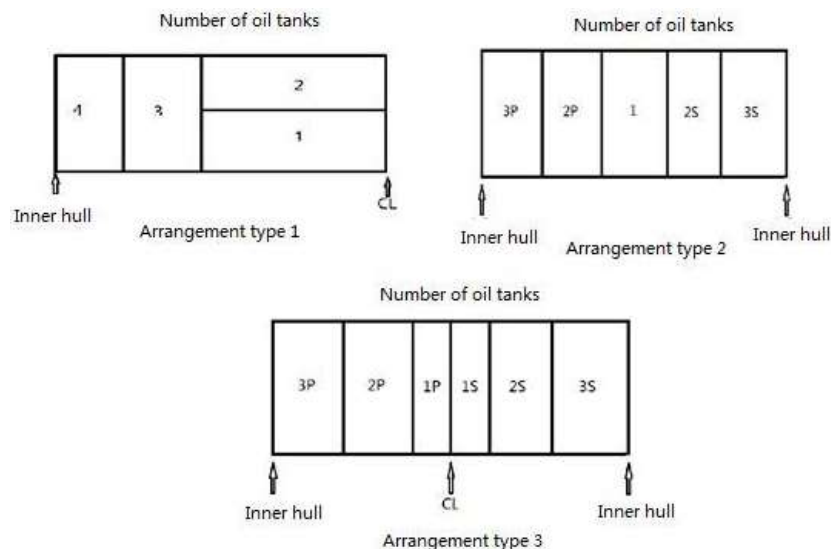


Figure 2.8.4.1 Diagram of Typical Fuel Oil Tank Arrangement Types (Vertical View)

Table 2.8.4.1(1) - Loading condition of Typical Fuel Oil Tank Arrangement Type 1

Loading Condition	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Wave	Hogging	Hogging	Hogging	Hogging	Sagging	Sagging	Sagging	Sagging	Hogging	Hogging	Hogging	Hogging	Hogging	Hogging
Draught	d	d	d	d	0.9d	0.9d	0.9d	0.9d	d	d	d	d	d	d
Weight of container (TEU)	Light	Light	Light	Light	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy
Side ballast tank	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	Empty	Empty
Bottom ballast tank	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	Empty	Empty
Oil tank	Empty	Full load	Tanks 1, 3, 4 full	Tanks 2, 3, 4 full	Tank 3 full	Tanks 1, 2, 4 full	Tanks 1, 3 full	Tanks 2, 4 full	Empty	Full load	Tanks 1, 3, 4 full	Tanks 2, 3, 4 full	Tanks 1, 3 full	Tank 2 full
Remark									One bay empty	One bay empty	One bay empty	One bay empty		

Note 1: In the column of “According to loading manual”, it will be empty if there is no corresponding condition in the loading manual.

2: “One bay empty” means it is empty inside the tank and on the hatch cover of one 40 ft bay.

Table 2.8.4.1(2) - Loading condition of Typical Fuel Oil Tank Arrangement Type 2

Loading Conditions	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Wave	Hogging	Hogging	Hogging	Hogging	Sagging	Sagging	Sagging	Sagging	Hogging	Hogging	Hogging	Hogging	Still water	Still water
Draught	d	d	d	d	0.9d	0.9d	0.9d	0.9d	d	d	d	d	d	d
Weight of Container (TEU)	Light	Light	Light	Light	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy
Side Ballast Tank	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	Empty	Empty
Bottom Ballast Tank	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	Empty	Empty
Oil Tank	Empty	Full load	No. 1 & 3 full load	No. 2 full load	Empty	Full load	No. 1 & 3 full load	No. 2 full load	Empty	Full load	No. 1 & 3 full load	No. 2 full load	No. 1 & 3 full load	No. 2 full load
Remark									One bay empty	One bay empty	One bay empty	One bay empty		

Note 1: In the column of “According to loading manual”, it will be empty if there is no corresponding condition in the loading manual.

2: “One bay empty” means it is empty inside the tank and on the hatch cover of one 40 ft bay.

Table 2.8.4.1(3) - Loading condition of Typical Fuel Oil Tank Arrangement Type 3

Loading condition	1	2	3	4	5	6	7	8	9
Wave	Hogging	Hogging	Hogging	Hogging	Sagging	Sagging	Sagging	Sagging	Hogging
Draught	d	d	d	d	0.9d	0.9d	0.9d	0.9d	d
Container weight (TEU)	Light	Light	Light	Light	Heavy	Heavy	Heavy	Heavy	Heavy
Side ballast tank	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual
Bottom ballast tank	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual
Oil tank	Empty	Full load	3P, 1P, 2S full load	2P, 1S, 3S full load	Empty	Full load	3P, 1P, 2S full load	2P, 1S, 3S full load	Empty
Remarks									

Loading condition	10	11	12	13	14	15	16	17	18
Wave	Hogging	Hogging	Hogging	Hogging	Hogging	Hogging	Hogging	Still water	Still water
Draught	d	d	d	d	d	d	d	d	d
Container weight (TEU)	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy
Side ballast tank	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	Empty	Empty
Bottom ballast tank	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	According to loading manual	Empty	Empty
Oil tank	Full load	3P, 1P, 2S full load	2P, 1S, 3S full load	Empty	Full load	3P, 1P, 2S full load	2P, 1S, 3S full load	Full load	3P, 1P, 2S full load
Remarks				One bay empty	One bay empty	One bay empty	One bay empty		

Note 1: In the column of “According to loading manual”, it will be empty if there is no corresponding condition in the loading manual.

2: “One bay empty” means it is empty inside the tank and on the hatch cover of one 40 ft bay.

2.8.5 Boundary conditions

2.8.5.1 The boundary conditions are to be in accordance with the relevant provisions of 2.5 in this Appendix.

2.8.6 Strength evaluation

2.8.6.1 Evaluated areas

2.8.6.1 The mid tank and primary structural members within the extent of one web frame extending forward and afterward are to be evaluated.

2.8.6.2 Yield strength evaluation

(1) The stresses generated by local load case and global load case are to be combined for strength check. The equivalent stress at midpoint of element is to be taken as the plate element stress.

(2) The permissible stress for each primary structural member is given in Table 2.8.6.2.

Table 2.8.6.2 - Permissible stress

Structural Member	Permissible Stress (N/mm ²)	
	[σ_e]	[τ]
Bottom plating, inner bottom plating	225/K	–
Side shell plating, inner hull longitudinal bulkhead	225/K	115/K
Bottom girder	235/K	115/K
Intersection of oil fuel boundaries and bottom girders	235/K	115/K
Double bottom floor	175/K	90/K
Transverse web frame	195/K	95/K
Fuel oil tank bulkhead (excluding inner hull longitudinal bulkhead)	180/K	100/K
Stringers in fuel oil tank and girder webs between bulkheads	195/K	100/K

Note: K —material factor.

2.8.6.3 Buckling strength evaluation

(1) The buckling strength evaluation method is given in the provisions of 2.6 in this Appendix.

2.8.6.4 Fine mesh analysis

(1) If the yield stress exceeds the permissible criteria, fine mesh analysis may be carried out in the critical areas, such as the connection of fuel oil tank boundaries to bottom girders, platform corners within fuel oil tanks, etc. The fine mesh analysis method, element requirements and evaluation criteria are given in 2.7 of this Appendix.

3 Direct Calculation of Global Strength of Ship

3.1 General requirements

3.1.1 Direct strength calculation of whole ship is to be used to evaluate the global strength of primary hull members under combined bending and torsional moments. In calculation, the following two methods may be used:

Method 1: Analysis where hull girder loads (vertical bending moment, horizontal bending moment and torsional moment) are directly applied to the full ship finite element model.

Method 2: Analysis where direct loads transferred from wave load analysis are applied to the full ship finite element model.

3.2 Loading conditions

3.2.1 Still water condition

3.2.1.1 The still water condition is to be selected according to the loading manual, and generally the full load condition where maximum still water bending moment occurs and normal ballast condition where maximum GM occurs are to be taken.

3.2.1.2 Under the maximum still water bending moment conditions, the ship is to be in or close to upright condition, at or near to the draught d , and the still water bending moment within $0.4L$ amidships is the maximum value. If one 40 ft bay in midship range is to be left empty, the maximum still water bending moment condition under this loading condition is required.

3.2.1.3 Consideration is also to be taken if more severe non-homogeneous loading conditions exist in the loading manual.

3.2.2 Wave load condition

3.2.2.1 The still water load condition as determined according to 3.2.1 is taken as the basic loading condition for wave load conditions.

3.2.2.2 Unless specified otherwise in the Appendix, the parameters of wave load conditions, such as length, height and phase of waves, are to be determined by the method and procedure used for equivalent design wave, see Section 5, Chapter 1 of this PART. The wave load conditions are to include head sea, oblique sea and beam sea conditions.

3.2.2.3 The dominant load parameters for direct calculation of wave loads include vertical wave bending moment, horizontal wave bending moment, torsional moment, acceleration and rolling angle. The prediction of the maximum wave load likely to be experienced during the service life covers mainly sea conditions to be encountered during navigation in sea areas around the world, expressed in the probability of waves occurring in various periods and heights. It is suggested that the wave scatter diagram recommended by IACS be adopted. The probability level of dominant load parameters is generally taken as 10^{-8} , and that of the prediction value of maximum vertical wave bending moment corresponding to the value as required in Section 2 of this Chapter may also be taken.

3.2.3 Loading conditions

3.2.3.1 Each calculation condition is based on different combination of still water condition and wave load condition. Generally, the global strength analysis of container ships is to be checked

in accordance with the loading conditions in Table 3.2.3.1. For two-island container ship, the considered condition of the maximum torque at fore and aft ends of the fore island is also to be checked.

Table 3.2.3.1 - Loading Conditions

Dominant Load Parameters	Homogeneous Full Load	Normal Ballast	Non-homogeneous Loading (if any)
Maximum vertical wave bending moment	Applicable	Applicable	Applicable
Maximum horizontal wave bending moment	Applicable	Applicable	Applicable
Maximum torque in way of $L/2$	Applicable	Applicable	Applicable
Maximum torque in way of $L/4$	Applicable	Applicable	Applicable
Maximum torque in way of $3L/4$	Applicable	Applicable	Applicable
Maximum vertical bow acceleration	Applicable	Applicable	Applicable
Maximum rolling angle	–	Applicable	–

3.3 Finite element model for whole ship

3.3.1 Extent of finite element model

3.3.1.1 The ship's global three-dimensional finite element model covers all longitudinal stressed members in main hull within ship's complete length and full breadth, such as deck structure, side and longitudinal bulkhead structure and double bottom structure. The model covers also primary transverse structures such as transverse bulkhead, transverse web frame, transverse deck strip, etc. Local supporting members such as brackets may be omitted in the model. Requirements for openings of web plates of primary structural members are defined in Section 5, Chapter 1 of this PART and openings in brackets may be omitted. A global structural FE model of a typical container ship is shown in Figure 3.3.1.1.

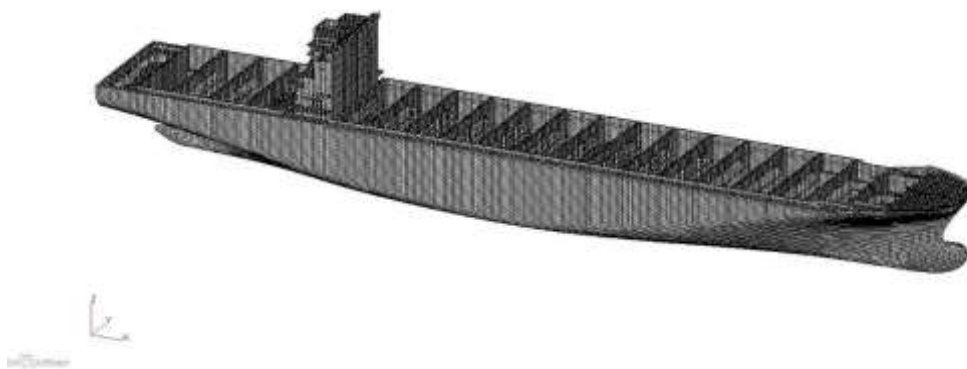


Figure 3.3.1.1 Global Structural FE Model of a Typical Container Ship

3.3.2 Selection of elements

3.3.2.1 All kinds of structures in the model are discretized into the following types of elements based on their structural responses:

- (1) Shell element (four-node and three-node elements): such as deck, side shell, bottom plating, inner bottom plating, longitudinal and transverse bulkheads, bottom girder, floor, wing space horizontal girder, transverse web frame, etc.

- (2) Beam element: such as girder, beam and watertight bulkhead stiffener, etc.
- (3) Rod element: such as pillar, etc.

3.3.3 Meshing

3.3.3.1 Unless otherwise specified in this Appendix, the requirements for structural modeling are given in Section 5, Chapter 1 of this PART.

3.3.3.2 The aspect ratio of elements amidships is not to exceed 1:3 and is not to exceed 1:2 elsewhere. Warped quadrilateral elements are to be avoided for meshing.

3.3.4 Boundary conditions

3.3.4.1 In order to prevent rigid displacements, suitable linear displacement constraints are to be applied at corresponding nodes of hull as shown in Figure 3.3.4.1.

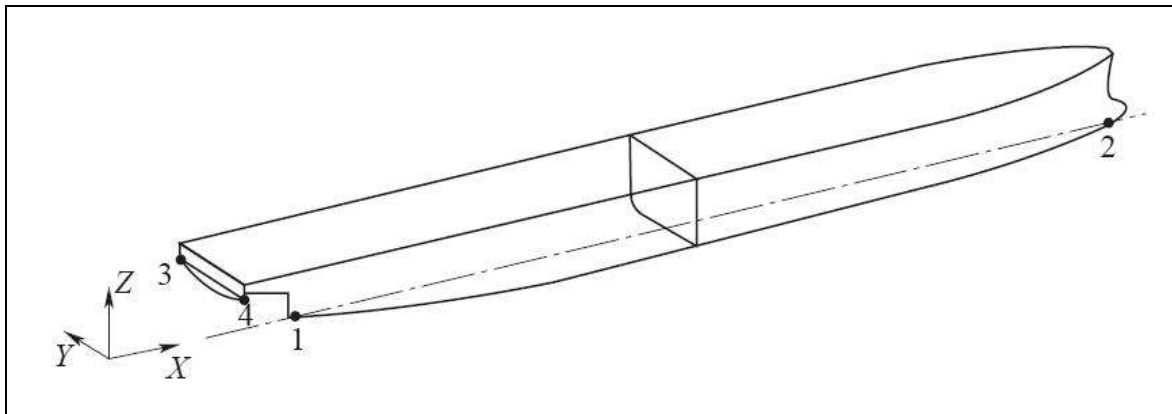


Figure 3.3.4.1 Diagram of Boundary Conditions

3.3.4.2 The displacement in transverse direction for bottom plate keel (in longitudinal centerline section) at aft end (node 1 in Figure 3.3.4.1 of this Appendix) is restrained, i.e.: $\delta y = 0$; the displacements in longitudinal, transverse and vertical directions for bottom plate keel (in longitudinal centreline section) at fore end (node 2 in Figure 3.3.4.1 of this Appendix) are restrained, i.e.: $\delta x = \delta y = \delta z = 0$.

3.3.4.3 The displacements in vertical direction for node 3 (port) and node 4 (starboard) respectively which are at an equal distance from the longitudinal centerline section on horizontal girder of stern transom plate are restrained, i.e.: $\delta z = 0$.

3.3.5 Fine mesh analysis

3.3.5.1 Fine mesh analysis is to be carried out if the result of whole ship FE calculation of stresses in the following areas exceeds 90% of the permissible stress specified in 3.4.1 of this Appendix:

- (1) in way of the steps of transverse web frames in cargo hold area;
- (2) connection of double bottom girder and transverse bulkhead;
- (3) face plate of horizontal girders and large bracket toe in way of the supporting transverse bulkhead;
- (4) in way of the bracket toe of longitudinal hatch coaming;
- (5) in way of hatch corners of hatch coamings top plates and deck plates;

(6) openings on inner shell, hatch coaming, deck and vertical girder and horizontal girder of transverse bulkheads.

3.3.5.2 Fine mesh analysis is to comply with the requirements of 2.7 of this Appendix.

3.4 Yield strength evaluation for global finite element structure of ship

3.4.1 The allowable stress of plates including girder web is as follows:

$$[\sigma_e] = 220/K \text{ N/mm}^2$$

where: K — material factor.

3.4.2 The beam element is taken as the axial stress and its allowable stress is as follows:

$$[\sigma] = 220/K \text{ N/mm}^2$$

where: K — material factor.

3.4.3 The stress criteria and checking method for fine mesh analysis are defined in 2.7.9 of this Appendix and $[\sigma_e]$ is to be calculated according to 3.4.1.

3.5 Buckling strength evaluation for global finite element structure of ship

3.5.1 The buckling strength evaluation for global finite element structure of ship is to be checked in accordance with 2.6.3 of this Appendix.

4 Fatigue Strength Evaluation

4.1 General requirements

4.1.1 This Section provides methods to evaluate fatigue strength of key positions of container ships under bending and torsional loads.

4.1.2 The wave load calculation for evaluation of fatigue strength of hatch corners is to be based on the equivalent design wave method used for structural analysis of the whole ship, as shown in Section 5 of Chapter 1.

4.1.3 Fatigue damage calculation is based on Palmgren-Miner linear cumulative damage principle, taking into account S-N curves and sea state parameters etc.

4.1.4 In addition to the evaluation method given in this Section, the fatigue evaluation may also be carried out in accordance with relevant requirements of ISC Guidelines for Spectrum-based Fatigue Assessment of Hull Structure.

4.1.5 Hull structures in way of key positions are to be screened based on the result of coarse mesh calculation to determine the fatigue evaluation spots. The evaluation spots are at least to include end bracket toes of longitudinal hatch coaming, hatch corners at the fore (aft) end of engine room, hatch corners at the end of No.1 cargo hold towards the fore end of the ship and a

cargo hold hatch corner amidships.

4.2 Loads

4.2.1 The loads for fatigue evaluation are to be obtained from the corresponding loading conditions for global analysis of the ship.

4.2.2 The loading condition is to be taken as the full load condition in loading manual where maximum still water bending moment occurs.

4.2.3 Loading conditions

4.2.3.1 In general, the design wave loads to be calculated are as follows:

- (1) LC1: maximum vertical wave bending moment in way of $1/2L$ from *AP* (hogging);
- (2) LC2: minimum vertical wave bending moment in way of $1/2L$ from *AP* (sagging);
- (3) LC3: maximum horizontal wave bending moment in way of $1/2L$ from *AP*;
- (4) LC4: minimum horizontal wave bending moment in way of $1/2L$ from *AP*;
- (5) LC5: maximum wave torque in way of $1/4L$ from *AP*;
- (6) LC6: minimum wave torque in way of $1/4L$ from *AP*;
- (7) LC7: maximum wave torque in way of $1/2L$ from *AP*;
- (8) LC8: minimum wave torque in way of $1/2L$ from *AP*;
- (9) LC9: maximum wave torque in way of $3/4L$ from *AP*;
- (10) LC10: minimum wave torque in way of $3/4L$ from *AP*.

4.2.3.2 The displacements and stresses of the global structure are to be obtained by the loading conditions specified in 4.2.3.1 of this Appendix.

4.2.3.3 The range of dynamic stresses at the edge of hatch corners is to be based on the calculation results of each loading condition specified in 4.2.3.1 of this Appendix and combined as follows:

$$\Delta\sigma_{12} = \sigma_{LC1} - \sigma_{LC2}$$

$$\Delta\sigma_{34} = \sigma_{LC3} - \sigma_{LC4}$$

$$\Delta\sigma_{56} = \sigma_{LC5} - \sigma_{LC6}$$

$$\Delta\sigma_{78} = \sigma_{LC7} - \sigma_{LC8}$$

$$\Delta\sigma_{910} = \sigma_{LC9} - \sigma_{LC10}$$

where: $\Delta\sigma_{ij}$ — range of stresses under the combined load cases *i* and *j*, taken as the range of tangential stresses at the free edge if the evaluation spot is the free edge of corners or openings, in N/mm^2 ;

σ_{LCi} — value of stress in load case *i*, taken as the value of tangential stresses at the free edge if the evaluation spot is the free edge of corners or openings, in N/mm^2 .

4.3 Structural modeling

4.3.1 General requirements

4.3.1.1 The local fine mesh model is to be in accordance with the requirements of 4.3.2 to 4.3.7 of this Appendix.

4.3.1.2 For the fatigue analysis, the three-dimensional fine mesh model of the local structure may be separated for an individual analysis, applying the displacement results obtained from global three-dimensional coarse mesh finite element analysis to the corresponding boundary nodes as

boundary conditions for forced displacements. Alternatively, the fine mesh model may be inserted directly into the global model for analysis. The boundary of fine mesh model is as far as practicable to be taken on the structure of primary supporting and web frames, provided that the following model extent is observed.

4.3.2 Fine mesh model of local structure of hatch corners in the midship region

4.3.2.1 For the local fine mesh model of the midship region, the deck openings where the maximum stress or maximum cross-deck strip warping displacement occurs are in general selected, see Figures 4.3.2.1(1) and (2), and the corresponding extent of model is as follows:

- (1) for longitudinal extent, half length of a 40 ft container bay, extending forward and afterward of cross deck strip corner;
- (2) for vertical extent, from No.2 deck to the top of hatch coaming;
- (3) for transverse extent, from the centerline to ship side, covering hatch corners in way of upper deck and the transitional structure of corners in way of hatch coaming top plate.

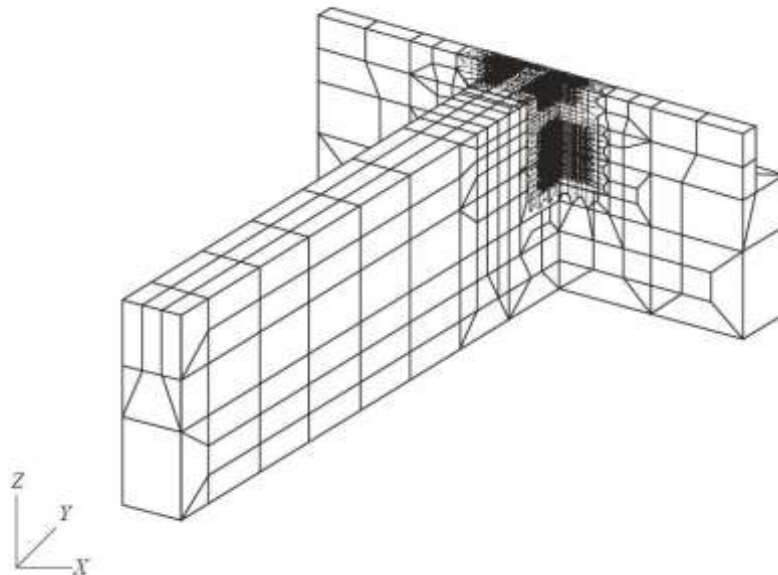


Figure 4.3.2.1(1) FE Model of Hatch Corners in Way of Cargo Hold Area

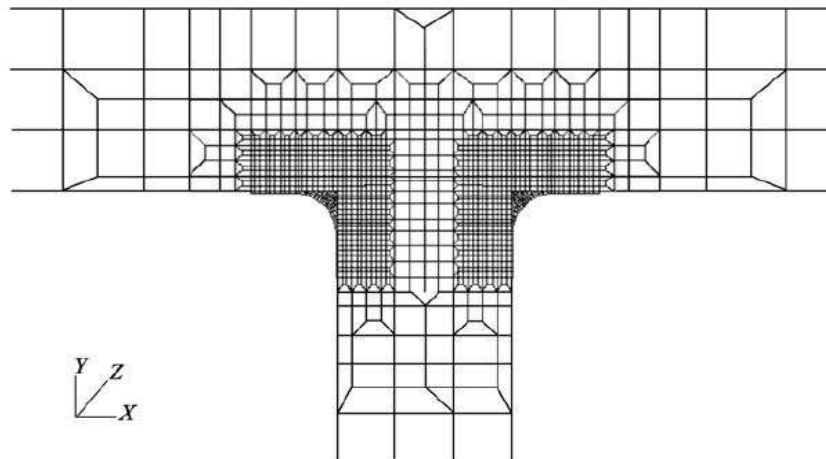


Figure 4.3.2.1(2) FE Model of Hatch Corners in Way of Cargo Hold Area
(Upper Deck Hatch Corners Amplified)

4.3.3 Fine mesh model of local structure of hatch corners at fore end of engine room

4.3.3.1 For the local fine mesh model at the fore end of the engine room, the hatch corners at the front bulkhead of the engine room at portside are to be selected, and the corresponding extent of model is as follows:

- (1) for longitudinal extent, half length of a 40 ft container bay extending forward from the front transverse bulkhead of the engine room and a similar distance extending afterward to the transverse web frame (in general, at the mesh line of the transverse web frame of the global model);
- (2) for vertical extent, from No.2 deck to hatch coaming (in general, up to the first-tier deck in way of superstructures);
- (3) for transverse extent, from the centerline to ship side.

4.3.3.2 All the models are to include upper deck structures with openings, radiused transition structures in way of the hatch coaming top plate and the tapered bracket between the forward end of superstructures and hatch coaming, and their geometry is to be described accurately in the model, see Figures 4.3.3.2(1) to (3).

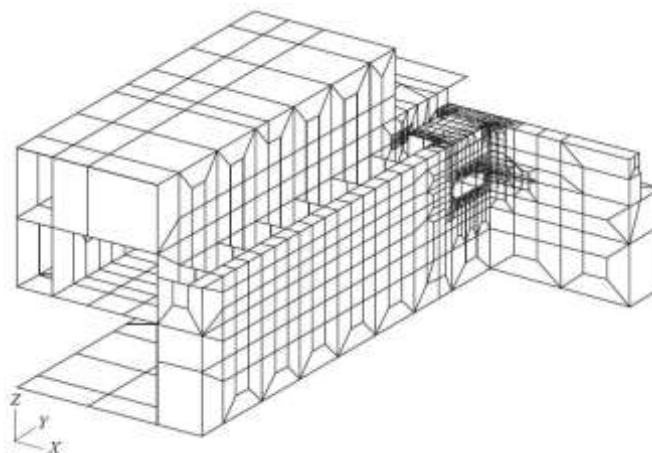


Figure 4.3.3.2(1) FE Model of Hatch Corners in Way of Engine Room Front Bulkhead

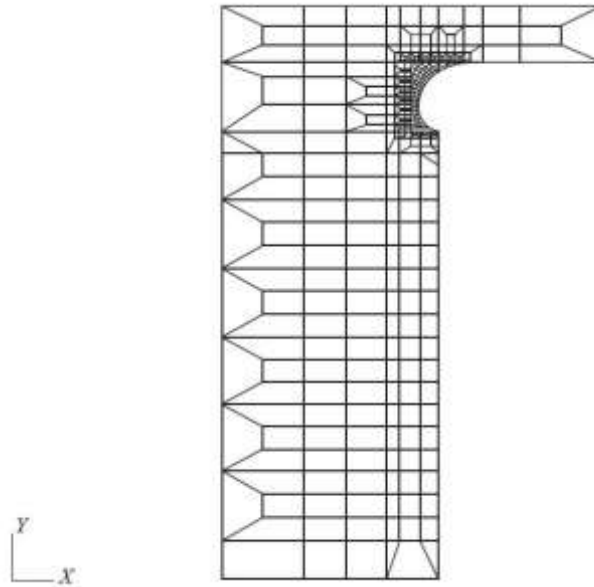


Figure 4.3.3.2(2) FE Model of Hatch Corners in Way of Engine Room Front Bulkhead (Upper Deck Hatch Corners)

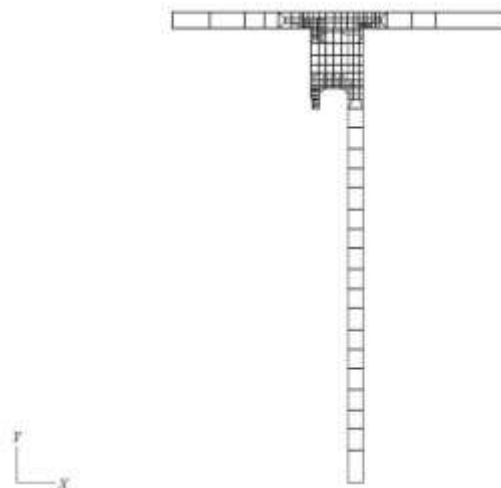


Figure 4.3.3.2(3) FE Model of Hatch Corner in Way of Engine Room Front Bulkhead (Hatch Coaming Top Plate)

4.3.4 The requirements for the local fine mesh model of hatch corners at the aft end of the engine room and the forward end of No.1 cargo hold are the same as those in 4.3.3.1.

4.3.5 Selection of elements and meshing

4.3.5.1 Plate elements are used to simulate primary structural members such as upper deck, shell plate, longitudinal bulkhead and transverse plates, and beam elements are used to simulate longitudinals and stiffeners. Meshing of the positions where hot-spot stress is checked is shown in 4.3.5.4 of this Appendix.

4.3.5.2 The geometry of radiused corners in upper deck area, radiused top plates of hatch coamings, etc. are to be reflected accurately in the fine mesh model, and all openings (ventilators, access openings) are also to be described accurately in the model.

4.3.5.3 Where the tangential stress at the edge of hatch corners can not be obtained from the finite element analysis program, the method of providing virtual rod elements at the edge of hatch corners to obtain the axial stress of elements is to be used to get the tangential stress, and virtual rod elements may be applied to the following positions:

- (1) along the radiused edge of hatch corners at the top level of upper deck and hatch coaming;
- (2) along the superstructure to the upper edge of the radiused connecting bracket of longitudinal hatch coaming, if any.

4.3.5.4 The plate elements of areas of hot-spot stress evaluation are to be divided in accordance with the mesh size of plate thickness $\times$ plate thickness ($t \times t$). This mesh density is to be maintained within the fine mesh zone, extending at least $10t$ distance in all directions from the center of hot spot stress to provide a smooth transition to the model boundary.

4.3.6 Boundary conditions

4.3.6.1 The boundary conditions for the global three-dimensional coarse mesh FE model are given in 3.3.4 of this Appendix.

4.3.6.2 Where an independent sub-model is used for analysis, the nodal displacements in way of the boundary of a coarse mesh model, which are obtained from calculations of the above-mentioned loading conditions for the global model, are to be transmitted to corresponding nodes of the fine mesh model as forced displacement boundary conditions of the fine mesh model.

4.4 Fatigue strength evaluation

4.4.1 Assuming that the long-term distribution of the stress ranges of hull structures is a two-parameter Weibull distribution, the shape parameter ξ of Weibull distribution is to be calculated as follows:

$$\xi = 1.45 - 0.036f\sqrt{L}$$

where: L — length of ship, in m;

$f = 1 - 0.08z/d_1$ For $z \leq d_1$;

$f = 0.92 + 0.08(z - d_1)/(D - d_1)$ for $z > d_1$;

$f = 0.92$ for the calculated point on transverse bulkhead;

D — moulded depth, in m;

d_1 — draught in the considered condition, in m;

z — vertical distance from calculation point to baseline, in m.

4.4.2 Design $S-N$ curves are to be selected as follows:

For welding type joint, D curves are selected for fatigue strength evaluation;

For free edge of base metal, C curves are selected for fatigue strength evaluation.

4.4.3 Cumulative damage DT is to be calculated as follows:

$$D_T = \frac{N_D \alpha}{K} \frac{S_D^m}{(\ln N_L)^{m/\xi}} t \Gamma \left(1 + \frac{m}{\xi} \right)$$

where: N_D — total cycles of loads within 20 years' service life of ships, normally taken as 0.65×10^8 ;

N_L — cycles of load spectrum response circle, taken as 10^8 ;

α — in-service coefficient of ship, taken as 0.85;

K — S-N curve parameter, see Table 4.4.3(1) of this Appendix;

S_D — design stress ranges, in N/mm^2 , calculated as follows:

$$S_D = \max(f_c \cdot f_{mean} \cdot f_t \cdot |\Delta\sigma_{ij}|)$$

$\Delta\sigma_{ij}$ — design stress ranges of the combined load cases i and j , see 4.2.3.3 of this Appendix;

f_c — corrosion correction factor, taken as 1.07;

f_{mean} — average stress correction factor, selected as follows:

for welding type joint:

$$f_{mean} = \begin{cases} \min(1.0, 0.85 + 0.3\sigma_{mean}/\Delta\sigma_y), \sigma_{mean} \geq 0 \\ \max(0.7, 0.85 - 0.3\sigma_{mean}/\Delta\sigma_y), \sigma_{mean} \leq 0 \end{cases}$$

for free edge of base metal

$$f_{mean} = \begin{cases} \min(1.0, 0.8 + 0.4\sigma_{mean}/\Delta\sigma_y), \sigma_{mean} \geq 0 \\ \max(0.6, 0.8 + 0.4\sigma_{mean}/\Delta\sigma_y), \sigma_{mean} \leq 0 \end{cases}$$

σ_{mean} — average stress of considered loading;

f_t — plating thickness correction coefficient, selected as follows: $f_t = 1.0$ for $t \leq 22$;

$$f_t = \left(\frac{t}{22} \right)^n \text{ for } t > 22;$$

n — coefficient, see Table 4.4.3(2) of this Appendix;

t — plating thickness at hot spot, in mm, taken as the thickness of plating of structure where cracks are easy to occur and extend;

ξ — parameter of Weibull distribution, see 4.4.1 of this Appendix;

m — inverse slope of the S-N curve, taken as 3;

Γ — complete GAMMA function values, to be calculated as follows:

$$\Gamma(x) = \int_0^\infty u^{x-1} e^{-u} du$$

$$\mu = 1.0 - \frac{\gamma\left(1 + \frac{m}{\xi}, v\right) - v^{-\frac{\nabla m}{\xi}} \gamma\left(1 + \frac{m + \nabla m}{\xi}, v\right)}{\Gamma\left(1 + \frac{m}{\xi}\right)}$$

$$v = \left(\frac{S_q}{S_D} \right)^\xi \ln N_L$$

S_q — stress amplitude values at intersection point of two-slope S-N curves, see Table 4.4.3(1) of this Appendix;

∇m — difference of inverse slope of two-slope S-N curves, taken as 2;

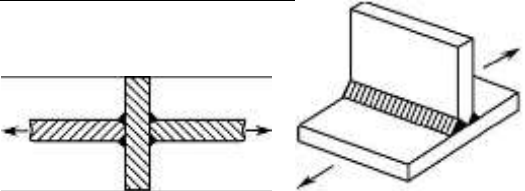
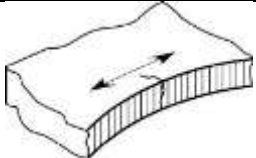
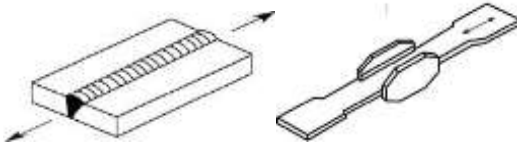
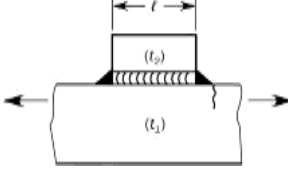
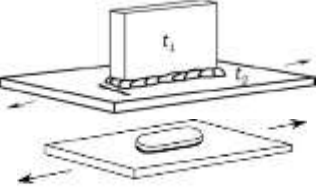
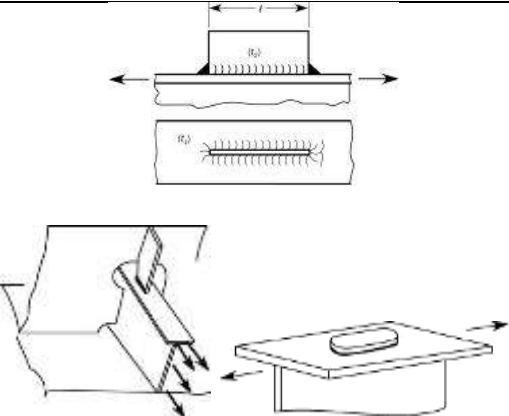
$\gamma(x, v)$ — incomplete GAMMA function values, to be calculated as follows:

$$\gamma(x, v) = \int_0^v u^{x-1} e^{-u} du$$

Table 4.4.3(1)

S–N Curve	K	Sq
C	3.464×10^{12}	70.2305
D	1.520×10^{12}	53.368

Table 4.4.3(2)

Structural Details	Sketches	Coefficient n
Cruciform joints or transverse T-joints, with weld perpendicular to the direction of load		0.25
Butt joints, with weld perpendicular to the direction of load		0.2
Machine controlled by program or plate with flame-cut edges, with plate edge parallel to the direction of load		0.1
Plate edge which is ground smooth by machine or other means after cutting		0
Butt welds, attachments on plate edge, with weld parallel to the direction of load		0.1
Attachments on the flat bar or bulb profile, with weld parallel to the direction of load		0
Bracket welded on the plate, with weld parallel to the direction of load, doubling plate		0.2
T section face plate welded with bracket or doubling plates, with weld parallel to the direction of load		0.1

4.4.4 Structure fatigue life is to be calculated as follows:

$$T_F = \frac{20}{D_T}$$

4.4.5 Cumulative damage DT for structure in its design service life is to meet the following requirement:

$$D_T \leq \frac{20}{T_D}$$

where: T_D — design fatigue life, in year.

APPENDIX 3 CALCULATION OF SHEAR FLOW

1 General Requirements

This Appendix describes the procedures of direct calculation of shear flow around a ship's cross section due to hull girder vertical shear force. The shear flow q_V at each location in the cross section, is calculated by considering the cross section is subjected to a unit vertical shear force of 1 N in the direction of Z coordinate.

The unit shear flow per mm, q_V , in N/mm, is to be taken as:

$$q_V = q_D + q_I$$

where:

q_D — determinate shear flow, as defined in 2;

q_I — indeterminate shear flow which circulates around the closed cells, as defined in 3.

In the calculation of the unit shear flow, q_V , the longitudinal stiffeners are to be taken into account.

2 Determinate Shear Flow

The determinate shear flow, q_D , in N/mm at each location in the cross section is to be obtained from the following line integration:

$$q_D(s) = -\frac{1}{10^6 I_{Y-net}} \int_0^s (z - z_n) t_{net} dz$$

where: s — coordinate value of running coordinate along the cross section, in m;

I_{Y-net} — net moment of inertia of the cross section, in m^4 ;

t_{net} — net thickness of plating, in mm;

z_n — Z coordinate of horizontal neutral axis from baseline, in m.

It is assumed that the cross section is composed of line segments as shown in Figure 1: where each line segment has a constant plate net thickness. The determinate shear flow is obtained by the following equation.

$$q_{Dk} = -\frac{t_{net} \ell}{2 \cdot 10^6 I_{Y-net}} (z_k + z_i - 2z_n) + q_{Di}$$

where: q_{Dk}, q_{Di} — determinate shear flow at node k and node i respectively, in N/mm;

ℓ — length of line segments, in m;

y_k, y_i — Y coordinate of the end points k and i of line segment, in m, as defined in Figure 1;

z_k, z_i — Z coordinate of the end points k and i of line segment, in m, as defined in Figure 1.

Where the cross section includes closed cells, the closed cells are to be cut with virtual slits, as shown in Figure 2, in order to obtain the determinate shear flow.

These virtual slits must not be located in walls which form part of another closed cell.

Determinate shear flow at bifurcation points is to be calculated by water flow calculations, or similar, as shown in Figure 2.

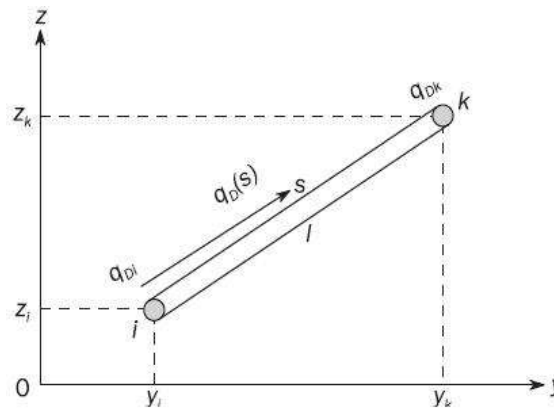


Figure 1 Definition of line segment

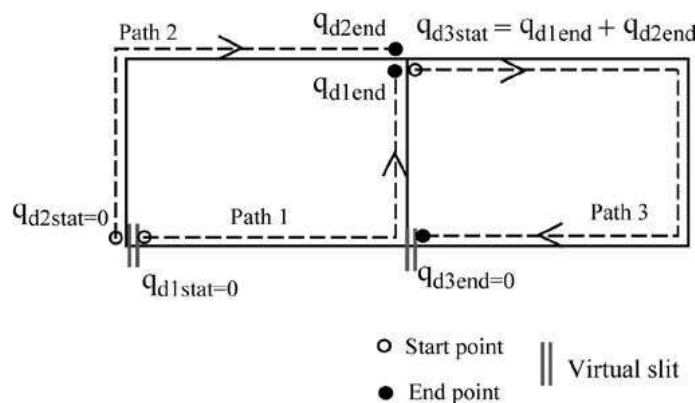


Figure 2 Calculation of determinate shear flow at bifurcation points

3 Indeterminate Shear Flow

The indeterminate shear flow around closed cells of a cross section is considered as a constant value within the same closed cell. The following system of equation for determination of indeterminate shear flows can be developed. In the equations, contour integrations of several parameters around all closed cells are performed.

$$q_{1c} \oint_c \frac{1}{t_{net}} ds - \sum_{m=1}^{N_w} \left(q_{1m} \oint_{c \& m} \frac{1}{t_{net}} ds \right) = - \oint_c \frac{q_D}{t_{net}} ds$$

where: N_w — number of common walls shared by cell c and all other cells;

c & m — common wall shared by cells c and m ;

q_{1c}, q_{1m} — indeterminate shear flow around the closed cell c and m respectively, in N/mm.

Under the assumption of the assembly of line segments shown in Figure 1 and constant plate thickness of each line segment, the above equation can be expressed as follows:

$$q_{Ic} \sum_{j=1}^{N_c} \left(\frac{\ell}{t_{net}} \right)_j - \sum_{m=1}^{N_w} \left\{ q_{Im} \left[\sum_{j=1}^{N_m} \left(\frac{\ell}{t_{net}} \right)_j \right]_m \right\} = - \sum_{j=1}^{N_c} \phi_j$$

$$\phi_j = \left[- \frac{\ell^2}{6 \cdot 10^3 I_{Y-net}} (z_k + 2z_i - 3z_n) + \frac{\ell}{t_{net}} q_{Di} \right]_j$$

where: N_c — number of line segments in cell c ;

N_m — number of line segments on the common wall shared by cells c and m ;

q_{Di} — determinate shear flow, in N/mm, calculated according to 2.

The difference in the directions of running coordinates specified in 2 and in this section has to be considered.

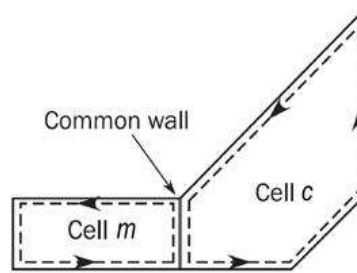


Figure 3 Closed cells and common wall

4 Computation of Sectional Properties

Properties of the cross section are to be obtained by the following formulae where the cross section is assumed as the assembly of line segments:

$$\ell = \sqrt{(y_k - y_i)^2 + (z_k - z_i)^2}$$

$$a_{net} = 10^{-3} \ell t_{net} \quad A_{net} = \sum a_{net}$$

$$S_{y-net} = \frac{a_{net}}{2} (z_k + z_i) \quad S_{y-net} = \sum S_{y-net}$$

$$I_{y0-net} = \frac{a_{net}}{3} (z_k^2 + z_k z_i + z_i^2) \quad I_{y0-net} = \sum I_{y0-net}$$

where: a_{net} , A_{net} — area of the line segment and the cross section respectively, in m^2 ;

S_{y-net} , S_{y-net} — first moment of the line segment and the cross section about the baseline, in m^3 ;

I_{y0-net} , I_{y0-net} — moment of inertia of the line segment and the cross section about the baseline, in m^4 . The height of horizontal neutral axis, z_n , in m , is to be obtained as follows:

$$z_n = \frac{S_{y-net}}{A_{net}}$$

Inertia moment about the horizontal neutral axis, in m^4 , is to be obtained as follows:

$$I_{y-net} = I_{y0-net} - z_n^2 A_{net}$$

APPENDIX 4 BUCKLING CAPACITY

Symbols

x axis : local axis of a rectangular buckling panel parallel to its long edge;

y axis : local axis of a rectangular buckling panel perpendicular to its long edge;

σ_x : membrane stress applied in x direction, in N/mm^2 ;

σ_y : membrane stress applied in y direction, in N/mm^2 ;

τ : membrane shear stress applied in xy plane, in N/mm^2 ;

σ_a : axial stress in the stiffener, in N/mm^2 ;

σ_b : bending stress in the stiffener, in N/mm^2 ;

σ_w : warping stress in the stiffener, in N/mm^2 ;

$\sigma_{cx}, \sigma_{cy}, \tau_c$: critical stress, in N/mm^2 , defined in 2.1.1 of this Appendix for plates;

ReH_S : specified minimum yield stress of the stiffener, in N/mm^2 ;

ReH_P : specified minimum yield stress of the plate, in N/mm^2 ;

a : length of the longer side of the plate panel as shown in Table 2, in mm;

b : length of the shorter side of the plate panel as shown in Table 2, in mm;

d : length of the side parallel to the axis of the cylinder corresponding to the curved plate panel as shown in Table 3, in mm;

σ_E : elastic buckling reference stress, in N/mm^2 , to be taken as:

(1) for the application of plate limit state according to 2.1.2 of this Appendix:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)} \left(\frac{t_p}{b} \right)^2;$$

(2) for the application of curved plate panels according to 2.2 of this Appendix:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)} \left(\frac{t_p}{d} \right)^2;$$

ν : Poisson's ratio to be taken equal to 0.3;

t_p : net thickness of plate panel, in mm; t_w : net stiffener web thickness, in mm; t_f : net flange thickness, in mm;

b_f : breadth of the stiffener flange, in mm;

h_w : stiffener web height, in mm;

ef : Distance from attached plating to centre of flange, in mm, to be taken as:

(1) $ef = h_w$ for flat bar profile;

(2) $ef = h_w - 0.5 t_f$ for bulb profile;

(3) $ef = h_w + 0.5 t_f$ for angle and Tee profiles;

α : aspect ratio of the plate panel, to be taken as:

$$\alpha = \frac{a}{b}$$

β : coefficient, to be taken as:

$$\beta = \frac{1-\nu}{\alpha}$$

ψ : edge stress ratio, to be taken as:

$$\psi = \frac{\sigma_2}{\sigma_1}$$

σ_1 : maximum stress, in N/mm²;

σ_2 : minimum stress, in N/mm²;

R : radius of curved plate panel, in mm;

ℓ : span, in mm, of stiffener equal to the spacing between primary supporting members;

S : spacing of stiffener, in mm;

ω : factor, to be taken as $\omega = \min(3; \alpha)$.

1 Elementary Plate Panel (EPP)

1.1 Definition

An Elementary Plate Panel (EPP) is the unstiffened part of the plating between stiffeners and/or primary supporting members.

All the edges of the elementary plate panel are forced to remain straight (but free to move in the in-plane directions) due to the surrounding structure/neighbouring plates (usually longitudinal stiffened panels in deck, bottom and inner-bottom plating, shell and longitudinal bulkheads).

1.2 EPP with different thicknesses

1.2.1 Longitudinally stiffened EPP with different thicknesses

In longitudinal stiffening arrangement, when the plate thickness varies over the width, b , in mm, of a plate panel, the buckling capacity is calculated on an equivalent plate panel width, having a thickness equal to the smaller plate thickness, t_1 . The width of this equivalent plate panel, b_{eq} , in mm, is defined by the following formula:

$$b_{eq} = \ell_1 + \ell_2 \left(\frac{t_1}{t_2} \right)^{1.5}$$

where:

ℓ_1 : width of the part of the plate panel with the smaller plate thickness, t_1 , in mm, as defined in Figure 1;

ℓ_2 : width of the part of the plate panel with the greater plate thickness, t_2 , in mm, as defined in Figure 1.

Where a panel is consisted of different materials, the minimum yield strength is to be used in buckling assessment.

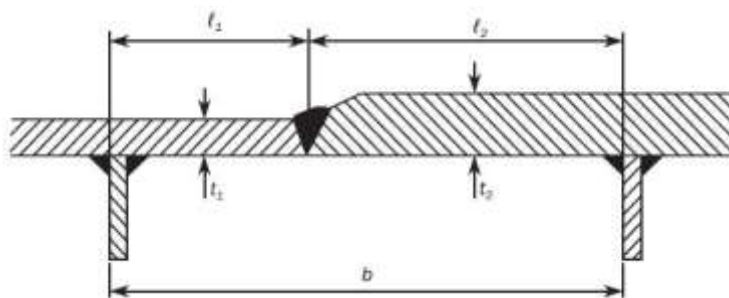


Figure 1 Plate thickness change over the width

1.2.2 Transversally stiffened EPP with different thicknesses

In transverse stiffening arrangement, when an EPP is made of different thicknesses, the buckling check of the plate and stiffeners is to be made for each thickness considered constant on the EPP. The applied stress and lateral pressure is to be measured from the load calculation point of the plate panel.

2 Buckling Capacity of Plates

2.1 Plate panel

2.1.1 Plate limit state

The plate limit state is based on the following interaction formulae. Buckling check under normal stress is for the compression stress, when the normal stress (σ_x) is less than zero, the corresponding item is to be deleted and pure shear buckling is to be checked:

(a) longitudinal stiffening arrangement:

$$\left(\frac{\gamma_c \sigma_x}{\sigma_{cx}}\right)^{2/\beta_p^{0.25}} + \left(\frac{\gamma_c |\tau|}{\tau_c}\right)^{2/\beta_p^{0.25}} = 1$$

(b) transverse stiffening arrangement:

$$\left(\frac{\gamma_c \sigma_y}{\sigma_{cy}}\right)^{2/\beta_p^{0.25}} + \left(\frac{\gamma_c |\tau|}{\tau_c}\right)^{2/\beta_p^{0.25}} = 1$$

where:

σ_x, σ_y — applied normal stress to the plate panel, in N/mm², as defined in 7.2.4.4 of this Chapter;

τ — applied shear stress to the plate panel, in N/mm², as defined in 7.2.4.4 of this Chapter;

σ_{cx} — ultimate buckling stress, in N/mm², in direction parallel to the longer edge of buckling panel as defined in 2.1.3 of this Appendix;

σ_{cy} — ultimate buckling stress, in N/mm², in direction parallel to the shorter edge of buckling panel as defined in 2.1.3 of this Appendix;

τ_c — ultimate buckling shear stress, in N/mm², as defined in 2.1.3 of this Appendix;

β_p — plate slenderness parameter, to be taken as:

$$\beta_p = \frac{b}{t_p} \sqrt{\frac{R_{eH-P}}{E}}$$

2.1.2 Reference degree of slenderness

The reference degree of slenderness is to be taken as:

$$\lambda = \sqrt{\frac{R_{eH-P}}{K\sigma_E}}$$

where:

K — buckling factor, as defined in Table 2 and Table 3

2.1.3 Ultimate buckling stresses

The ultimate buckling stress of plate panels, in N/mm², is to be taken as:

$$\begin{aligned}\sigma_{cx} &= C_x R_{eH-P} \\ \sigma_{cy} &= C_y R_{eH-P}\end{aligned}$$

The ultimate buckling stress of plate panels subject to shear, in N/mm², is to be taken as:

$$\tau_c = C_\tau \frac{R_{eH} P}{\sqrt{3}}$$

where:

C_x, C_y, C_τ — reduction factors, as defined in Table 2.

The boundary conditions for plates are to be considered as simply supported (see cases 1, 2 and 15 of Table 2). If the boundary conditions differ significantly from simple support, a more appropriate boundary condition can be applied according to the different cases of Table 2 subject to the agreement of ISC.

2.1.4 Correction factor F_{long}

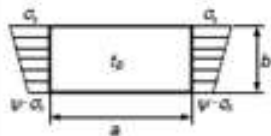
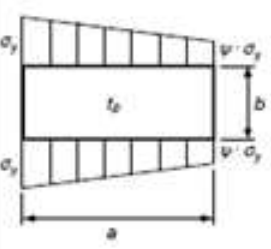
The correction factor F_{long} depending on the edge stiffener types on the longer side of the buckling panel is defined in Table 1. An average value of F_{long} is to be used for plate panels having different edge stiffeners.

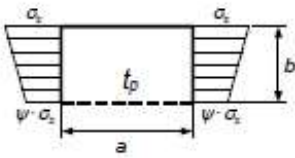
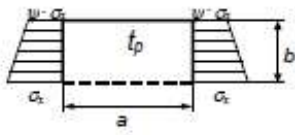
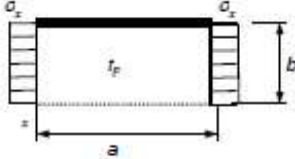
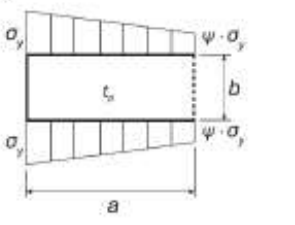
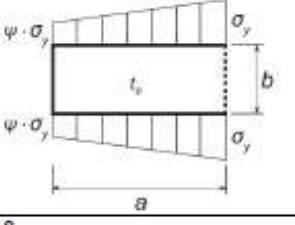
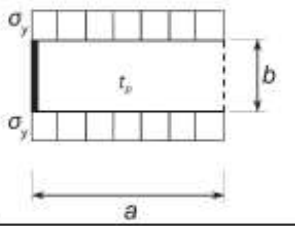
For stiffener types other than those mentioned in Table 1, the value of c is to be agreed by ISC. In such a case, value of c higher than those mentioned in Table 1 can be used, provided it is verified by buckling strength check of panel using non-linear FE analysis and deemed appropriate by ISC.

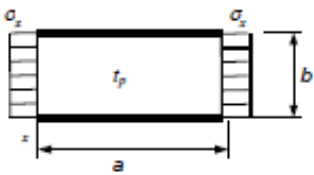
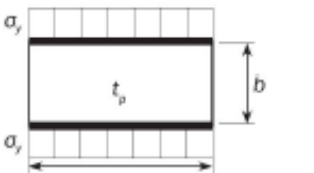
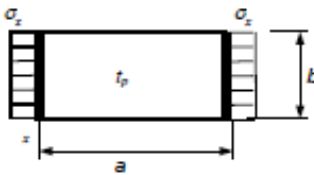
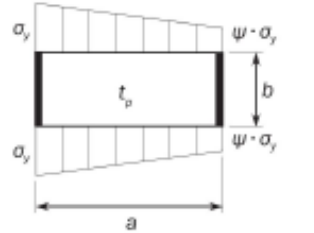
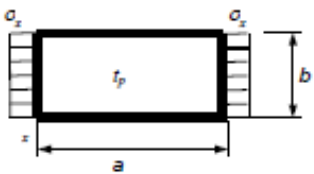
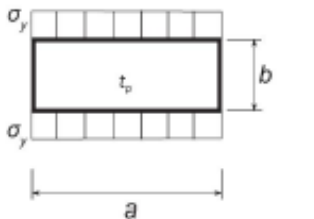
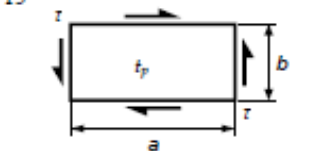
Table 1 - Correction factor F_{long}

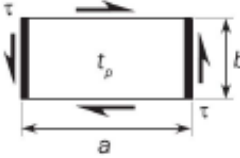
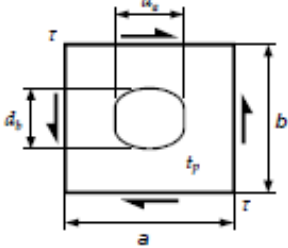
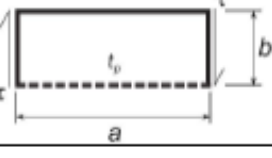
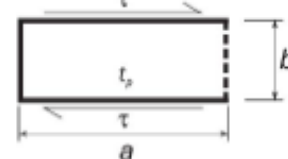
Structural Element Type			F _{long}	c
Unstiffened panel			1	N/A
Stiffened panel	Stiffener not fixed at both ends		1	N/A
	Stiffener fixed at both ends	Flat bar ⁽¹⁾	$F_{long}=c+1 \text{ for } \frac{t_w}{t_p}>1$ $F_{long}=c\left(\frac{t_w}{t_p}\right)^3+1 \text{ for } \frac{t_w}{t_p}\leq 1$	0.1
		Bulb profile		0.3
		Angle profile		0.4
		T profile		0.3
		Girder of high rigidity (e.g. bottom transverse)	1.4	N/A
Note: (1) t _w is the net web thickness, in mm, without the correction defined in 4.3.5 of this Appendix.				

Table 2 - Buckling factor and reduction factor for plane plate panels

Case	Stress ratio ψ	Aspect ratio α	Buckling factor K	Reduction factor C
1 	$\frac{\lambda_1}{\lambda_2} \geq 0$ $\frac{\lambda_1}{\lambda_2} = 1$		$K_x = F_{\text{avg}} \frac{8.4}{\psi + 1.1}$	$C_x = 1$ for $\lambda \leq \lambda_c$ $C_x = c \left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2} \right)$ for $\lambda > \lambda_c$ where: $c = (1.25 - 0.12\psi) \leq 1.25$
	$\frac{\lambda_1}{\lambda_2} \geq 0$ $\frac{\lambda_1}{\lambda_2} = 1$		$K_x = F_{\text{avg}} [7.63 - \psi (6.26 - 10\psi)]$	
	$\frac{\lambda_1}{\lambda_2} \geq 0$ $\frac{\lambda_1}{\lambda_2} = 1$		$K_x = F_{\text{avg}} [5.975 (1 - \psi)^2]$	$\lambda_y = \frac{c}{2} \left(1 + \sqrt{1 - \frac{0.88}{c}} \right)$
2 	$\frac{\lambda_1}{\lambda_2} \geq 0$ $\frac{\lambda_1}{\lambda_2} = 1$	$\alpha \leq 6$	$K_y = \frac{2 \left(1 + \frac{1}{\alpha^2} \right)}{1 + \psi + \frac{(1-\psi)}{100} \left(\frac{2.4}{\alpha^2} + 6.9f_1 \right)}$ $f_1 = (1 - \psi)(\alpha - 1)$	$C_y = c \left(\frac{1}{\lambda} - \frac{R + F^2(H - R)}{\lambda^2} \right)$ where: $c = (1.25 - 0.12\psi) \leq 1.25$ $R = \lambda(1 - \lambda/c)$ for $\lambda < \lambda_c$ $R = 0.22$ for $\lambda \geq \lambda_c$ $\lambda_c = 0.5c \left(1 + \sqrt{1 - 0.88/c} \right)$ $F = \left(1 - \left(\frac{K}{0.91} - 1 \right) / \lambda_p^2 \right) c_1 \geq 0$ $\lambda_p^2 = \lambda^2 - 0.5$ for $1 \leq \lambda_p^2 \leq 3$
	$\frac{\lambda_1}{\lambda_2} \geq 0$ $\frac{\lambda_1}{\lambda_2} = 1$	$\alpha > 6$	$f_1 = 0.6 \left(1 - \frac{6\psi}{\alpha} \right) \left(\alpha + \frac{14}{\alpha} \right)$ but not greater than $14.5 - \frac{0.35}{\alpha^2}$	
	$0 > \psi \geq 1 - 4\alpha/3$		$K_y = \frac{200(1 + \beta^2)^2}{(1 - f_1)(100 + 2.4\beta^2 + 6.9f_1 + 23f_2)}$ $f_1 = 0.6 \left(\frac{1}{\beta} + 14\beta \right)$ but not greater than $14.5 - 0.35\beta^2$ $f_2 = f_1 = 0$	$c_1 = \left(1 - \frac{1}{\alpha} \right) \geq 0$ $H = \lambda - \frac{2\lambda}{c(T + \sqrt{T^2 - 4})} \geq R$ $T = \lambda + \frac{14}{15\lambda} + \frac{1}{3}$
	$0 > \psi \geq 1 - 4\alpha/3$	$\frac{3(1-\psi)/\alpha}{6(1-\psi)} \leq 1$	$f_1 = \frac{1}{\beta} - 1$ $f_2 = f_1 = 0$	
	$0 > \psi \geq 1 - 4\alpha/3$	$\frac{1.5(1-\psi)/\alpha}{3(1-\psi)} < 1$	$f_1 = \frac{1}{\beta} - (2 - \alpha\beta)^2 - 9(\alpha\beta - 1) \left(\frac{2}{3} - \beta \right)$ $f_2 = f_1 = 0$	
	$0 > \psi \geq 1 - 4\alpha/3$	$1 - \psi \leq \alpha < 1.5(1 - \psi)$	For $\alpha > 1.5$: $f_1 = 2 \left(\frac{1}{\beta} - 16 \left(1 - \frac{\omega}{3} \right)^4 \right) \left(\frac{1}{\beta} - 1 \right)$ $f_2 = 3\beta - 2$ $f_3 = 0$ For $\alpha \leq 1.5$: $f_1 = 2 \left(\frac{1.5}{1 - \psi} - 1 \right) \left(\frac{1}{\beta} - 1 \right)$ $f_2 = \frac{\psi(1 - 16f_1^2)}{1 - \alpha}$ $f_3 = 0$ $f_4 = (1.5 - Mm(1.5, \alpha))^2$ $f_5 = 0$	
	$0.75(1 - \psi) \leq \alpha < 1.5$		$f_1 = 1 + 2.31(\beta - 1) - 48 \left(\frac{4}{3} - \beta \right) f_2^2$ $f_2 = 3f_1(\beta - 1) \left(\frac{f_1}{1.81} - \frac{\alpha - 1}{1.31} \right)$ $f_4 = (1.5 - Mm(1.5, \alpha))^2$	

Case	Stress ratio ψ	Aspect ratio α	Buckling factor K	Reduction factor C
	$\psi < 1 - 4\alpha/3$		$K_y = 5.972 \frac{\beta^2}{1 - f_3}$ where: $f_3 = f_5 \left(\frac{f_5}{1.81} + \frac{1 + 3\psi}{5.24} \right)$ $f_5 = \frac{9}{16} (1 + \text{Max}(-1; \psi))^2$	
3		$1 \leq \psi \leq 0$	$K_x = \frac{4(0.425 + 1/\alpha^2)}{3\psi + 1}$	$C_x = 1 \quad \text{for } \lambda \leq 0.7$ $C_x = \frac{1}{\lambda^2 + 0.51} \quad \text{for } \lambda > 0.7$
		$0 > \psi \geq -1$	$K_x = 4(0.425 + 1/\alpha^2)(1 + \psi)$ $-5\psi(1 - 3.42\psi)$	
4		$1 \leq \psi \leq -1$	$K_x = \left(0.425 + \frac{1}{\alpha^2} \right) \frac{3 - \psi}{2}$	
5		$\alpha \geq 1.64$	$K_x = 1.28$	
		$\alpha < 1.64$	$K_x = \frac{1}{\alpha^2} + 0.56 + 0.13\alpha^2$	
6		$1 \leq \psi \leq 0$	$K_y = \frac{4(0.425 + \alpha^2)}{(3\psi + 1)\alpha^2}$	$C_y = 1 \quad \text{for } \lambda \leq 0.7$ $C_y = \frac{1}{\lambda^2 + 0.51} \quad \text{for } \lambda > 0.7$
		$0 > \psi \geq -1$	$K_y = 4(0.425 + \alpha^2)(1 + \psi) \frac{1}{\alpha^2}$ $-5\psi(1 - 3.42\psi) \frac{1}{\alpha^2}$	
7		$1 \leq \psi \leq -1$	$K_y = (0.425 + \alpha^2) \frac{(3 - \psi)}{2\alpha^2}$	
8		-	$K_y = 1 + \frac{0.56}{\alpha^2} + \frac{0.13}{\alpha^4}$	

Case	Stress ratio ψ	Aspect ratio α	Buckling factor K	Reduction factor C
9 	–		$K_x = 6.97$	
10 	–		$K_y = 4 + \frac{2.07}{\alpha^2} + \frac{0.67}{\alpha^4}$	$C_x = 1$ for $\lambda \leq 0.83$ $C_x = 1.13 \left[\frac{1}{\lambda} - \frac{0.22}{\lambda^2} \right]$ for $\lambda > 0.83$
11 	–	$\alpha \geq 4$	$K_x = 4$	
	–	$\alpha < 4$	$K_x = 4 + 2.74 \left(\frac{4 - \alpha}{3} \right)^4$	
12 	–		K_y determined as per case 2	- For $\alpha < 2$: $C_y = C_{y2}$ - For $\alpha \geq 2$: $C_y = \left(1.06 + \frac{1}{10\alpha} \right) C_{y2}$ where: $C_{y2} = C_y$ (determined as per case 2)
13 	–	$\alpha \geq 4$	$K_x = 6.97$	$C_x = 1$ for $\lambda \leq 0.83$
	–	$\alpha < 4$	$K_x = 6.97 + 3.1 \left(\frac{4 - \alpha}{3} \right)^4$	$C_x = 1.13 \left[\frac{1}{\lambda} - \frac{0.22}{\lambda^2} \right]$ for $\lambda > 0.83$
14 	–		$K_y = \frac{6.97}{\alpha^2} + \frac{3.1}{\alpha^2} \left[\frac{4 - 1/\alpha}{3} \right]^4$	$C_y = 1$ for $\lambda \leq 0.83$ $C_y = 1.13 \left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2} \right)$ for $\lambda > 0.83$
15 	–		$K_\tau = \sqrt{3} \left[5.34 + \frac{4}{\alpha^2} \right]$	$C_\tau = 1$ for $\lambda \leq 0.84$ $C_\tau = \frac{0.84}{\lambda}$ for $\lambda > 0.84$

Case	Stress ratio ψ	Aspect ratio α	Buckling factor K	Reduction factor C
16 	—		$K_r = \sqrt{3} \left\{ 5.34 + \text{Max} \left[\frac{4}{\alpha^2}, \frac{7.15}{\alpha^{2.5}} \right] \right\}$	
17 	—		$K = K' r$ $K' = K$ according to case 15 r = opening reduction factor taken as: $r = \left(1 - \frac{d_o}{a} \right) \left(1 - \frac{d_o}{b} \right)$ with $\frac{d_o}{a} \leq 0.7$ and $\frac{d_o}{b} \leq 0.7$	
18 	—		$K_r = 3^{0.5} (0.6 + 4/\alpha^2)$	$C_r = 1$ for $\lambda \leq 0.84$ $C_r = \frac{0.84}{\lambda}$ for $\lambda > 0.84$
19 	—		$K_r = 8$	
Edge boundary conditions: ----- Plate edge free ————— Plate edge simply supported ————— Plate edge clamped.				
Note: (1) Cases listed are general cases. Each stress component (σ_x , σ_y) is to be understood in local coordinates.				

2.2 Curved plate panels

This requirement for curved plate limit state is applicable when $R/t_p \leq 2500$. Otherwise, the requirement for plate limit state given in 2.1.1 of this Appendix is applicable.

The curved plate limit state is based on the following interaction formula:

$$\left(\frac{\gamma_c \sigma_{ax}}{C_{ax} R_{eH_P}} \right)^{1.25} + \left(\frac{\gamma_c \tau \sqrt{3}}{C_\tau R_{eH_P}} \right)^2 = 1.0$$

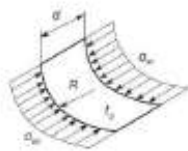
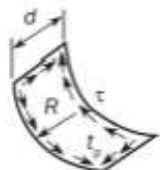
where:

σ_{ax} — applied axial stress to the cylinder corresponding to the curved plate panel, in N/mm². In case of tensile axial stresses, $\sigma_{ax} = 0$;

C_{ax} , C_τ — buckling reduction factor of the curved plate panel, as defined in Table 3.

The stress multiplier factor γ_c of the curved plate panel needs not be taken less than the stress multiplier factor γ_c for the expanded plane panel according to 2.1.1 of this Appendix.

Table 3 - Buckling Factor and reduction factor for curved plate panel with $R/t_p \leq 2500$

Case	Aspect ratio	Buckling factor K	Reduction factor C
1 	$\frac{d}{R} \leq 0.5 \sqrt{\frac{R}{t_p}}$	$K = 1 + \frac{2}{3} \frac{d^2}{R t_p}$	For general application: $C_{ax} = 1$ for $\lambda \leq 0.25$ $C_{ax} = 1.233 - 0.933\lambda$ for $0.25 < \lambda \leq 1$ $C_{ax} = 0.3/\lambda^2$ for $1 < \lambda \leq 1.5$ $C_{ax} = 0.2/\lambda^2$ for $\lambda > 1.5$ For curved single fields, e.g. bilge strake, which are bounded by plane panels: $C_{ax} = 0.65/\lambda^2 \leq 1.0$
	$\frac{d}{R} > 0.5 \sqrt{\frac{R}{t_p}}$	$K = 0.267 \frac{d^2}{R t_p} \left[3 - \frac{d}{R} \sqrt{\frac{t_p}{R}} \right]$ $\geq 0.4 \frac{d^2}{R t_p}$	
2 	$\frac{d}{R} \leq 8.7 \sqrt{\frac{R}{t_p}}$	$K = \sqrt{3} \sqrt{28.3 + \frac{0.67 d^2}{R^{1.5} t_p^{1.5}}}$	$C_r = 1$ for $\lambda \leq 0.4$ $C_r = 1.274 - 0.686\lambda$ for $0.4 < \lambda \leq 1.2$ $C_r = 0.65/\lambda^2$ for $\lambda > 1.2$
	$\frac{d}{R} > 8.7 \sqrt{\frac{R}{t_p}}$	$K = \sqrt{3} \frac{0.28 d^2}{R \sqrt{R t_p}}$	
Explanations for boundary conditions: — Plate edge simply supported.			

3 Buckling Capacity of Overall Stiffened Panel

The elastic stiffened panel limit state is based on the following interaction formula:

$$\frac{P_z}{c_f} = 1$$

where: P_z and c_f are defined in 4.4.3 of this Appendix.

4 Buckling Capacity of Longitudinal Stiffeners

4.1 Stiffeners limit states

The buckling capacity of longitudinal stiffeners is to be checked for the following limit states:

- (1) stiffener induced failure (SI);
- (2) associated plate induced failure (PI).

4.2 Lateral pressure

The lateral pressure is to be considered as constant in the buckling strength assessment of longitudinal stiffeners.

4.3 Stiffener idealization

4.3.1 Effective length of the stiffener ℓ_{eff}

The effective length of the stiffener ℓ_{eff} , in mm, is to be taken equal to:

(1)	$\ell_{eff} = \frac{\ell}{\sqrt{3}}$	for stiffener fixed at both ends;
(2)	$\ell_{eff} = 0.75\ell$	for stiffener simply supported at one end and fixed at the other;
(3)	$\ell_{eff} = \ell$	for stiffener simply supported at both ends.

4.3.2 Effective width of the attached plating b_{eff1}

The effective width of the attached plating of a stiffener b_{eff1} , in mm, without the shear lag effect is to be taken equal to:

$$b_{eff1} = \frac{C_{x1}b_1 + C_{x2}b_2}{2}$$

where:

C_{x1} , C_{x2} — reduction factor defined in Table 2 calculated for each side of the considered stiffener according to case 1;

b_1 , b_2 — width of plate panel on each side of the considered stiffener, in mm.

4.3.3 Effective width of attached plating b_{eff}

The effective width of attached plating of stiffeners, b_{eff} , in mm, is to be taken as:

$$b_{eff} = \min(b_{eff1}, \chi_s s)$$

where:

χ_s — effective width coefficient to be taken as:

$$\begin{aligned} \bullet \quad \chi_s &= \min \left[\frac{1.12}{1 + \frac{1.75}{\left(\frac{\ell_{eff}}{s}\right)^{1.6}}}; 1 \right] \quad \text{for } \frac{\ell_{eff}}{s} \geq 1 \\ \bullet \quad \chi_s &= 0.407 \frac{\ell_{eff}}{s} \quad \text{for } \frac{\ell_{eff}}{s} < 1 \end{aligned}$$

4.3.4 Net thickness of attached plating t_p

The net thickness of plate t_p , in mm, is to be taken as the mean thickness of the two attached plating panels.

4.3.5 Effective web thickness of flat bar

For accounting the decrease of stiffness due to local lateral deformation, the effective web thickness of flat bar stiffener, in mm, is to be used for the calculation of the net sectional area, A_s , the net section modulus, Z , and the moment of inertia, I , of the stiffener and is taken as:

$$t_{w\_red} = t_w \left(1 - \frac{2\pi^2}{3} \left(\frac{h_w}{s} \right)^2 \left(1 - \frac{b_{eff1}}{s} \right) \right)$$

4.3.6 Net section modulus Z of a stiffener

The net section modulus Z of a stiffener, in cm^3 , including effective width of plating b_{eff} is to be taken equal to:

- (1) the section modulus calculated at the top of stiffener flange for stiffener induced failure (SI).
- (2) the section modulus calculated at the attached plating for plate induced failure (PI).

4.3.7 Net moment of inertia I of a stiffener

The net moment of inertia I , in cm^4 , of a stiffener including effective width of attached plating b_{eff} is to comply with the following requirement:

$$I \geq \frac{s t_p^3}{12 \cdot 10^4}$$

4.3.8 Idealisation of bulb profile

$$h_w = h'_w - \frac{h'_w}{9.2} + 2$$

$$b_f = \alpha \left(t'_w + \frac{h'_w}{6.7} - 2 \right)$$

$$t_f = \frac{h'_w}{9.2} - 2$$

$$t_w = t'_w$$

Bulb profiles may be considered as equivalent angle profiles. The net dimensions of the equivalent built-up section are to be obtained, in mm, from the following formulae:

where: h'_w , t'_w — net height and thickness of a bulb section, in mm, as shown in Figure 2;

α — coefficient equal to:

$$\alpha = 1.1 + \frac{(120 - h'_w)^2}{3000} \quad \text{for } h'_w \leq 120$$

$$\alpha = 1.0 \quad \text{for } h'_w > 120$$

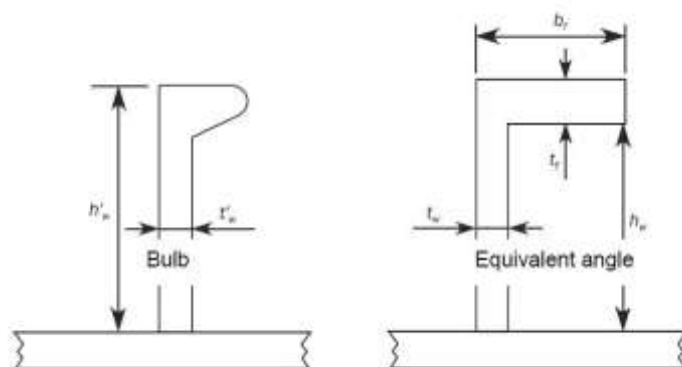


Figure 2 Idealisation of bulb stiffener

4.4 Ultimate buckling capacity

4.4.1 Longitudinal stiffener limit state

When $\sigma_a + \sigma_b + \sigma_w > 0$, the ultimate buckling capacity for stiffeners is to be checked according to the following interaction formula:

$$\frac{\gamma_c \sigma_a + \sigma_b + \sigma_w}{R_{eH}} = 1$$

where:

σ_a — effective axial stress, in N/mm², at mid-span of the stiffener, defined in 4.4.2 of this Appendix;

σ_b — bending stress in the stiffener, in N/mm², defined in 4.4.3 of this Appendix;

σ_w — stress due to torsional deformation, in N/mm², defined in 4.4.4 of this Appendix;

R_{eH} — specified minimum yield stress of the material, in N/mm²:

(1) $R_{eH} = R_{eH-S}$ for stiffener induced failure (SI);

(2) $R_{eH} = R_{eH-P}$ for plate induced failure (PI).

4.4.2 Effective axial stress σ_a

The effective axial stress σ_a , in N/mm², at mid-span of the stiffener, acting on the stiffener with its attached plating is to be taken equal to:

$$\sigma_a = \sigma_x \frac{s t_p + A_s}{b_{eff1} t_p + A_s}$$

where:

σ_x — nominal axial stress, in N/mm², acting on the stiffener with its attached plating, calculated according to 7.2.4.4.1 a) of this Chapter;

A_s — net sectional area, in mm², of the considered stiffener.

4.4.3 Bending stress σ_b

The bending stress in the stiffener σ_b , in N/mm², is to be taken equal to:

$$\sigma_b = \frac{M_o + M_1}{1000 Z}$$

where: M_1 — bending moment, in Nmm, due to the lateral load P :

$$1 \quad M_1 = C_i \frac{|P| s \ell^2}{24 \cdot 10^3} \quad \text{for continuous stiffener;}$$

$$2 \quad M_1 = C_i \frac{|P| s \ell^2}{8 \cdot 10^3} \quad \text{for sniped stiffener;}$$

P — lateral load, in kN/m², to be equal to the static pressure at the load calculation point of the stiffener;

C_i — pressure coefficient;

(1) $C_i = C_{SI}$, for stiffener induced failure (SI);

(2) $C_i = C_{PI}$, for plate induced failure (PI);

C_{PI} — plate induced failure pressure coefficient:

(1) $C_{PI} = 1$, if the lateral pressure is applied on the side opposite to the stiffener;

(2) $C_{PI} = -1$, if the lateral pressure is applied on the same side as the stiffener;

C_{SI} — stiffener induced failure pressure coefficient:

(1) $C_{SI} = -1$, if the lateral pressure is applied on the side opposite to the stiffener;

(2) $C_{SI} = 1$, if the lateral pressure is applied on the same side as the stiffener;

M_0 — bending moment, in Nmm, due to the lateral deformation w of stiffener:

$$M_0 = F_E \left(\frac{P_z w}{c_f - P_z} \right), \text{ with } c_f - P_z > 0;$$

F_E — ideal elastic buckling force of the stiffener, in N:

$$F_E = \left(\frac{\pi}{\ell} \right)^2 EI \cdot 10^4;$$

P_z — normal lateral load, in N/mm^2 , acting on stiffeners due to stresses σ_x , σ_y and τ , in the attached plating in way of stiffener mid span:

$$P_z = \frac{t_p}{s} \left(\sigma_{xl} \left(\frac{\pi s}{\ell} \right)^2 + \sqrt{2} \tau_1 \right);$$

$$\sigma_{xl} = \gamma_c \sigma_x \left(1 + \frac{A_s}{s t_p} \right), \text{ but not less than } 0;$$

$$\tau_1 = \gamma |\tau| - t_p \sqrt{R_{eH-P} E \left(\frac{m_1}{a^2} + \frac{m_2}{b^2} \right)}, \text{ but not less than } 0;$$

m_1, m_2 — coefficients, taken equal to:

(1) $m_1 = 1.47, m_2 = 0.49$ for $\alpha \geq 2$;

(2) $m_1 = 1.96, m_2 = 0.37$ for $\alpha < 2$;

w — deformation of stiffener, in mm, taken equal to:

$$w = w_0 + w_1$$

w_0 — assumed imperfection, in mm, taken equal to:

(1) $w_0 = \ell/1000$ in general;

(2) $w_0 = -w_{na}$ for stiffeners sniped at both ends, considering stiffener induced failure (SI);

(3) $w_0 = w_{na}$ for stiffeners sniped at both ends, considering plate induced failure (PI);

w_{na} — distance, in mm, from the mid-point of attached plating to the neutral axis of the stiffener calculated with the effective width of the attached plating;

w_1 — deformation of stiffener at midpoint of stiffener span due to lateral load P , in mm. In case of uniformly distributed load, w_1 is to be taken as:

$$1 \quad w_1 = C_i \frac{|P| s \ell^4}{384 \cdot 10^7 E I} \text{ in general;}$$

$$2 \quad w_1 = C_i \frac{5 |P| s \ell^4}{384 \cdot 10^7 E I} \text{ for stiffener sniped at both ends;}$$

c_f — elastic support provided by the stiffener, in N/mm^2 , to be taken equal to:

$$c_f = F_E \left(\frac{\pi}{\ell} \right)^2 (1 + c_p);$$

c_p — coefficient, to be taken as:

$$c_p = \frac{1}{1 + \frac{0.91}{c_{sa}} \left(\frac{12 I}{s t_p^3} 10^4 - 1 \right)}$$

c_{sa} — coefficient, to be taken as:

$$(1) \quad c_{\omega} = \left[\frac{\ell}{2s} + \frac{2s}{\ell} \right]^2 \quad \text{for } \ell \geq 2s$$

$$(2) \quad c_{\omega} = \left[1 + \left(\frac{\ell}{2s} \right)^2 \right]^2 \quad \text{for } \ell < 2s.$$

4.4.4 Stress due to torsional deformation σ_w The stress due to torsional deformation σ_w , in N/mm², is to be taken equal to:

$$(1) \quad \sigma_w = E y_w \left(\frac{t_f}{2} + h_w \right) \Phi_0 \left(\frac{\pi}{\ell} \right)^2 \left(\frac{1}{1 - \frac{0.4 R_{eff} s}{\sigma_{ET}}} - 1 \right) \quad \text{for stiffener induced failure (SI);}$$

$$(2) \quad \sigma_w = 0 \text{ for plate induced failure (PI).}$$

where:

y_w — distance, in mm, from centroid of stiffener cross-section to the free edge of stiffener flange, to be taken as:

$$(1) \quad y_w = \frac{t_w}{2} \quad \text{for flat bar;}$$

$$(2) \quad y_w = b_f \frac{h_w t_w^2 + t_f b_f^2}{2 A_s} \quad \text{for angle and bulb profiles;}$$

$$(3) \quad y_w = \frac{b_f}{2} \quad \text{for Tee profile;}$$

Φ_0 — coefficient, to be taken as:

$$\Phi_0 = \frac{\ell}{h_w} 10^{-3}$$

σ_{ET} — reference stress for torsional buckling, in N/mm²:

$$\sigma_{ET} = \frac{E}{I_p} \left(\frac{\varepsilon \pi^2 I_{\omega} 10^2}{\ell^2} + 0.385 I_T \right)$$

I_p — net polar moment of inertia of the stiffener about point C as shown in Figure 3, as defined in Table 4, in cm⁴;

I_T — net St. Venant's moment of inertia of the stiffener, as defined in Table 4, in cm⁴

I_{ω} — net sectional moment of inertia of the stiffener about point C as shown in Figure 3, as defined in Table 4, in cm⁶;

ε — degree of fixation, to be taken as:

$$\varepsilon = 1 + \frac{\left(\frac{\ell}{\pi} \right)^2 10^{-3}}{\sqrt{I_{\omega} \left(\frac{0.75s}{t_p^3} + \frac{e_f - 0.5t_f}{t_r^3} \right)}}$$

Table 4 - Moments of inertia

Characteristics of cross section	Flat bars	Bulb, angle and Tee profiles
I_P	$\frac{h_w^3 t_w}{3 \cdot 10^4}$	$\left(\frac{A_w (e_f - 0.5 t_f)^2}{3} + A_f e_f^2 \right) 10^{-4}$
I_T	$\frac{h_w t_w^3}{3 \cdot 10^4} \left(1 - 0.63 \frac{t_w}{h_w} \right)$	$\frac{(e_f - 0.5 t_f) t_w^3}{3 \cdot 10^4} \left(1 - 0.63 \frac{t_w}{e_f - 0.5 t_f} \right) + \frac{b_f t_f^3}{3 \cdot 10^4} \left(1 - 0.63 \frac{t_f}{b_f} \right)$
I_w	$\frac{h_w^3 t_w^3}{36 \cdot 10^6}$	$\frac{A_f e_f^2 b_f^2}{12 \cdot 10^6} \left(\frac{A_f + 2.6 A_w}{A_f + A_w} \right)$ for bulb and angle profiles $\frac{b_f^3 t_f e_f^2}{12 \cdot 10^6}$ for Tee profiles

A_w : net web area, in mm²;
 A_f : net flange area, in mm².

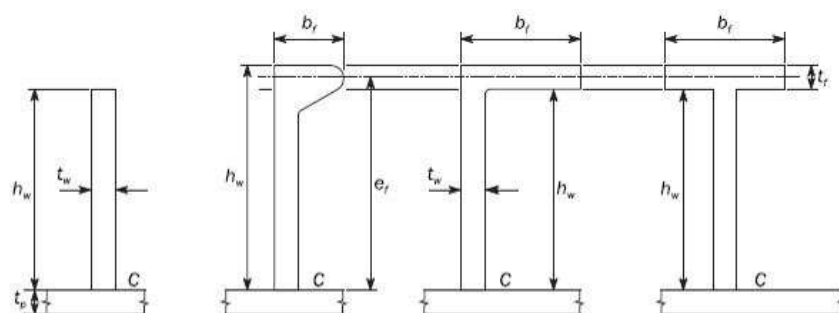


Figure 3 Stiffener cross sections

APPENDIX 5

HULL GIRDER ULTIMATE BENDING CAPACITY

Symbols

I_{y-net} : net moment of inertia, in m^4 , of the hull transverse section around its horizontal neutral axis;
 $ZB-net$, $ZD-net$: section moduli, in m^3 , at bottom and deck, respectively;
 ReH_S : minimum yield stress, in N/mm^2 , of the material of the considered stiffener;
 ReH_P : minimum yield stress, in N/mm^2 , of the material of the considered plate;
 $As-net$: net sectional area, in cm^2 , of stiffener, without attached plating;
 $Ap-net$: net sectional area, in cm^2 , of attached plating.

1 General Assumptions

1.1 The method for calculating the ultimate hull girder capacity is to identify the critical failure modes of all main longitudinal structural elements.

1.2 Structures compressed beyond their buckling limit have reduced load carrying capacity. All relevant failure modes for individual structural elements, such as plate buckling, torsional stiffener buckling, stiffener web buckling, lateral or global stiffener buckling and their interactions, are to be considered in order to identify the weakest inter-frame failure mode.

2 Incremental-Iterative Method

2.1 Assumptions

In applying the incremental-iterative method, the following assumptions are generally to be made:

- The ultimate strength is calculated at hull transverse sections between two adjacent transverse webs.
- The hull girder transverse section remains plane during each curvature increment.
- The hull material has an elasto-plastic behaviour.
- The hull girder transverse section is divided into a set of elements, see 2.2.2 of this Appendix, which are considered to act independently.

According to the iterative procedure, the bending moment M_i acting on the transverse section at each curvature value χ_i is obtained by summing the contribution given by the stress σ acting on each element.

The stress σ corresponding to the element strain, ε is to be obtained for each curvature increment from the non-linear load-end shortening curves σ - ε of the element.

These curves are to be calculated, for the failure mechanisms of the element, from the formulae specified in 2.3. The stress σ is selected as the lowest among the values obtained from each of the considered load-end shortening curves σ - ε .

The procedure is to be repeated until the value of the imposed curvature reaches the value χ_F , in m^{-1} , in hogging and sagging conditions, obtained from the following formula:

$$\chi_F = \pm 0.003 \frac{M_y}{EI_{y-net}}$$

where: M_y — lesser of the values $MY1$ and $MY2$, in kNm .;

$$M_{Y1} = 10^3 \text{ ReH ZB-net.}$$

$$M_{Y2} = 10^3 \text{ ReH ZD-net.}$$

If the value χF is not sufficient to evaluate the peaks of the curve $M-\chi$, the procedure is to be repeated until the value of the imposed curvature permits the calculation of the maximum bending moments of the curve.

2.2 Procedure

2.2.1 General

The curve $M-\chi$ is to be obtained by means of an incremental-iterative approach, summarized in the flow chart in Figure 1. In this procedure, the ultimate hull girder bending moment capacity, M_U is defined as the peak value of the curve with vertical bending moment M versus the curvature χ of the ship cross section as shown in Figure 1. The curve is to be obtained through an incremental iterative approach. Each step of the incremental procedure is represented by the calculation of the bending moment M_i which acts on the hull transverse section as the effect of an imposed curvature χ_i . For each step, the value χ_i is to be obtained by summing an increment of curvature, $\Delta\chi$ to the value relevant to the previous step χ_{i-1} . This increment of curvature corresponds to an increment of the rotation angle of the hull girder transverse section around its horizontal neutral axis. This rotation increment induces axial strains ε in each hull structural element, whose value depends on the position of the element. In hogging condition, the structural elements above the neutral axis are lengthened, while the elements below the neutral axis are shortened, and vice-versa in sagging condition. The stress σ induced in each structural element by the strain ε is to be obtained from the load-end shortening curve $\sigma-\varepsilon$ of the element, which takes into account the behaviour of the element in the non-linear elasto-plastic domain. The distribution of the stresses induced in all the elements composing the hull transverse section determines, for each step, a variation of the neutral axis position due to the nonlinear $\sigma-\varepsilon$, relationship. The new position of the neutral axis relevant to the step considered is to be obtained by means of an iterative process, imposing the equilibrium among the stresses acting in all the hull elements on the transverse section. Once the position of the neutral axis is known and the relevant element stress distribution in the section is obtained, the bending moment of the section M_i around the new position of the neutral axis, which corresponds to the curvature χ_i imposed in the step considered, is to be obtained by summing the contribution given by each element stress. The main steps of the incremental-iterative approach described above are summarised as follows (see also Figure 1):

Step 1: Divide the transverse section of hull into stiffened plate elements.

Step 2: Define stress-strain relationships for all elements as shown in Table 1.

Step 3: Initialise curvature χ_1 and neutral axis for the first incremental step with the value of incremental curvature (i.e. curvature that induces a stress equal to 1% of yield strength in strength deck) as:

$$\chi_1 = \Delta\chi = 0.01 \frac{R_{dH}}{E} \frac{1}{z_D - z_n}$$

where: z_D — Z coordinate, in m, of strength deck at side;

z_n — Z coordinate, in m, of horizontal neutral axis of the hull transverse section with

respect to the reference coordinate system defined in 7.2.1.2, Section 2 of this Chapter.

Step 4: Calculate for each element the corresponding strain, $\epsilon_i = \chi(z_i - z_n)$ and the corresponding stress σ_i .

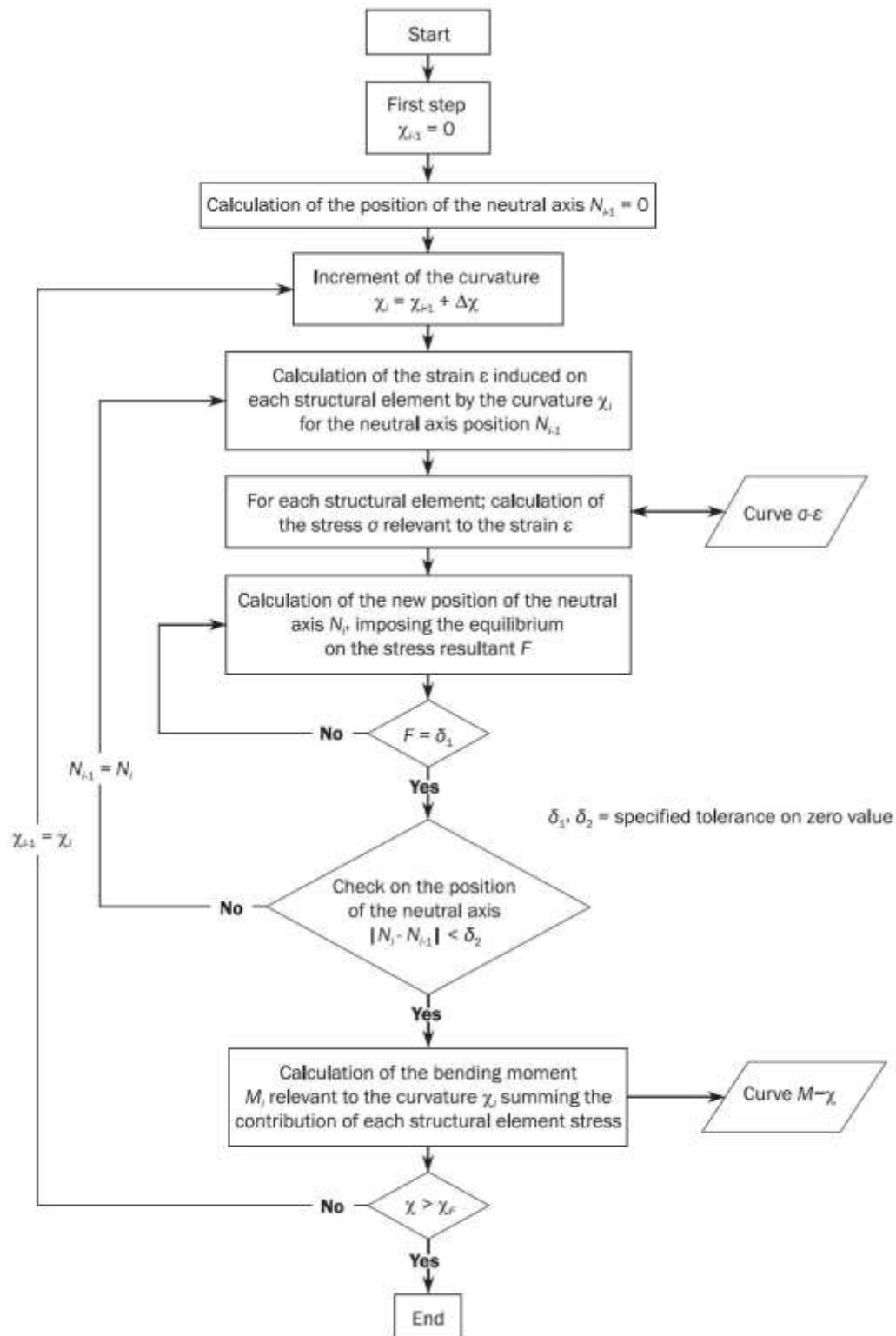
Step 5: Determine the neutral axis z_{NA_cur} at each incremental step by establishing force equilibrium over the whole transverse section as:

$$\sum A_{i-net} \sigma_i = \sum A_{j-net} \sigma_j \quad (i\text{-th element is under compression, } j\text{-th element under tension}).$$

Step 6: Calculate the corresponding moment by summing the contributions of all elements as:

$$M_U = \sum \sigma_{Ui} A_{i-net} (z_i - z_{NA\_cur})$$

Step 7: Compare the moment in the current incremental step with the moment in the previous incremental step. If the slope in $M-\chi$ relationship is less than a negative fixed value, terminate the process and define the peak value M_U . Otherwise, increase the curvature by the amount of $\Delta\chi$ and go to Step 4.

Figure 1 Flow chart of the procedure for the evaluation of the curve $M-\chi$

2.2.2 Modelling of the hull girder cross section

Hull girder transverse sections are to be considered as being constituted by the members contributing to the hull girder ultimate strength.

Sniped stiffeners are also to be modelled, taking account that they do not contribute to the hull girder strength.

The structural members are categorised into a stiffener element, a stiffened plate element or a hard corner element.

The plate panel including web plate of girder or side stringer is idealised into a stiffened plate element, an attached plate of a stiffener element or a hard corner element.

The plate panel is categorised into the following two kinds:

- longitudinally stiffened panel of which the longer side is in ship's longitudinal direction, and
- transversely stiffened panel of which the longer side is in the perpendicular direction to ship's longitudinal direction.

- Hard corner element:

Hard corner elements are sturdier elements composing the hull girder transverse section, which collapse mainly according to an elasto-plastic mode of failure (material yielding); they are generally constituted by two plates not lying in the same plane.

The extent of a hard corner element from the point of intersection of the plates is to be taken equal to $20 t_{net}$ on a transversely stiffened panel and to $0.5 s$ on a longitudinally stiffened panel, see Figure 2. where:

t_{net} — net thickness of plate, in mm;

s — spacing of the adjacent longitudinal stiffener, in m.

Bilge, sheer strake-deck stringer elements, girder-deck connections and face plate-web connections on large girders are typical hard corners.

- Stiffener element:

The stiffener constitutes a stiffener element together with the attached plate. The attached plate width is in principle:

- equal to the mean spacing of the stiffener when the panels on both sides of the stiffener are longitudinally stiffened, or
- equal to the width of the longitudinally stiffened panel when the panel on one side of the stiffener is longitudinally stiffened and the other panel is of the transversely stiffened, see Figure 2.

- Stiffened plate element:

The plate between stiffener elements, between a stiffener element and a hard corner element or between hard corner elements is to be treated as a stiffened plate element, see Figure 2.

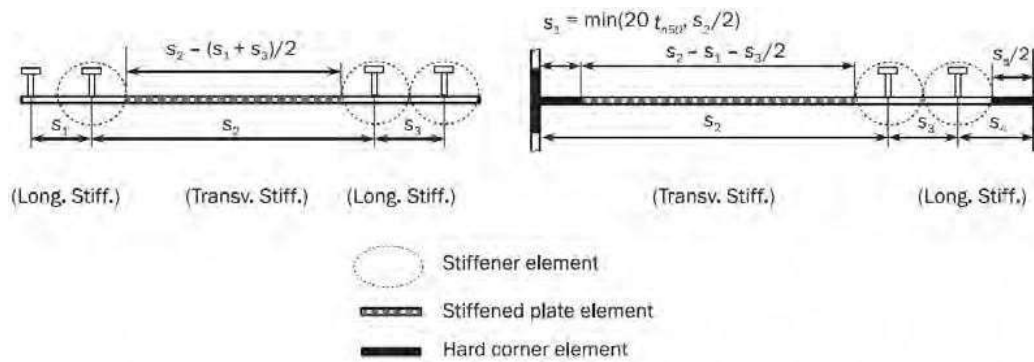


Figure 2 Extension of the breadth of the attached plating and hard corner element

The typical examples of modelling of hull girder section are illustrated in Figure 3. Notwithstanding the foregoing principle, these figures are to be applied to the modelling in the vicinity of upper deck, sheer strake and hatch coaming.

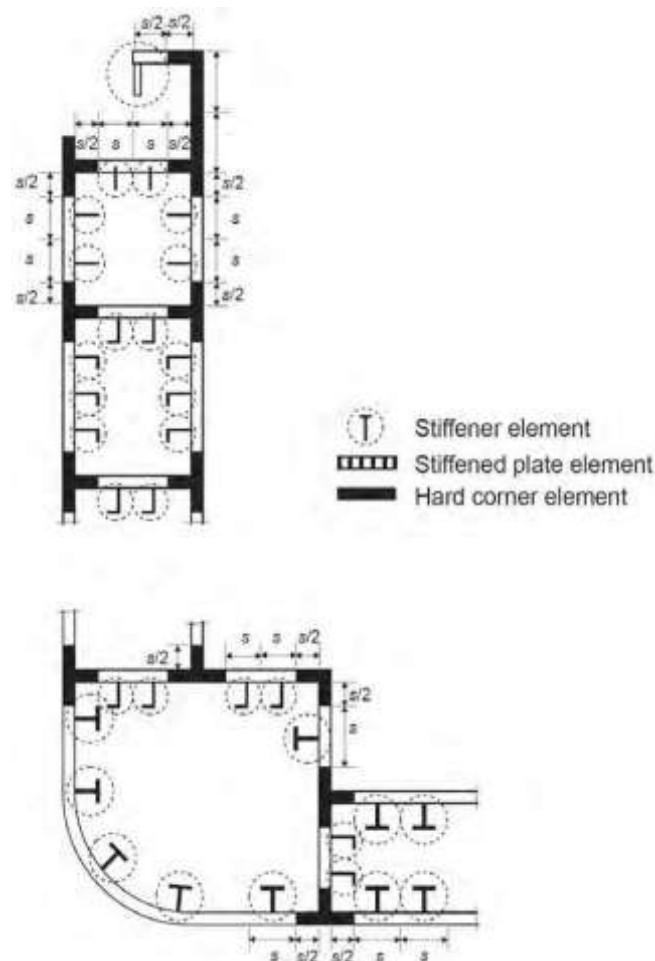


Figure 3 Examples of the configuration of stiffened plate elements, stiffener elements and hard corner elements on a hull section

Notes:

- (1) In case of the knuckle point as shown in Figure 4, the plating area adjacent to knuckles in the plating with an angle greater than 30 degrees is defined as a hard corner. The extent of one side of the corner is taken equal to $20 t_{net}$ on transversely framed panels and to $0.5 s$ on longitudinally framed panels from the knuckle point.
- (2) Where the plate members are stiffened by non-continuous longitudinal stiffeners, the non-continuous stiffeners are considered only as dividing a plate into various elementary plate panels.

- (3) Where the opening is provided in the stiffened plate element, the openings are to be considered in accordance with the requirements of Figure 2.2.4.7 of Section 2, Chapter 2 of this PART.
- (4) Where attached plating is made of steels having different thicknesses and/or yield stresses, an average thickness and/or average yield stress obtained from the following formula are to be used for the calculation:

$$t_{net} = \frac{t_{1-net}s_1 + t_{2-net}s_2}{s} \quad R_{eH\_P} = \frac{R_{eH\_P1}t_{1-net}s_1 + R_{eH\_P2}t_{2-net}s_2}{t_{net}s}$$

where: R_{eH_p1} , R_{eH_p2} , t_{1-net} , t_{2-net} , s_1 , s_2 and s are shown in Figure 5.

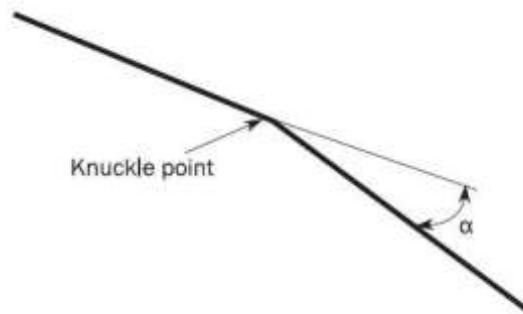


Figure 4 Plating with knuckle point

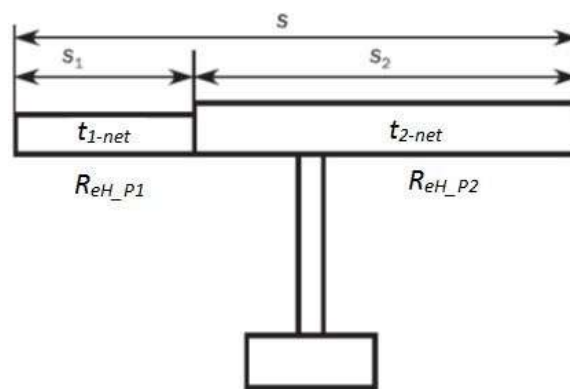


Figure 5 Element with different thickness and yield strength

2.3 Load-end shortening curves

2.3.1 Stiffened plate element and stiffener element

Stiffened plate element and stiffener element composing the hull girder transverse sections may collapse following one of the modes of failure specified in Table 1.

- Where the plate members are stiffened by non-continuous longitudinal stiffeners, the stress of the element is to be obtained in accordance with 2.3.2 to 2.3.7 of this Appendix, taking into account the non-continuous longitudinal stiffener.

In calculating the total forces for checking the hull girder ultimate strength, the area of non-continuous longitudinal stiffener is to be assumed as zero.

- Where the opening is provided in the stiffened plate element, the considered area of the stiffened plate element is to be obtained by deducting the opening area from the plating in calculating the total forces for checking the hull girder ultimate strength.
- For stiffened plate element, the effective width of plate for the load shortening portion of the stress-strain curve is to be taken as full plate width, i.e. to the intersection of other plate or

longitudinal stiffener – neither from the end of the hard corner element nor from the attached plating of stiffener element, if any. In calculating the total forces for checking the hull girder ultimate strength, the area of the stiffened plate element is to be taken between the hard corner element and the stiffener element or between the hard corner elements, as applicable.

Table 1 - Modes of failure of stiffened plate element and stiffener element

Element	Mode of Failure	Curve σ - ϵ Defined in
Lengthened stiffened plate element or stiffener element	Elasto-plastic collapse	2.3.2 of this Appendix
Shortened stiffener element	Beam column buckling	2.3.3 of this Appendix
	Torsional buckling	2.3.4 of this Appendix
	Web local buckling of flanged profiles	2.3.5 of this Appendix
	Web local buckling of flat bars	2.3.6 of this Appendix
Shortened stiffened plate element	Plate buckling	2.3.7 of this Appendix

2.3.2 Elasto-plastic collapse of structural elements (Hard corner element)

The equation describing the load-end shortening curve σ - ϵ for the elasto-plastic collapse of structural elements composing the hull girder transverse section is to be obtained from the following formula.

$$\sigma = \Phi R_{eHA}$$

where: R_{eHA} — equivalent minimum yield stress, in N/mm^2 , of the considered element, obtained by the following formula:

$$R_{eHA} = \frac{R_{eH\_P} A_{p-net} + R_{eH\_S} A_{s-net}}{A_{p-net} + A_{s-net}}$$

Φ — edge function, equal to:

$$\Phi = -1 \text{ for } \epsilon < -1$$

$$\Phi = \epsilon \quad \text{for } -1 \leq \epsilon \leq 1$$

$$\Phi = 1 \quad \text{for } \epsilon > 1$$

ϵ — relative strain, equal to:

$$\epsilon = \frac{\epsilon_E}{\epsilon_Y};$$

ϵ_E — element strain;

ϵ_Y — strain at yield stress in the element, equal to:

$$\epsilon_Y = \frac{R_{eHA}}{E}.$$

2.3.3 Beam column buckling

The positive strain portion of the average stress – average strain curve σ_{CRI} - ϵ based on beam column buckling of plate-stiffener combinations is described according to the following:

$$\sigma_{CR1} = \Phi \sigma_{C1} \frac{A_{s-net} + A_{pE-net}}{A_{s-net} + A_{p-net}}$$

where:

Φ — edge function, as defined in 2.3.2 of this Appendix;

σ_{C1} — critical stress, in N/mm², equal to:

$$\begin{aligned} \sigma_{C1} &= \frac{\sigma_{E1}}{\varepsilon} & \text{for } \sigma_{E1} \leq \frac{R_{eHB}}{2} \varepsilon; \\ \sigma_{C1} &= R_{eHB} \left(1 - \frac{R_{eHB} \varepsilon}{4 \sigma_{E1}} \right) & \text{for } \sigma_{E1} > \frac{R_{eHB}}{2} \varepsilon; \end{aligned}$$

R_{eHB} — equivalent minimum yield stress, in N/mm², of the considered element, obtained by the following formula:

$$R_{eHB} = \frac{R_{eH_P} A_{pEI-net} \ell_{pE} + R_{eH_S} A_{s-net} \ell_{sE}}{A_{pEI-net} \ell_{pE} + A_{s-net} \ell_{sE}};$$

$A_{pEI-net}$ — effective area, in cm², equal to:

$$A_{pEI-net} = 10 b_{E1} t_{net};$$

ℓ_{pE} — distance, in mm, measured from the neutral axis of the stiffener with attached plate of width b_{E1} to the bottom of the attached plate;

ℓ_{sE} — distance, in mm, measured from the neutral axis of the stiffener with attached plate of width b_{E1} to the top of the stiffener;

ε — relative strain, as defined in 2.3.2 of this Appendix;

σ_{E1} — Euler column buckling stress, in N/mm², equal to:

$$\sigma_{E1} = \pi^2 E \frac{I_{E-net}}{A_{E-net} \ell^2} 10^{-4};$$

I_{E-net} — net moment of inertia of stiffeners, in cm⁴, with attached plate of width b_{E1} ;

A_{E-net} — net area, in cm², of stiffeners with attached plating of width b_{E1} ;

b_{E1} — effective width corrected for relative strain, in m, of the attached plating, equal to:

$$b_{E1} = \frac{s}{\beta_E} \quad \text{for } \beta_E > 1.0;$$

$$b_{E1} = s \quad \text{for } \beta_E \leq 1.0;$$

$$\text{where: } \beta_E = 10^3 \frac{s}{t_{n50}} \sqrt{\frac{\varepsilon R_{eHp}}{E}};$$

A_{pE-net} — net area, in cm², of attached plating of width b_E , equal to:

b_E — effective width, in m, of the attached plating, equal to:

$$b_E = \left(\frac{2.25}{\beta_E} - \frac{1.25}{\beta_E^2} \right) s \quad \text{for } \beta_E > 1.25;$$

$$b_E = s \quad \text{for } \beta_E \leq 1.25.$$

2.3.4 Torsional buckling

The load-end shortening curve $\sigma_{CR2}-\varepsilon$ for the flexural-torsional buckling of stiffeners composing the hull girder transverse section is to be obtained according to the following formula:

$$\sigma_{CR2} = \Phi \frac{A_{s-net}\sigma_{C2} + A_{p-net}\sigma_{CP}}{A_{s-net} + A_{p-net}}$$

where:

Φ — edge function, as defined in 2.3.2 of this Appendix;

σ_{C2} — critical stress, in N/mm², equal to:

$$\begin{aligned} \sigma_{C2} &= \frac{\sigma_{E2}}{\varepsilon} & \text{for } \sigma_{E2} \leq \frac{R_{eH_S}}{2} \varepsilon ; \\ \sigma_{C2} &= R_{eH_S} \left(1 - \frac{R_{eH_S} \varepsilon}{4\sigma_{E2}} \right) & \text{for } \sigma_{E2} > \frac{R_{eH_S}}{2} \varepsilon ; \end{aligned}$$

ε — relative strain, as defined in 2.3.2 of this Appendix;

σ_{E2} — Euler column buckling stress, in N/mm², taken as σ_{ET} defined in 4.4.4 of Appendix 4 of this Chapter;

σ_{CP} — buckling stress of the attached plating, in N/mm², equal to:

$$\begin{aligned} \sigma_{CP} &= \left(\frac{2.25}{\beta_E} - \frac{1.25}{\beta_E^2} \right) R_{eH_P} & \text{for } \beta_E > 1.25 \\ \sigma_{CP} &= R_{eH_P} & \text{for } \beta_E \leq 1.25 \end{aligned}$$

β_E — coefficient, as defined in 2.3.3 of this Appendix.

2.3.5 Web local buckling of stiffeners made of flanged profiles

The load-end shortening curve $\sigma_{CR3} - \varepsilon$ for the web local buckling of flanged stiffeners composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR3} = \Phi \frac{10^3 b_E t_{net} R_{eH_P} + (h_{we} t_{w-net} + b_f t_{f-net}) R_{eH_S}}{10^3 s t_{net} + h_w t_{w-net} + b_f t_{f-net}}$$

where:

Φ — edge function, as defined in 2.3.2 of this Appendix;

b_E — effective width, in m, of the attached plating, as defined in 2.3.3 of this Appendix;

h_{we} — effective height, in mm, of the web, equal to:

$$\begin{aligned} h_{we} &= \left(\frac{2.25}{\beta_w} - \frac{1.25}{\beta_w^2} \right) h_w & \text{for } \beta_w \geq 1.25 ; \\ h_{we} &= h_w & \text{for } \beta_w < 1.25 ; \end{aligned}$$

$$\beta_w \text{ — } \beta_w = \frac{h_w}{t_{w-net}} \sqrt{\frac{\varepsilon R_{eH_S}}{E}};$$

ε — relative strain, as defined in 2.3.2 of this Appendix.

2.3.6 Web local buckling of stiffeners made of flat bars

The load-end shortening curve $\sigma_{CR4}-\varepsilon$ for the web local buckling of flat bar stiffeners composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR4} = \Phi \frac{A_{p-net}\sigma_{CP} + A_{s-net}\sigma_{C4}}{A_{p-net} + A_{s-net}}$$

where:

Φ — edge function, as defined in 2.3.2 of this Appendix;

σ_{CP} — buckling stress of the attached plating, in N/mm², as defined in 2.3.4 of this Appendix;

σ_{C4} — critical stress, in N/mm², equal to:

$$\begin{aligned} \sigma_{C4} &= \frac{\sigma_{E4}}{\varepsilon} & \text{for } \sigma_{E4} \leq \frac{R_{eH,S}}{2} \varepsilon; \\ \sigma_{C4} &= R_{eH,S} \left(1 - \frac{R_{eH,S}\varepsilon}{4\sigma_{E4}}\right) & \text{for } \sigma_{E4} > \frac{R_{eH,S}}{2} \varepsilon; \end{aligned}$$

σ_{E4} — local Euler buckling stress, in N/mm², equal to:

$$\sigma_{E4} = 160000 \left(\frac{t_{w-net}}{h_w} \right)^2;$$

ε — relative strain, as defined in 2.3.2 of this Appendix.

2.3.7 Plate buckling

The load-end shortening curve $\sigma_{CR5}-\varepsilon$ for the buckling of transversely stiffened panels composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR5} = \min \left\{ \begin{array}{l} R_{eH,P} \Phi \\ \Phi R_{eH,P} \left[\frac{s}{\ell} \left(\frac{2.25}{\beta_E} - \frac{1.25}{\beta_E^2} \right) + 0.1 \left(1 - \frac{s}{\ell} \right) \left(1 + \frac{1}{\beta_E^2} \right)^2 \right] \end{array} \right\}$$

where:

Φ — edge function, as defined in 2.3.2 of this Appendix;

β_E — coefficient as defined in 2.3.3 of this Appendix;

s — plate breadth, in m, taken as the spacing between the stiffeners;

ℓ — longer side of the plate, in m.

3 Alternative Methods

3.1 General

3.1.1 Application of alternative methods is to be agreed by ISC prior to commencement. Documentation of the analysis methodology and detailed comparison of its results are to be submitted for review and acceptance. The use of such methods may require the partial safety factors to be recalibrated.

3.1.2 The bending moment-curvature relationship, $M-\chi$, may be established by alternative methods. Such models are to consider all the relevant effects important to the non-linear response with due considerations of:

- (a) non-linear geometrical behavior;
- (b) inelastic material behavior;
- (c) geometrical imperfections and residual stresses (geometrical out-of-flatness of plate and stiffeners);
- (d) simultaneously acting loads:

- bi-axial compression;
 - bi-axial tension;
 - shear and lateral pressure;
- (e) boundary conditions;
- (f) interactions between buckling modes;
- (g) interactions between structural elements such as plates, stiffeners, girders, etc.;
- (h) post-buckling capacity;
- (i) overstressed elements on the compression side of hull girder cross section possibly leading to local permanent sets/buckle damages in plating, stiffeners, etc. (double bottom effects or similar).

3.2 Non-linear finite element analysis

3.2.1 Advanced non-linear finite element analyses models may be used for the assessment of the hull girder ultimate capacity. Such models are to consider the relevant effects important to the non-linear responses with due consideration of the items listed in 3.1.2.

3.2.2 Particular attention is to be given to modelling the shape and size of geometrical imperfections. It is to be ensured that the shape and size of geometrical imperfections trigger the most critical failure modes.

CHAPTER 7 BULK CARRIERS

SECTION 1 - GENERAL PROVISIONS

7.1.1 Application

7.1.1.1 Bulk carriers are ships provided with single deck, double bottom, topside tank and hopper tank, and intended primarily to carry dry cargo in bulk, not including ore carriers.

7.1.1.2 This Chapter applies to bulk carriers as defined in 7.1.1.1 above, with the exception of those complying with 7.1.1.3 below.

7.1.1.3 CSR bulk carriers are to comply with the requirements in PART NINE of the Rules.

7.1.1.4 Those not covered in this Chapter are to comply with the relevant requirements of Chapter 2 of this PART.

7.1.2 Class notations

7.1.2.1 Bulk carriers complying with the provisions of this Chapter are eligible for one of the following notations:

- (1) "Bulk Carrier" for bulk carriers;
- (2) "Bulk Carrier, Strengthened for Heavy Cargoes" for bulk carriers strengthened for heavy cargoes;
- (3) "Bulk Carrier, Strengthened for Heavy Cargoes, Holds a,b,... may be empty" for bulk carriers

strengthened for heavy cargoes with specified or alternate holds empty.

7.1.2.2 Bulk carriers complying with the provisions of this Chapter, of which all cargo holds are bounded by double side skin construction of not less than 1000 mm breadth between the inner shell and the outer shell, are to be assigned one of the following notations:

- (1) “Bulk Carrier, Double Side Skin” for double side skin bulk carriers;
- (2) “Bulk Carrier, Double Side Skin, Strengthened for Heavy Cargoes” for double side skin bulk carriers strengthened for heavy cargoes;
- (3) “Bulk Carrier, Double Side Skin, Strengthened for Heavy Cargoes, Holds a,b,... may be empty” for double side skin bulk carriers strengthened for heavy cargoes with specified or alternate holds empty.

7.1.2.3 Typical bulk carriers of 150 m or over in length and constructed with single deck, double bottom,

topside tanks and hopper tanks in the cargo hold region and of single side skin or double side skin construction are to be assigned one of the following harmonized notations: BC-A; BC-B; BC-C. The harmonized notations and relevant design loading conditions are to comply with the requirements of Section 12 of this Chapter.

7.1.2.4 Bulk carriers with self-unloading function complying with the requirements of this Chapter are assigned the class notation “Self-Unloading Bulk Carrier”.

7.1.3 Plans and documents

7.1.3.1 In addition to the plans and documents specified in Section 1, Chapter 2 of this PART, the following are to be submitted for information:

- (1) the maximum pressure head in service on tanks and details of any double bottom tanks interconnected with hopper tanks, ballast tanks within double side skin and topside tanks;
- (2) details of the proposed depths of any partial fillings where water ballast or liquid cargo is intended to be carried in the holds.

7.1.4 Direct strength calculation and fatigue strength assessment for hull structure

7.1.4.1 For bulk carriers of 150 m or over in length, direct calculation is to be carried out for the strength of primary structural members (both longitudinal and transverse) within cargo area in accordance with the requirements of Appendix 1 of this Chapter.

7.1.4.2 For bulk carriers of 150 m or over in length, the fatigue strength check is to be carried out for the following structural members in the cargo area in accordance with ISC Guidelines for Fatigue Strength of Ship Structure:

- (1) connections of longitudinals (bottom, side, deck and inner shell) to transverse web frames;
- (2) connections of longitudinals (bottom, side, deck and inner shell) to transverse bulkheads;
- (3) connections of hopper tanks or inner shell to inner bottoms;
- (4) connections of inner bottoms to lower stool side plates;
- (5) connections of corrugated transverse bulkheads to lower stool top plates;
- (6) connections of corrugated transverse bulkheads to upper stool sloping plates;

(7) connections of frames to top side tanks and hopper tanks of single hull bulk carriers.

7.1.5 Protection of cargo holds from loading/discharge equipment

7.1.5.1 In bulk carriers of 150 m in load line length LL and upwards, carrying solid bulk cargoes having a density of $1,000 \text{ kg/m}^3$ and above, cargo holds are to be protected from loading/discharge equipment as follows:

- (1) structural strengthening is to be provided and the Grab notation assigned in accordance with Section 23, Chapter 2 of this PART;
- (2) wire rope grooving in way of cargo holds openings is to be prevented by fitting suitable protection such as half-round bar on the hatch side girders (i.e. upper portion of topside tank plates), hatch end beams or upper portion of hatch coamings.

SECTION 2 - BOTTOM STRUCTURES

7.2.1 General requirements

7.2.1.1 For bulk carriers intended to be assigned the class notation of Bulk Carrier, Strengthened for Heavy Cargoes, the bottom structures are to comply with the provisions in Section 22, Chapter 2 of this PART.

7.2.1.2 Where the double bottom tanks are interconnected with hopper side tanks, the scantlings are to satisfy the requirements of Section 13, Chapter 2 of this PART for deep tanks.

7.2.1.3 For bulk carriers of 150 m and over in length, the thickness of solid floors are determined by direction calculations, but the minimum thickness is not be less than that obtained from the following formula:

$$t_{\min} = \max(0.6\sqrt{L} + 3, \quad 12) \quad \text{mm}$$

where: L —length of ship, in m, to be taken not greater than 300 m in calculation.

7.2.1.4 For bulk carriers of 150 m and over in length, the thickness of watertight solid floors is also to comply with the requirements for deep tanks in Section 13, Chapter 2, in addition to complying with the requirements of 7.2.1.3.

7.2.1.5 For longitudinally framed double bottom, where it is verified by direct calculation, a maximum of 1.5 times frame spacing may be accepted for the spacing between bottom and inner bottom stiffening members within the duct keel.

7.2.1.6 For bulk carriers of less than 150 m in length intended to be assigned the class notation “Bulk Carrier, Strengthened for Heavy Cargoes, Hold Nos... may be Empty”, the bottom structures are to comply with the requirements of this Section and in addition, the direct calculation is to be carried out for the strength of primary members of double bottom (both longitudinal and transverse) in accordance with the requirements of Appendix 1 of this Chapter.

SECTION 3 - SIDE FRAMING

7.3.1 Application

7.3.1.1 This Section applies to side structures of cargo holds bounded by the side shell only of bulk carriers constructed with single deck, topside tanks and hopper tanks in cargo spaces intended primarily to carry dry cargo in bulk.

7.3.2 Side shell plating

7.3.2.1 The thickness of the side shell plating is to be determined according to the requirements in Chapter 2 of this PART. The thickness t of the shell plating between hopper and topside tanks within the cargo area is not to be less than that obtained from the following formula:

$$t = \sqrt{L} \quad \text{mm}$$

where: L — length of ship, in m.

7.3.3 Main Frames

7.3.3.1 For bulk carriers of 190 m and over in length, the main frames within the cargo area are to be integral with their upper and lower brackets and symmetrical in their transverse section.

7.3.3.2 In bulk carriers less than 190 m in length, mild steel main frames within the cargo area may be fitted with separate brackets and asymmetric in their transverse section.

7.3.3.3 The minimum web thickness of main frames is to be obtained from the following formula:

$$t = 7.0 + 0.03L \text{ mm}$$

where: L — length of ship, in m, need not be taken greater than 200 m.

7.3.3.4 The section modulus W of the main frames in holds is not to be less than that obtained from the following formula:

$$W = 5.8 s h_1^2 K \text{ cm}^3$$

where: s — spacing of frames, in m;

K — material factor;

h_1 — vertical distance, in m, measured between the midpoint of the span of frames and a point situated at $0.01L + 0.8$ above the load waterline, see Figure 8.3.3.4,

where: L — the length of ship, in m;

l — span of frame, in m, i.e. the distance measured between the intersection of sloping plating with the side shell; for $l < 0.25D$, to be taken as $0.25D$ (D being moulded depth, in m).

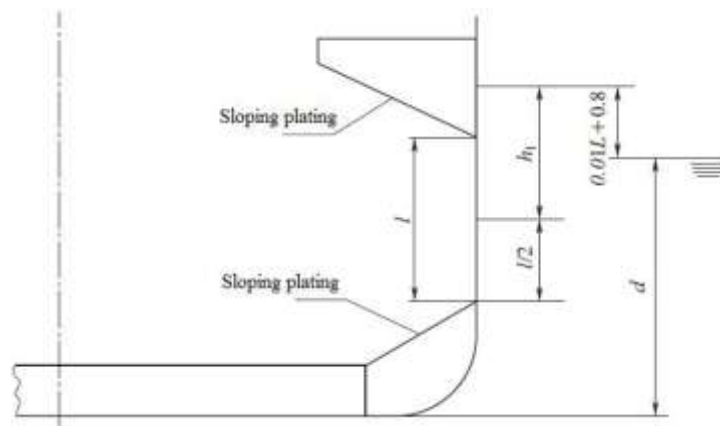


Figure 7.3.3.4

7.3.3.5 The web depth to thickness ratio of main frames is not to exceed the following values:

60 K for symmetrically flanged frames

50 K for unsymmetrically flanged frames

where: K — material factor.

7.3.3.6 The maximum breadth of the frame flange outstand is not to exceed 10 K times the thickness of the flange.

7.3.3.7 The frame flange is to be radiused at the connection with the end brackets (see Figure 7.3.3.7), with the radius of curvature being not less than that obtained by the following formula:

$$r = \frac{0.4b_f^2}{t_f} \quad \text{mm}$$

where: b_f — face plate width of lower or upper bracket, in
 t_f — face plate thickness of lower or upper bracket,

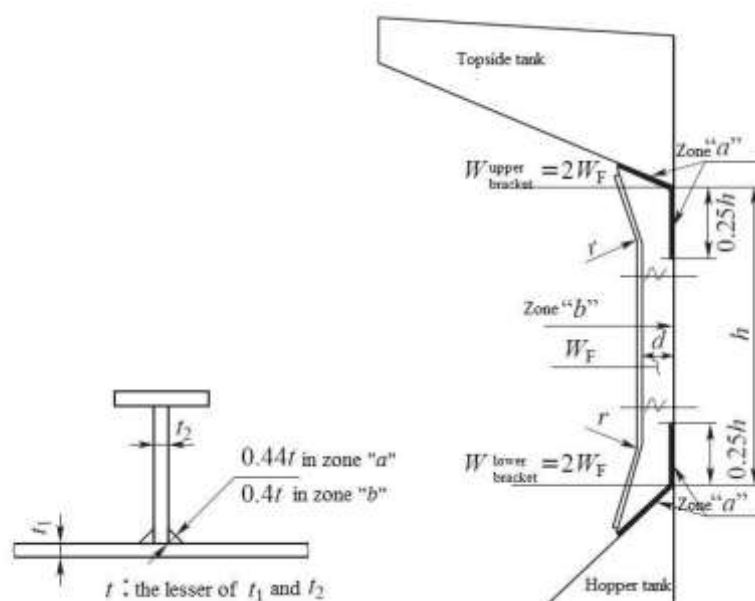


Figure 7.3.3.7

7.3.4 Lower and upper brackets of main frames

7.3.4.1 The thickness of the lower brackets is not to be less than that of the frame webs, nor to be less than that derived from 8.3.3.3 of this Section plus 2 mm.

7.3.4.2 The thickness of the upper brackets is not to be less than that of the frame webs.

7.3.4.3 The dimensions of the lower and upper brackets are not to be less than those shown in Figure 7.3.4.3.

7.3.4.4 The section modulus of the frame and the bracket or integral bracket, at the locations shown in Figure 8.3.3.7, is not to be less than twice the value obtained as per 7.3.3.4 of this Section.

7.3.4.5 The structural continuity of the upper and lower end connections of the frames is to be ensured by connecting brackets, as shown in Figure 7.3.4.5, within topside and hopper tanks. The brackets are in general to be stiffened against buckling in accordance with Figure 7.3.4.5.

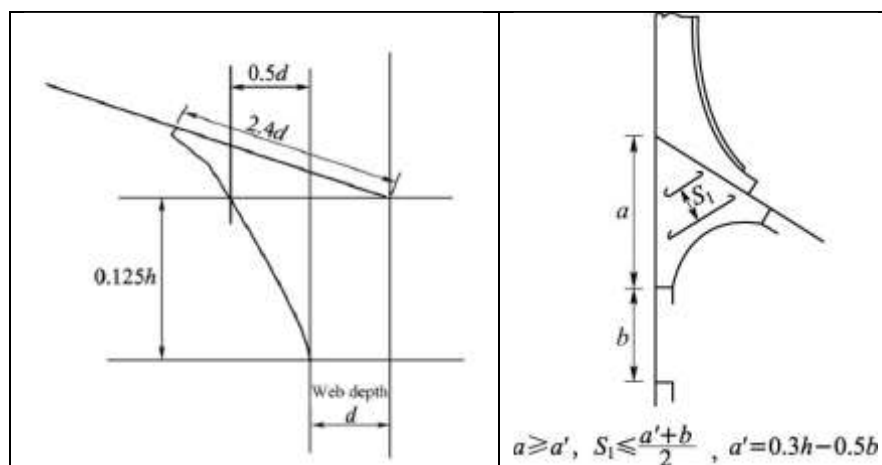


Figure 7.3.4.3

Figure 7.3.4.5

7.3.4.6 Upper and lower brackets are to be arranged at their ends with soft toes as shown in Figure 1.2.7.6 of Section 2, Chapter 1 of this PART.

7.3.4.7 The section moduli of the side longitudinals, topside tank sloping plate longitudinals and hopper tank sloping plate longitudinals which support the connecting brackets in 7.3.4.5 are to be determined with the span taken between transverses. When the arrangement of the upper and lower brackets of the frames and the connecting brackets is different from this Section, the side longitudinals, topside tank sloping plate longitudinals and hopper tank sloping plate longitudinals are to effectively support the connecting brackets, subject to agreement of ISC.

7.3.5 Strengthening of side structures in the foremost hold

7.3.5.1 The minimum web thickness of main frames is to be 1.15 times that required in 7.3.3.3 of this Section.

7.3.5.2 The scantlings of the main frames immediately adjacent to the collision bulkhead are to be properly increased in order to prevent deformation of the shell plating. As an alternative, side stingers or perforated platforms in the forepeak may be extended to the foremost frame of the foremost hold. The extension is to be provided with an adequate shear-resistant area for connection with the frame.

7.3.5.3 Where main frames of the foremost hold are asymmetrical in their transverse section, tripping brackets are to be fitted close to the mid-span of every second frame, as shown in Figure 7.3.5.3.

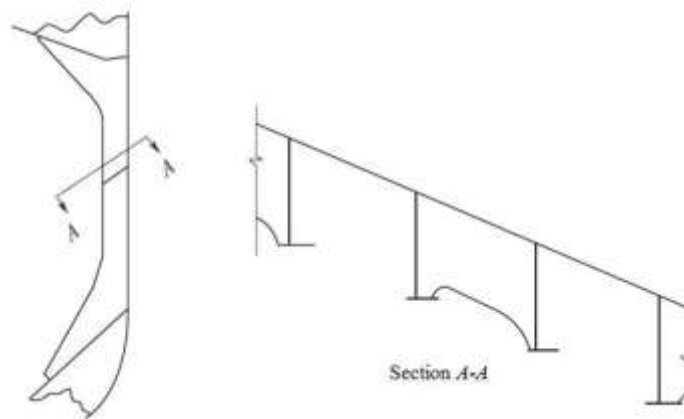


Figure 7.3.5.3

7.3.6 Weld connections of frames and brackets to side shell and sloping plating

7.3.6.1 Double continuous welding is to be adopted for the fillet-weld connections of frames and brackets to side shell, topside and hopper tank sloping plating and web to face plates. For this purpose, the weld throat is to be (see Figure 8.3.3.7):

$0.44 t$ in zone “a”

$0.4 t$ in zone “b”

where: t — the thinner of the two connected members, in mm.

7.3.6.2 Where the hull form is such that an effective fillet weld cannot be made, edge preparation of the web of the frame and bracket may be required, in order to ensure the required efficiency of the weld connection.

SECTION 4 - WATERTIGHT BULKHEADS

7.4.1 General requirements

7.4.1.1 Watertight bulkheads are to comply with the requirements of Section 12, Chapter 2 of this PART. The transverse bulkheads forming boundaries of ballast holds are also to comply with the requirements of Section 13, Chapter 2 of this PART for deep tank bulkheads.

7.4.1.2 Stools, if fitted at the top and bottom of the corrugated watertight bulkhead, are to comply with the following requirements:

- (1) The sloping plating of lower stools is to be fitted on solid floors. The thickness of the sloping plating is not to be less than that of the bulkhead plating required in Section 12, Chapter 2 of this PART and in addition, is not to be less than that required in 8.5.2.1 of this Chapter for the sloping plating of hopper tanks.
- (2) Where stiffeners are fitted on the sloping plating of lower stools, their section modulus is not to be less than that required in 8.5.3.1 of this Chapter for the longitudinals on the sloping plating of hopper tanks.
- (3) Diaphragms are to be fitted in lower stools in way of bottom girders, having the same thickness as that of the inner bottom longitudinal girders.
- (4) The scantlings of upper stools are not to be less than those required in Section 12, Chapter 2 of this PART.
- (5) Stool structures situated in liquid tanks are also to comply with the requirements of Section 13, Chapter 2 of this PART for deep tanks.

SECTION 5 - HOPPER TANKS

7.5.1 General requirements

7.5.1.1 Watertight bulkheads are to be fitted, as far as practicable, in the hopper tanks in way of the watertight bulkheads in holds. Otherwise wash bulkheads are to be fitted.

7.5.1.2 Consideration is to be given to the structural continuity of both ends of hopper tanks.

7.5.1.3 For the calculation of scantlings of hopper tank structural members, the tank top is the highest point of the topside tank where hopper tanks are interconnected with topside tanks, or the highest point of the ballast tank within double side skin where hopper tanks are interconnected with such ballast tanks.

7.5.1.4 The requirements of this Section apply to hopper tanks framed longitudinally.

7.5.2 Sloping plating

7.5.2.1 The thickness of the sloping plating is not to be less than that of inner bottom plating as required in Section 6, Chapter 2 of this PART. For ships intended to be assigned the class notation of Bulk Carrier, Strengthened for Heavy Cargoes, the sloping plating is to be increased in thickness in accordance with the requirements of 2.22.3.4 of this PART, but this increase may be gradually tapered from the intersection of sloping plating and inner bottom plating to nil at the top corner of the tank. Where hopper tanks are interconnected with topside tanks or form boundaries of ballast holds, the thickness of the sloping plating is not to be less than that required in Section 13, Chapter 2 of this PART for deep tanks.

7.5.2.2 Where the hopper tanks are fitted with watertight side bulkheads, the thickness t of the side bulkhead plating is not to be less than that obtained from the following formula:

$$t = 4s\sqrt{hK} + 2.5 \text{ mm}$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, measured from the lower edge of strake to the tank top or half of the vertical distance to the top of the overflow, whichever is the greater;

K — material factor.

7.5.3 Longitudinals

7.5.3.1 The section modulus W of the sloping plating longitudinals is not to be less than that of the inner bottom longitudinals as required in Section 6, Chapter 2 of this PART.

If the class notation of Strengthened for Heavy Cargoes is intended, the section modulus is not to be less than that obtained from the following formula:

$$W = 8.5HsI^2K/\gamma \text{ cm}^3$$

where: γ — see Section 22, Chapter 2 of this PART;

H — vertical distance, in m, measured from longitudinal to the lower edge of the sloping plating of topside tanks; where no topside tank is provided, measured from longitudinal to upper deck;

s — spacing of longitudinals, in m;

I — span of longitudinal, in m;

K — material factor.

Where hopper tanks are interconnected with topside tanks or form boundaries of ballast holds, the section modulus W of the sloping plating longitudinals is not to be less than:

$$W = 9shI^2K \text{ cm}^3$$

where: s, I, K — same as defined above;

h — vertical distance, in m, measured from the longitudinal to the tank top, or half of the vertical distance to the top of the overflow, whichever is the greater.

7.5.3.2 The section modulus W of side and bilge longitudinals in hopper tanks is not to be less than that required in Section 7, Chapter 2 of this PART.

7.5.3.3 The section modulus W of bottom longitudinals in hopper tanks is not to be less than that required in Section 6, Chapter 2 of this PART.

7.5.4 Transverse supporting structural members

7.5.4.1 Transverse structural members supporting the longitudinals of the hopper tanks are to be fitted in way of the floors within holds.

7.5.4.2 The section modulus W and the section moment of inertia I of bottom transverses and side shell transverses are not to be less than those obtained from the following formulae:

$$W = 12Shl^2K \text{ cm}^3$$

$$I = 2.5Wl/K \text{ cm}^4$$

where: S — spacing of bottom or side shell transverses, in m;
 l — span of bottom or side shell transverse, in m;
 h — vertical distance, in m, from the mid-point of span to the upper deck at side;
 K — material factor.

7.5.4.3 The section modulus W and the section moment of inertial I of sloping plating transverses are not to be less than those obtained from the following formulae:

$$W = 12Shl^2K \text{ cm}^3$$

$$I = 2.5Wl/K \text{ cm}^4$$

where: S — spacing of transverses, in m;
 l — span of transverse, in m;
 h — vertical distance, in m, measured from the mid-point of span to the tank top of or half of the vertical distance to the top of the overflow, whichever is the greater;
 K — material factor.

If the class notation of Strengthened for Heavy Cargoes is intended, the section modulus W and the section moment of inertial I of sloping plating transverses are not to be less than those obtained from the following formulae:

$$W = 6.6HS^2K/\gamma \text{ cm}^3$$

$$I = 1.8Wl/K \text{ cm}^4$$

where: γ — see Section 22, Chapter 2 of this PART;
 H — vertical distance, in m, measured from the mid-point of span to the lower edge of the sloping plating of the topside tank;
 S — spacing of transverses, in m;
 l — span of transverse, in m;
 K — material factor.

7.5.4.4 Bottom transverses, side shell transverses and sloping plating transverses are to be effectively connected one another. Longitudinals are to be continuous through the bottom and side shell transverses and the sloping plating transverses, and are to be welded to their web plates. The web depth of primary supporting members is not to be less than 2.5 times the depth of the slot for the passage of longitudinals, and the web is to be suitably fitted with stiffeners between sloping plating longitudinals and bottom longitudinals or side longitudinals in compliance with the same requirements in 2.6.11.2 of Section 6, Chapter 2 of this PART. Brackets connecting the face plate of primary supporting members and the longitudinals are to be fitted at least at alternate longitudinals, and the thickness of brackets is to be the same as that of the web of the primary supporting members.

7.5.4.5 Where non-watertight transverse webs are provided in lieu of the above-mentioned bottom transverses, side shell transverses and slopping plating transverses, the thickness and stiffeners of such webs are to meet the requirements of 7.5.6.

7.5.4.6 Where the side shell in way of cargo holds is framed transversely, brackets are to be fitted above the hopper tank at every frame. The thickness of the brackets is to be the same as the web depth in way of the side shell transverse ring in the hopper tank, and the length of the brackets, measured along the sloping plating and the side shell, is not to be less than that of the free edge of the lower brackets of the hold main frames. These brackets are to be welded to the adjacent longitudinals. Buckling-restrained stiffeners are to be fitted to the brackets. The direction of stiffeners is shown in Figure 7.3.4.5 of this Chapter and their sectional scantlings are to be the same as that of the stiffeners on bottom transverses.

7.5.5 Watertight bulkheads

7.5.5.1 The thickness t of watertight bulkhead plating is not to be less than that obtained from the following formula:

$$t = 4s\sqrt{hK} + 2.5 \text{ mm}$$

where: s — spacing of stiffeners, in m;

K — material factor;

h — vertical distance, in m, measured from the lower edge of strake to the tank top or half of the vertical distance to the top of the overflow, whichever is the greater.

7.5.5.2 The section modulus W of stiffeners on the watertight bulkheads is not to be less than that obtained from the following formula:

$$W = 8.2shl^2K \text{ cm}^3$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, measured from the mid-point of span of the stiffeners to the tank top or half of the vertical distance to the top of the overflow, whichever is the greater;

l — span of stiffener, in m;

K — material factor.

Stiffeners are to be bracketed at both ends.

7.5.6 Non-watertight bulkheads and wash bulkheads

7.5.6.1 The plating thickness t of non-watertight or wash bulkheads is not to be less than that obtained from the following formula and not to be less than 8 mm:

$$t = 12s \text{ mm}$$

where: s — spacing of stiffeners, in m.

7.5.6.2 The section modulus of the stiffeners on the non-watertight or wash bulkheads is not to be less than 50% of that derived from 7.5.5.2 of this Section. Stiffeners are to be bracketed at both ends.

SECTION 6 - TOPSIDE TANKS

7.6.1 General requirements

7.6.1.1 Watertight bulkheads are to be fitted, as far as practicable, in the topside tanks in way of the watertight bulkheads in holds. Otherwise, wash bulkheads are to be fitted.

7.6.1.2 Consideration is to be given to the structural continuity of both ends of topside tanks.

7.6.2 Sloping plating and vertical side plating

7.6.2.1 The thickness t of the sloping plating is not to be less than that obtained from the following formula, and not to be less than 8 mm:

$$t = 4s\sqrt{hK} + 2.5 \quad \text{mm}$$

$$t = 12s/\sqrt{K} \quad \text{mm}$$

where: s — spacing of longitudinals, in m;

K — material factor;

$h = h_1 \cos \vartheta$ or vertical distance, in m, measured from the lower edge of strake to the tank top or half of the vertical distance to the top of the overflow, whichever is the greater;

h_1 — vertical distance, in m, measured from the lower edge of strake to the highest point of the topside tank;

b_1 — horizontal distance, in m, measured from the lower edge of strake to the highest point of the topside tank at either side, whichever is the greater;

$\vartheta = 30^\circ$.

The thickness of the lowest strake is to be increased by 1 mm above that obtained from the above formula.

7.6.2.2 The thickness of the vertical side plating fitted in line with hatch side coamings and of the top strake of the topside tank sloping plating is not to be less than 60% of that of the deck plate outside the line of openings, nor to be less than $18s$ (s being the spacing of longitudinals, in m). Brackets, spaced not more than 2 frame spaces apart, are to be fitted at the vertical side plating, and extended to deck and sloping plating longitudinals and welded to them.

7.6.3 Longitudinals

7.6.3.1 The section modulus W of deck, sloping plating and side longitudinals are not to be less than that of the following formula:

$$W = 10sh^2K \text{ cm}^3$$

where: s — spacing of longitudinals, in m;

l — span of longitudinal, in m;

K — material factor;

$h = h_1 \cos\theta + b_1 \sin\theta$, or vertical distance, in m, measured from the longitudinal to the tank top or half of the vertical distance to the top of the overflow, whichever is the greater, and not to be less than 1.5 m;

h_1 — vertical distance, in m, measured from the longitudinal to the highest point of the topside tank;

b_1 — horizontal distance, in m, measured from the longitudinal to the highest point of the topside tank at either side, whichever is the greater;

$\theta = 30^\circ$.

7.6.3.2 The scantlings of deck and side longitudinals are also to comply with the relevant requirements of Chapter 2 of this PART.

7.6.4 Transverse supporting structural members

7.6.4.1 The section modulus W and the section moment of inertia I of the deck, sloping plating and side shell transverses supporting the longitudinals are not to be less than those obtained from the following formulae:

$$W = 7.5Sh^2K \text{ cm}^3$$

$$I = 2.5Wl/K \text{ cm}^4$$

where: S — spacing of deck or side shell transverses, in m;

l — span of deck or side shell transverse, in m;

K — material factor;

$h = h_1 \cos\theta + b_1 \sin\theta$, or vertical distance, in m, measured from the mid-point of span to the tank top, or half of the vertical distance to the top of the overflow, whichever is the greater, and not to be less than 1.5 m;

h_1 — vertical distance, in m, measured from the mid-point of span to the highest point of the topside tank;

b_1 — horizontal distance, in m, measured from the mid-point of span to the highest point of the topside tank at either side, whichever is the greater;

$\theta = 30^\circ$.

7.6.4.2 The scantlings of deck or side shell transverses are not to be less than as required in Chapter 2 of this PART. Their web depth is not to be less than twice the depth of the slot for the passage of longitudinals. The web thickness is not to be less than 1% of its depth plus 4 mm.

7.6.4.3 The deck, sloping plating and side shell transverses are to be connected one another by brackets.

7.6.4.4 The longitudinals are to be continuous through the deck, sloping plating and side shell transverses, and are to be welded to their web plates. Brackets connecting the face plate of primary supporting members and the longitudinals are to be fitted at least at alternate longitudinals, and the thickness of brackets is to be the same as that of the web of the primary supporting members.

7.6.4.5 Primary transverse members supporting the longitudinals in topside tanks are, in general, to be spaced not more than 3.6 m apart for ships equal to or less than 100 m in length, and not more than $0.006L + 3.0$ m apart for ships more than 100 m in length. Larger spacing may be accepted where the evaluation is carried out by means of direct strength calculation in accordance with the requirements of Appendix 1 of this Chapter.

7.6.4.6 Where non-watertight transverse webs are provided in lieu of the above-mentioned deck transverses, side shell transverses and sloping plating transverses, the thickness and stiffeners of such webs are to meet the requirements of 8.6.7.

7.6.4.7 Where the side shell in way of cargo holds is framed transversely, brackets are to be fitted below the topside tank at every frame. The thickness of the brackets is to be the same as the web depth in way of the side shell transverse ring in the topside tank, and these brackets are to be extended and welded to the adjacent longitudinals along the side shell and sloping plating. The brackets are to be in line with the upper brackets of the hold main frames.

7.6.4.8 Where a rounded gunwale is adopted, a bracket is to be fitted in way of the rounded gunwale approximately halfway between transverses, extending and welded to the adjacent deck and shell longitudinals.

7.6.4.9 Transverse supporting members are to be arranged in topside tanks in line with hatch end coamings.

7.6.5 Shell framing

7.6.5.1 Where the side shell is framed transversely, the section modulus W of the frames is not to be less than that obtained from the following formula:

$$W = 10sh^2K \text{ cm}^3$$

where: s — spacing of frames, in m;

l — span of frame, in m;

K — material factor;

$h = h_1 \cos \theta + b_1 \sin \theta$, or vertical distance, in m, measured from the mid-point of span to the tank top, or half of the vertical distance to the top of the overflow, whichever is the greater;

h_1 — vertical distance, in m, measured from the mid-point of span to the highest point of the topside tank;

b_1 — horizontal distance, in m, measured from the mid-point of span to the highest point of the topside tank at either side, whichever is the greater;

$\theta = 30^\circ$.

Frames are also to comply with the requirements of 2.13.6.1 of this PART.

7.6.5.2 Bracket are to be fitted at both ends of frames, extended and welded to the adjacent deck and sloping plating longitudinally. The thickness of brackets is to be the same as that of the upper brackets of hold main frames.

7.6.6 Watertight bulkheads

7.6.6.1 The thickness t of the watertight bulkheads is not to be less than that obtained from the following formula, and not to be less than 8 mm:

$$\begin{aligned} t &= 4s\sqrt{hK} + 2.5 & \text{mm} \\ t &= 12s/\sqrt{K} & \text{mm} \end{aligned}$$

where: s — spacing of stiffeners, in m;

K — material factor;

$h = h_1 \cos \theta + b_1 \sin \theta$, or vertical distance, in m, measured from the lower edge of strake to the tank top, or half of the vertical distance to the top of the overflow, whichever is the greater;

h_1 — vertical distance, in m, measured from the lower edge of strake to the highest point of the topside tank;

b_1 — horizontal distance, in m, measured from the lower edge of strake to the highest point of the topside tank at either side, whichever is the greater;

$\theta = 30^\circ$.

The thickness of the lowest strake is to be increased by 1 mm above that derived from above.

7.6.6.2 The section modulus W of stiffeners on the watertight bulkheads is not to be less than that obtained from the following formula:

$$W = 10shl^2K \text{ cm}^3$$

where: s — spacing of stiffeners, in m;

l — span of stiffener, in m;

K — material factor;

$h = h_1 \cos \theta + b_1 \sin \theta$, or vertical distance, in m, measured from the mid-point of span to the tank top, or half of the vertical distance to the top of the overflow, whichever is the greater;

h_1 — the vertical distance, in m, measured from the mid-point of span to the highest

point of the topside tank;

b_1 — horizontal distance, in m, measured from the mid-point of span to the highest point of the topside tank at either side, whichever is the greater;

$\theta = 30^\circ$.

The stiffeners are to be bracketed at both ends.

7.6.7 Non-watertight and wash bulkheads

7.6.7.1 The plating thickness t of non-watertight or wash bulkheads is to be in compliance with 7.5.6.1 of this Chapter.

7.6.7.2 The section modulus of the stiffeners on the non-watertight or wash bulkheads is not to be less than 50% of that derived from 8.6.6.2 of this Section. The stiffeners are to be bracketed at both ends.

SECTION 7 - ADDITIONAL REQUIREMENTS FOR LOADING MANUALS AND LOADING INSTRUMENTS

7.7.1 Application

7.7.1.1 This Section applies to bulk carriers, ore carriers and combination carriers of 150 m and over in length.

7.7.1.2 Hold mass curves are calculated and drawn in accordance with Appendix 2 of this Chapter.

7.7.2 Loading manuals

7.7.2.1 The loading manual is to describe:

- (1) the loading condition on which the design of the ship has been based, including still water bending moments and shear forces and where applicable, the results of the calculations of torsional loads;
- (2) permissible limits of still water bending moments and shear forces;
- (3) envelope results and still water bending moments and shear forces in the hold flooded condition according to Section 8 of this Chapter as applicable;
- (4) the cargo hold(s) or combination of cargo holds that may be empty at full draught. If no cargo hold is allowed to be empty at full draught, this is to be clearly stated in the loading manual;
- (5) maximum allowable and minimum required mass of cargo and double bottom contents of each hold as a function of the draught at mid-hold position;
- (6) maximum allowable and minimum required mass of cargo and double bottom contents of any two adjacent holds as a function of the mean draught in way of these holds. This mean draught is to be calculated by averaging the draught at the two mid-hold positions;
- (7) maximum allowable tank top loading together with specification of the nature of the cargo for cargoes other than bulk cargoes;
- (8) maximum allowable load on deck and hatch covers. If the vessel is not approved to carry load on deck or hatch covers, this is to be clearly stated in the loading manual;
- (9) the maximum rate of ballast change together with the advice that a load plan is to be agreed

with the terminal on the achievable rates of change of ballast.

7.7.2.2 Conditions of approval of loading manuals

In addition to the requirements given in 2.2.8.11 of this PART, the following conditions, subdivided into departure and arrival conditions as appropriate, are to be included in the loading manual:

- (1) Alternate light and heavy cargo loading conditions at maximum draught, where applicable;
- (2) Homogeneous light and heavy cargo loading conditions at maximum draught;
- (3) Ballast conditions. For bulk carriers having ballast holds adjacent to topside wing, hopper and double bottom tanks, it is to be strengthwise acceptable that the ballast holds are filled when the topside wing, hopper and double bottom tanks are empty;
- (4) Short voyage conditions where the ship is to be loaded to maximum draught but with limited amount of bunkers, where applicable;
- (5) Multiple port loading/unloading conditions, where applicable;
- (6) Deck cargo conditions, where applicable;
- (7) Typical loading sequences where the ship is loaded from commencement of cargo loading to reaching full deadweight capacity, for homogeneous conditions, relevant part load conditions and alternate conditions where applicable. Typical unloading sequences for these conditions are also to be included. The typical loading/unloading sequences are to be developed not to exceed applicable strength limitations. These sequences are to be developed paying due attention to loading/unloading rate and deballasting capacity. Table 7.7.2.2 shows an example of the Sheet of Loading Sequences for guidance;
- (8) Typical sequences for exchange of ballast water at sea, where applicable.

Table 7.7.2.2 - Typical Sheet of Loading Sequences for Guidance

		Vessel name: Yard: Id. number:	
Port (specific or typical): Total mass of cargo to be loaded/discharged: Dock water density (t/m^3): Number of loaders/dischargers: 		Condition at commencement of loading/discharging: Condition at end of loading/discharging: Maximum loading/discharging rate: Average loading/discharging rate: Maximum ballasting/deballasting rate: Average ballasting/deballasting rate: 	
Note: During each pour it has to be controlled that allowable limits for hull girder shear forces, bending moments and mass in holds are not exceeded. Loading/discharging operations may have to be paused to allow for ballasting/deballasting in order to keep actual values within limits.			
Volume of Hold, V_h (m^3) Height of hold, h (m)		Hold content at commencement of loading/discharging Wings or peaks Upper: Lower/Peaks:	
Cargo mass: Density (t/m^3): Grade:		Ballast content at commencement of loading/discharging APT Ball. no. 5 Ball. no. 4 No. 6 hold Ball. no. 3 No. 4 hold Ball. no. 2 Ball. no. 1 PPT	
CARGO OPERATIONS		BALLAST OPERATIONS	
Pour no. / grade	Hold 8	Hold 6	Hold 7
1			
2			
3			
4			
5			
6			
7			
8			
Draft Survey (for loading):	Total cargo onboard (t):	Remaining cargo to be loaded (t):	Total amount of bunkers onboard (t):
n-1			
n			
Hold content at end of loading/discharging Cargo mass: Total mass loaded/discharged (t):		Ballast content at end of loading/discharging Wings or peaks Upper: Lower/Peaks:	
Maximum occurring values among all conditions above Net load on Double Bottom: Net load in two adjacent holds:		Net load on double bottom = $\frac{(M_h/V)}{h} \geq T$ (t/m^2) - where: M_h = Mass in hold + mass in DB (t) V = Total volume of hold (m^3) h = height of hold from inner bottom to top of coaming (m) T = draught (m)	
		Approved by:	
		Place, date, stamp and sign	

7.7.3 Loading instrument

7.7.3.1 A loading instrument with the display function is an approved digital system as defined in 2.2.8.4 of this PART. In addition to the requirements in 2.2.8.4 of this PART, it is to ascertain as appropriate that:

- (1) the mass of cargo and double bottom contents in way of each hold as a function of the draught at mid-hold position;
- (2) the mass of cargo and double bottom contents of any two adjacent holds as a function of the mean draught in way of these holds;
- (3) the still water bending moment and shear forces in the hold flooded conditions according to Section 8 of this Chapter are permissible.

7.7.3.2 Conditions of approval of loading instruments

The loading instrument is subject to approval. In addition to the requirements given in 2.2.8.12 of this PART, the approval is to include as applicable:

- (1) acceptance of hull girder bending moment limits for all read-out points;
- (2) acceptance of hull girder shear force limits for all read-out points;
- (3) acceptance of limits for mass of cargo and double bottom contents of each hold as a function of draught;
- (4) acceptance of limits for mass of cargo and double bottom contents in any two adjacent holds as a function of draught.

7.7.4 Guidance for loading/unloading sequences

7.7.4.1 Where a typical loading/unloading sequences manual is prepared, due attention is to be given to the loading/unloading rate, ballasting/deballasting capacity and applicable strength limitations.

7.7.4.2 The typical loading/unloading sequence is to be prepared and submitted for approval by shipyard.

7.7.4.3 The relevant contents of typical loading/unloading sequences are to include:

- (1) alternate light and heavy cargo loading conditions;
- (2) homogeneous light and heavy cargo loading conditions;
- (3) short voyage conditions where the ship is to be loaded to maximum draught but with limited amount of bunkers;
- (4) multi-port loading/unloading conditions;
- (5) deck cargo condition;
- (6) alt-block loading condition.

7.7.4.4 The loading/unloading sequences may be for a specific port or a typical sequence.

7.7.4.5 The loading/unloading sequences of the selected loading condition are to be compiled one step by one step from commencement of cargo loading to reaching full deadweight capacity. A

step is finished when the loading equipment is moved to another cargo hold. File is to be submitted to ISC for each step. In addition to the longitudinal strength, the local strength of each cargo hold is to be taken into consideration.

7.7.4.6 Each loading condition is to include the summary of all steps. It is to focus on the key information of each step, such as:

- (1) the capacity of cargoes in each cargo hold for different steps;
- (2) the volume of discharged ballast water for each ballast tank in different steps;
- (3) the maximum still water bending moment and shear force when each step is finished; (4) the trim and draught of ship when each step is finished.

SECTION 8 - OVERALL LONGITUDINAL STRENGTH IN FLOODED CONDITION

7.8.1 General requirements

7.8.1.1 This Section applies to non-CSR bulk carriers of 150 m and over in length, intending to carry solid bulk cargoes having a density of 1.0 t/m³ and above, and

- (1) single hull, or
- (2) double side skin construction in which any part of longitudinal bulkhead is located within $B/5$ or 11.5 m, whichever is less, inboard from the ship's side at right angle to the centreline at the assigned summer load line.

7.8.1.2 Such ships are to have their hull girder strength checked for conditions as specified in Section 2, Chapter 2 and Section 7, Chapter 7 of this PART and in every other condition considered in the intact longitudinal strength calculations, except the following conditions:

- (1) harbor conditions;
- (2) docking condition afloat;
- (3) loading and unloading transitory conditions in port;
- (4) loading conditions encountered during ballast water exchange.

7.8.1.3 The hull girder is to be considered intact for checking its overall longitudinal strength.

7.8.2 Flooding criteria

7.8.2.1 The permeability of empty cargo spaces and volume left in loaded cargo spaces above any cargo is to be taken as 0.95.

7.8.2.2 Appropriate permeability and bulk density are to be determined for any cargo carried. "Permeability" for solid bulk cargo means the ratio of the floodable volume between the particles, granules or any larger pieces of cargo, to the gross volume of the bulk cargo. For iron ore, a minimum permeability of 0.3 with a corresponding bulk density of 3.0 t/m³ is to be used. For cement, a minimum permeability of 0.3 with a corresponding bulk density of 1.3 t/m³ is to be used.

7.8.2.3 For packed cargo (such as steel mill products), the actual density of the cargo is to be used with a permeability of zero.

7.8.3 Flooding conditions

7.8.3.1 Each cargo hold is to be considered individually flooded up to the equilibrium waterline. This application is to be applied to self-unloading bulk carriers (SUBC) where the unloading system maintains the watertightness during seagoing operations. In SUBCs with unloading systems that do not maintain watertightness, the longitudinal strength in the flooded conditions is to be considered using the extent to which the flooding may occur.

7.8.3.2 The wave loads in the flooded conditions are assumed to be equal to 80% of those given in Section 2 of Chapter 2.

7.8.4 Stress calculations

7.8.4.1 The overall longitudinal bending stress σ of hull girders at deck and bottom is to be obtained according to 2.2.5.5 of Chapter 2 of this PART, but the wave bending moment is to be determined according to 7.8.3.2 of this Section, with permissible still water bending moment being taken as that in flooding conditions.

7.8.4.2 The shear stress τ of hull girders at any point on the side shell is to be obtained according to 2.2.6.4 of Chapter 2 of this PART, but the wave shear force is to be determined according to 7.8.3.2 of this Section, with permissible still water shear force being taken as that in flooding conditions.

7.8.5 Strength criteria

7.8.5.1 The permissible hull girder bending and shear stresses are to comply with the requirements of Section 2, Chapter 2 of this PART.

7.8.5.2 The buckling strength is to be checked according to 2.2.7 of this PART.

SECTION 9 - STRENGTH OF CORRUGATED TRANSVERSE WATERTIGHT BULKHEADS IN HOLD-FLOODED CONDITIONS

7.9.1 General requirements

7.9.1.1 This Section applies to non-CSR bulk carriers of 150 m and over in length, intending to carry solid bulk cargoes having a density of 1.0 t/m³, or above, and

- (1) single hull, or
- (2) double side skin construction in which any part of longitudinal bulkhead is located within $B/5$ or 11.5 m, whichever is less, inboard from the ship's side at right angle to the centreline at the assigned summer load line.

7.9.1.2 The thickness obtained according to the strength criteria given in 7.9.4 of this Section is

the net thickness t_{net} required for the strength.

7.9.1.3 The required actual thickness is obtained by adding the corrosion addition given in 7.9.5 of this Section to the net thickness t_{net} .

7.9.1.4 The homogeneous loading condition stated in this Section means a loading condition in which the ratio between the highest and lowest filling ratios, evaluated for any hold, does not exceed 1.20, to be corrected for different cargo densities.

7.9.1.5 The scantlings of corrugated transverse watertight bulkheads determined according to this Section need not be checked again according to 7.4.1 of this Chapter.

7.9.2 Load model

7.9.2.1 General requirements

The loads to be considered as acting on the bulkheads are those given by the combination of the cargo loads with those induced by the flooding of one hold adjacent to the bulkhead under examination. In any case, the pressure due to the flooding water alone is to be considered. This application is to be applied to self-unloading bulk carriers (SUBC) where the unloading system maintains the watertightness during seagoing operations. In SUBCs with unloading systems that do not maintain watertightness, the combination loads acting on the bulkheads in the flooded conditions are to be considered using the extent to which the flooding may occur.

The most severe combinations of cargo induced loads and flooding loads are to be used for the check of strength of each bulkhead, depending on the loading conditions included in the loading manual:

- homogeneous loading conditions;
- non-homogeneous loading conditions;

considering the individual flooding of both loaded and empty holds.

The specified design load limits for the cargo holds are to be represented by loading conditions defined by the Designer in the loading manual.

Non-homogeneous part loading conditions associated with multi-port loading and unloading operations for homogeneous loading conditions need not to be considered according to these requirements. Holds carrying packed cargoes are to be considered as empty holds for this application.

Unless the ship is intended to carry, in non-homogeneous conditions, only iron ore or cargo having bulk density equal to or greater than 1.78 t/m^3 , the maximum mass of cargo which may be carried in the hold is to be the mass that fills the hold up to the upper deck level at centreline.

7.9.2.2 The bulkhead flooding head h_f (see Figure 7.9.2.3(1)) is the distance, in m, measured vertically with the ship in the upright position, from the calculation point to a level located at a distance df , in m, from the baseline equal to (D being moulded depth):

(1) in general:

- D , for the foremost transverse corrugated bulkhead;
- $0.9 D$, for the other corrugated bulkheads.

Where the ship is to carry cargoes having bulk density less than 1.78 t/m^3 in non-homogeneous loading conditions, the following values are to be taken:

- $0.95 D$, for the foremost transverse corrugated bulkhead;
- $0.85 D$, for the other corrugated bulkheads;

(2) for ships less than 50,000 tons deadweight with type B freeboard:

- $0.95 D$, for the foremost transverse corrugated bulkhead;
- $0.85 D$, for the other corrugated bulkheads.

Where the ship is to carry cargoes having bulk density less than 1.78 t/m^3 in non-homogeneous loading conditions, the following values are to be taken:

- $0.9 D$, for the foremost transverse corrugated bulkhead;
- $0.8 D$, for the other corrugated bulkheads.

7.9.2.3 The pressure P_c exerted by bulk cargo on bulkheads and the force F_c acting on a corrugation in the non-flooded holds are to be obtained from the following formulae:

$$P_c = 9.81 \rho_c h_1 \tan^2 \gamma \quad \text{kN/m}^2$$

$$F_c = 4.91 \rho_c s_1 (d_1 - h_{DB} - h_{LS})^2 \tan^2 \gamma \quad \text{kN}$$

where: ρ_c — bulk cargo density, in t/m^3 ;

h_1 — vertical distance, in m, from the calculation point to horizontal plane corresponding to the level height of the cargo, located at a distance d_1 , in m, from the baseline (see Figure 7.9.2.3(1));

γ — $45^\circ - (\varphi/2)$, in degrees;

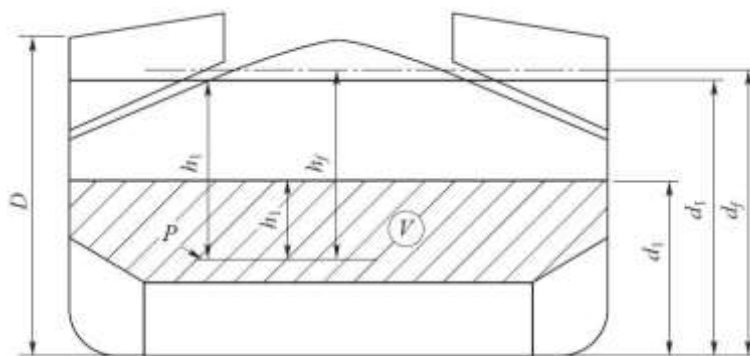
φ — angle of repose of the cargo, in degrees, that may be taken as 35° for iron ore and 25° for cement;

d_1 — see Figure 7.9.2.3 (1), in m;

s_1 — spacing of corrugations, in m (see Figure 7.9.2.3 (2));

h_{LS} — mean height of the lower stool, in m, from the inner bottom;

h_{DB} — height of the double bottom, in m.



V = Volume of cargo P = Calculation point

Figure 7.9.2.3(1)

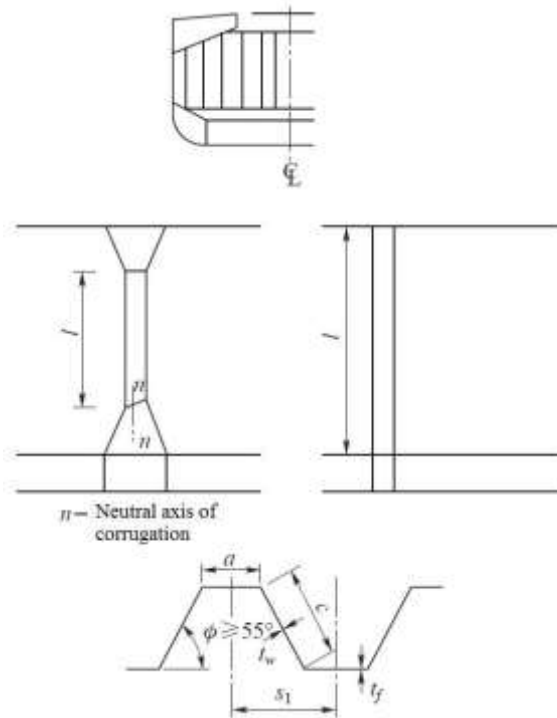


Figure 7.9.2.3(2)

7.9.2.4 Pressure in the flooded holds

(1) The pressure P_{cf} acting on bulkheads and the force F_{cf} acting on a corrugation in the flooded loaded holds are to be obtained from the following formulae:

In the case of $d_f \geq d_1$ (the distance d_f from horizontal plane to the baseline is equal to or greater than the distance d_1 from the level height of the cargo to the baseline in flooded conditions):

$$\begin{aligned}
 P_{cf} &= 10h_f \text{ kN/m}^2, && \text{calculation point between } d_f \text{ and } d_1 \\
 P_{cf} &= 10\{h_f + [\rho_c - (1 - perm)]h_1 \tan^2 \gamma\} \text{ kN/m}^2, && \text{calculation point below } d_1 \\
 F_{cf} &= 5s_1 \left[(d_f - d_1)^2 + (d_f - d_1 + 0.1P_{le})(d_1 - h_{DB} - h_{LS}) \right] \text{ kN}
 \end{aligned}$$

In the case of $d_f < d_1$ (the distance from horizontal plane to the baseline is less than the distance from the height of the cargo to the baseline in flooded conditions):

$$\begin{aligned}
 P_{cf} &= 9.81\rho_c h_1 \tan^2 \gamma \text{ kN/m}^2, && \text{calculation point between } d_f \text{ and } d_1 \\
 P_{cf} &= 10\{h_f + [\rho_c h_1 - (1 - perm)h_f] \tan^2 \gamma\} \text{ kN/m}^2, && \text{calculation point below } d_f \\
 F_{cf} &= 4.91s_1 \left\{ \rho_c (d_1 - d_f)^2 \tan^2 \gamma + [\rho_c (d_1 - d_f)^2 \tan^2 \gamma + 0.1P_{le}] (d_f - h_{DB} - h_{LS}) \right\} \text{ kN}
 \end{aligned}$$

where: ρ_c , h_1 , γ , s_1 , d_1 , h_{DB} and h_{LS} are as given in 7.9.2.3 of this Section;

h_f — flooding head, see 7.9.2.2 of this Section;

$perm$ — permeability of cargo, see 7.8.2.2 of this Chapter;

P_{le} — pressure, in kN/m², at the lower end of the corrugation.

(2) The pressure P_f acting on bulkheads and the force F_f acting on a corrugation in the flooded

empty holds are to be obtained as follows:

For the pressure acting on bulkheads, the hydrostatic pressure is to be calculated according to the flooding head h_f .

The force, induced by hydrostatic pressure and acting on a corrugation, is to be obtained from the following formula:

$$F_f = 5s_1 (d_f - h_{DB} - h_{LS})^2 \text{ kN}$$

where: s_1 , h_{DB} , h_{LS} and d_f are as given in 7.9.2.3 of this Section

7.9.2.5 The resultant pressure P acting on any point of bulkheads and the resultant force F acting on a corrugation are to be obtained from the following formulae:

$$\begin{aligned} \text{For homogeneous loading} \quad P &= P_{cf} - 0.8 P_c \quad \text{kN / m}^2 \\ F &= F_{cf} - 0.8 F_c \quad \text{kN} \end{aligned}$$

where: P_c , F_c — see 7.9.2.3 of this Section;

P_{cf} , F_{cf} — see 7.9.2.4(1) of this Section.

For non-homogeneous loading conditions: $P = P_{cf} \quad \text{kN / m}^2$

$$F = F_{cf} \quad \text{kN}$$

where: P_c , F_c — see 7.9.2.3 of this Section;

P_{cf} , F_{cf} — whichever is the greatest as given in 8.9.2.4(1) and (2) of this Section.

7.9.3 Bending moment and shear force in bulkhead corrugations

7.9.3.1 The bending moment in bulkhead corrugations is to be obtained from the following formula:

$$M = Fl / 8 \text{ kN} \cdot \text{m}$$

where: F — see 8.9.2.5 of this Section;

l — span of corrugation, in m, to be taken according to Figure 7.9.3.1. For the definition of l , the internal end of the upper stool is not to be taken more than a distance from the deck at the center line equal to: 3 times the depth of corrugations, in general; 2 times the depth of corrugations, for rectangular stool.

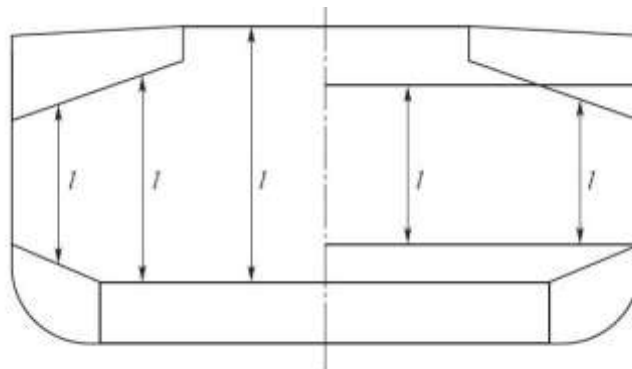


Figure 7.9.3.1

7.9.3.2 The shear force Q at the lower end of bulkhead corrugations is to be obtained from the following formula:

$$Q = 0.8F \text{ kN}$$

where: F — see 8.9.2.5 of this Section.

7.9.4 Strength criteria for corrugated bulkheads

7.9.4.1 General requirements

The following criteria are applicable to transverse bulkheads with vertical corrugations (see Figure 7.9.2.3(2)).

For ships of 190 m or over in length, the bulkheads are to be fitted with a lower stool, and generally with an upper stool below deck. For small bulk carriers, both lower and upper stools may not be fitted and corrugations may extend from inner bottom to deck, and if these stools are fitted, they are to comply with the requirements of 7.9.4.1.

The corrugation angle φ shown in Figure 7.9.2.3 (2) is not to be less than 55°.

The net plate thickness of corrugated transverse bulkheads is to comply with 7.9.4.7 of this Section and in addition, corrugated transverse bulkheads are to comply with 7.9.4.2 and 7.9.4.5 of this Section.

The thickness of the lower part of corrugations complying with 7.9.4.2 and 7.9.4.3 is to be maintained for a distance from the inner bottom (if no lower stool is fitted) or the top of the lower stool not less than 0.15 l .

The thickness of the middle part of corrugations complying with 7.9.4.2 and 7.9.4.4 is to be maintained for a distance from the deck (if no upper stool is fitted) or the bottom of the upper stool not greater than 0.3 l .

The section modulus of the corrugation in the remaining upper part of the bulkhead is not to be less than 75% of that required for the middle part, corrected for different yield stresses.

Excessive stress concentration is, as far as practicable, to be avoided for transferring the corrugated bulkhead forces and moments to the boundary structures, in particular to the double bottom and cross-deck structures.

In particular, the thickness and stiffening of effective gusset and shedder plates, as defined in 7.9.4.2 of this Section, is to comply with ISC requirements, on the basis of the load model in 7.9.2 of this Section.

Unless otherwise stated, weld connections and materials are to be dimensioned and selected in accordance with the relevant requirements of ISC.

(1) Lower stool

The height of the lower stool is generally not to be less than 3 times the depth of the corrugations. The thickness and material properties of the stool top plate are not to be less than those required for the bulkhead plating above. The thickness and material properties of the upper portion of vertical or sloping stool side plating within the depth equal to the corrugation flange width from the top are not to be less than the required flange plate thickness and material properties to meet the bulkhead stiffness requirement at lower end of corrugation. The structural scantlings of the lower stool are to comply with the relevant requirements of 7.4.1.2 of this Chapter. The section modulus of the stool side vertical stiffeners is not to be less than 85% of that of the corresponding inner bottom longitudinals, and the ends of the stiffeners are to be attached to brackets at the upper and lower ends of the stool.

The distance d from the edge of the stool top plate to the surface of the corrugation flange is to be determined in accordance with Figure 7.9.4.1(1). The stool bottom is to be installed in line with

double floors and is to have a width not less than 2.5 times the mean depth of the corrugation. The stool is to be fitted with diaphragms in line with the longitudinal double bottom girders for effective support of the corrugated bulkhead. The thickness of the diaphragms is to be the same as that of the longitudinal double bottom girders. Scallops in the brackets and diaphragms in way of the connections to the stool top plate are to be avoided.

Where corrugations are cut at the lower stool, corrugated bulkhead plating is to be connected to the stool top plate by full penetration welds. The stool side plating is to be connected to the stool top plate and the inner bottom plating by either full penetration or deep penetration welds (see Figure 7.9.4.1(2)). The supporting floors are to be connected to the inner bottom by either full penetration or deep penetration welds (see Figure 7.9.4.1(2)).

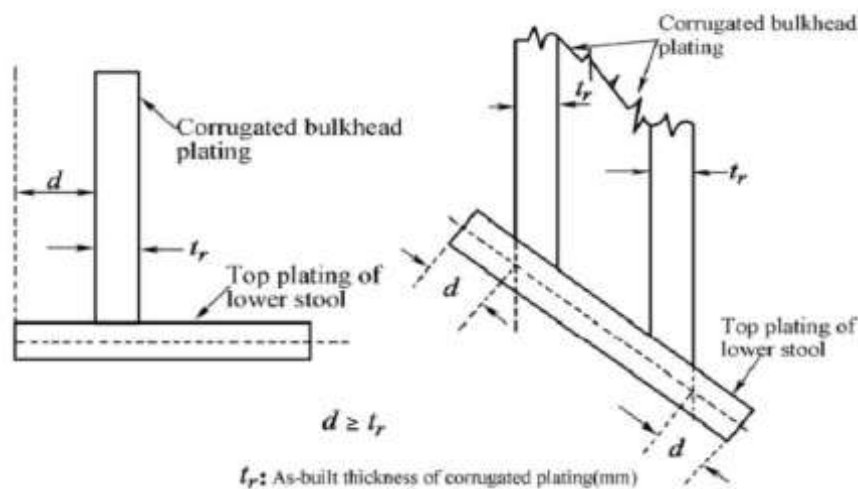
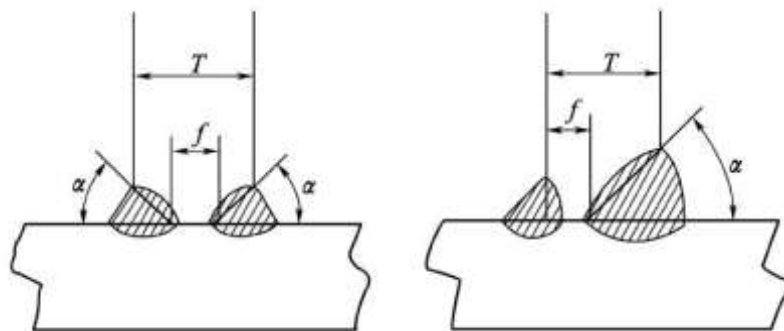


Figure 7.9.4.1(1)



Root face (f) $3 \sim T/3\text{mm}$ Groove angle (α) $40^\circ \sim 60^\circ$

Figure 7.9.4.1(2)

(2) Upper stool

The upper stool, where fitted, is to have a height generally between 2 and 3 times the depth of corrugations. Rectangular stools are to have a height generally equal to twice the depth of corrugations, measured from the depth level and at hatch side girder. The upper stool is to be supported by girders or deep brackets or between the adjacent hatch-end beams.

The width of the stool bottom plate is generally to be the same as that of the lower stool top plate. The top of non-rectangular stools is to have a width not less than twice the depth of corrugations. The thickness and material properties of the stool bottom plate are to be the same as those of the

bulkhead plating below. The thickness of stool side plating is not to be less than 80% of that required for the upper part of the bulkhead plating where the same material is used. The structural scantlings of the upper stool are to comply with the relevant requirements of 7.4.1.2 of this Chapter. The section modulus of the stool side vertical stiffeners is not to be less than 85 % of that of the corresponding deck longitudinals. The ends of the stool side vertical stiffeners are to be attached to brackets at upper and lower ends of the stool. Diaphragms are to be fitted inside the stool in line with and effectively attached to longitudinal deck girders extending to the hatch end coaming girders for effective support of the corrugated bulkhead. Scallops in the brackets and diaphragms in way of the connections to the stool bottom plate are to be avoided.

(3) Structural arrangement

At deck, if no stool is fitted, two transverse reinforced beams are to be fitted in line with the corrugation flanges.

At bottom, if no stool is fitted, the corrugated flanges are to be in line with the supporting floors. Corrugated bulkhead plating is to be connected to the inner bottom plating by full penetration welds. The plating of supporting floors is to be connected to the inner bottom by either full penetration or deep penetration welds (see Figure 7.9.4.1(2)). The thickness and material properties of the supporting floors are to be at least equal to those provided for the corrugation flanges. Moreover, the cut-outs for connections of the inner bottom longitudinals to double bottom floors are to be closed by collar plates. The supporting floors are to be connected to each other by shear plates.

Stool side plating is to align with the corrugation flanges and stool side vertical stiffeners and their brackets in lower stool are to align with the inner bottom longitudinals to provide appropriate load transmission between these stiffening members. Stool side plating is not to be knuckled anywhere between the inner bottom plating and the stool top.

7.9.4.2 Bending capacity and shear stress of corrugations

The bending capacity is to comply with the following relationship:

$$\frac{M}{0.5Z_{le}\sigma_{a,le} + Z_m\sigma_{a,m}} \times 10^3 \leq 0.95$$

where: M — bending moment, in kN · m, as given in 8.9.3.1 of this Section;

Z_{le} — section modulus, in cm³, at the lower end of corrugations, calculated according to 7.9.4.3;

Z_m — section modulus, in cm³, at the mid-span of corrugations, calculated according to 7.9.4.4; $\sigma_{a,le}$ — allowable bending stress, in N/mm², as given in 7.9.4.5, for the lower end of corrugations; $\sigma_{a,m}$ — allowable bending stress, in N/mm², as given in 8.9.4.5, for the mid-span of corrugations.

In no case Z_m is to be taken greater than the lesser of 1.15 Z_{le} and 1.15 Z'_{le} for calculation of the bending capacity, Z'_{le} being defined below.

In case shedder plates are fitted which:

- are not knuckled;

- are welded to the corrugations and the top of the lower stool by one side penetration welds or equivalent;
- are fitted with a minimum slope of 45° (angle to horizontal plane) and their lower edge is in line with the stool side plating;
- have thickness not less than 75% of that provided by the corrugation flanges;
- and material properties at least equal to those provided by the flanges. Or gusset plates are fitted which:
- are in combination with shedder plates having thickness, material properties and welded connections in accordance with the above requirements;
- have a height not less than half of the flange width;
- are fitted in line with the stool side plating;
- are generally welded to the top of the lower stool by full penetration welds, and to the corrugations and shedder plates by one side penetration welds or equivalent;
- have thickness and material properties at least equal to those provided by the flanges; the section modulus Z_{le} , in cm^3 , is to be taken not larger than the value Z'_{le} , in cm^3 , given by:

$$Z'_{le} = Z_g + 10^3 \frac{Q \cdot h_g - 0.5 h_g^2 s_1 P_g}{\sigma_a} \quad \text{cm}^3$$

where: Z_g — section modulus, in cm^3 , of the corrugations calculated according to 7.9.4.4 of this

Section, in way of the upper end of shedder or gusset plates, as applicable;

Q — shear force, in kN, as given in 7.9.3.2 of this Section;

h_g — height, in m, of shedder or gusset plates, as applicable, see Figures 7.9.4.2(1) and 8.9.4.2(2);

s_1 — see 8.9.2.3 of this Section;

P_g — resultant pressure, in kN/m^2 , as defined in 7.9.2.5 of this Section, calculated in way of the middle of the shedder or gusset plates, as applicable;

σ_a — allowable bending stress of material, in N/mm^2 , as given in 7.9.4.5.

The shear stress τ is obtained by dividing the shear force Q by the shear area. In general, the shear area may be obtained by multiplying the web sectional area by $\sin \varphi$, φ being the angle between the web and the flange, in order to account for possible non-perpendicularity between the corrugation webs and flanges. When calculating the section modulus and the shear area, the net plate thicknesses are to be used.

The section modulus of corrugations is to be calculated on the basis of the following requirements given in 7.9.4.3 and 7.9.4.4.

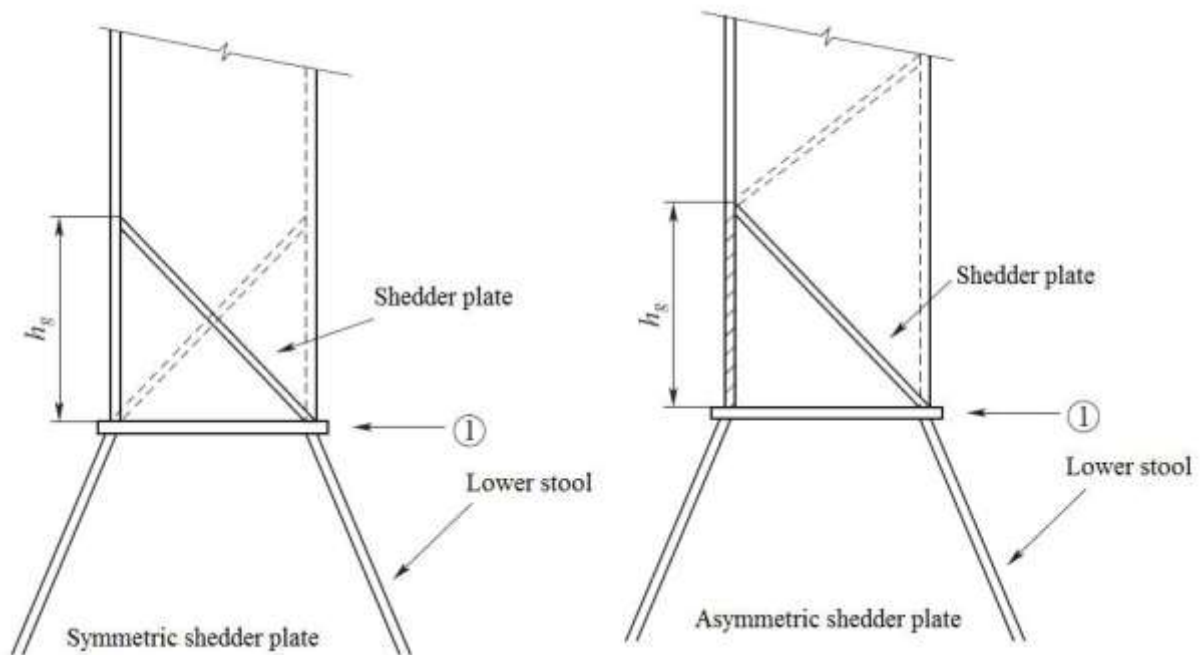


Figure 7.9.4.2(1)

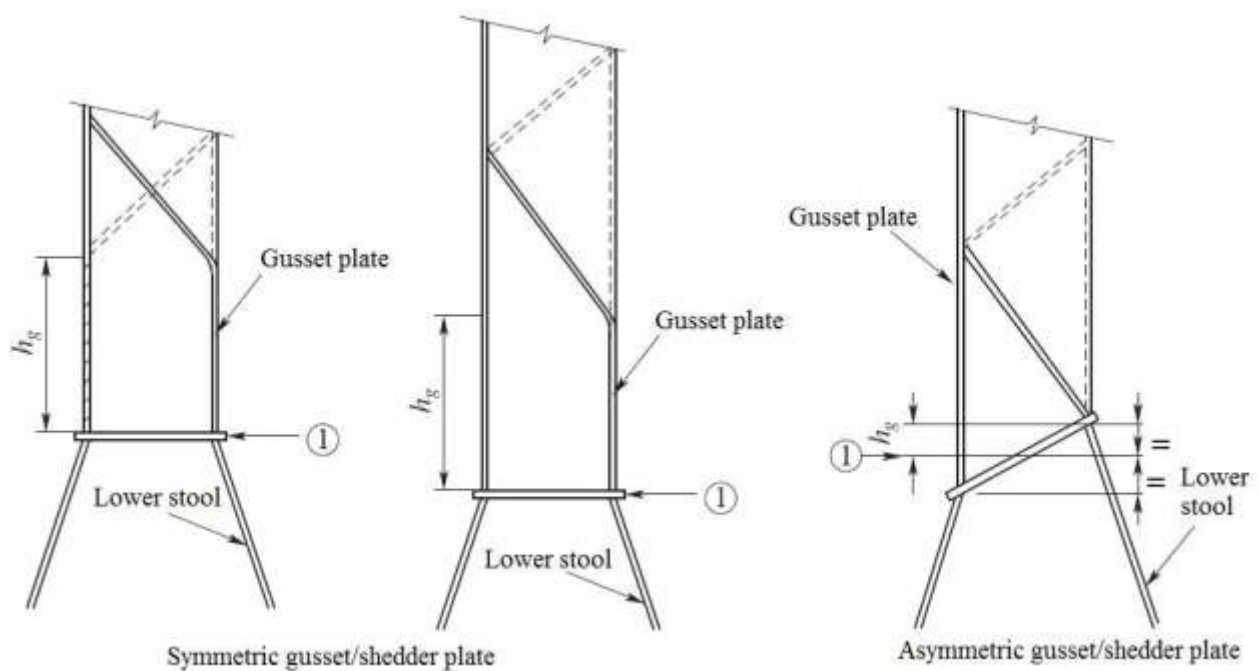


Figure 7.9.4.2(2)

7.9.4.3 Section modulus Z_{le} at the lower end of corrugations

The section modulus is to be calculated with the compression flange having an effective flange width, b_{ef} , not larger than as given in 7.9.4.6(1).

If the corrugation webs are not supported by local brackets below the stool top (or below the inner bottom) in the lower part, the section modulus of the corrugations is to be calculated considering the corrugation webs 30% effective.

(1) Provided that effective shedder plates are fitted (see Figure 7.9.4.2(1)), when calculating the section modulus of corrugations at the lower end (cross-section ① in Figure 7.9.4.2(1)), the area

of flange plates, in cm^2 , may be increased by:

$$2.5a \sqrt{t_f t_{sh}}, \text{ but not greater than } 2.5at_f \text{ cm}^2$$

where: a — width of the corrugation flange, in m, see Figure 7.9.2.3(2);

t_{sh} — net thickness of shedder plate, in mm;

t_f — net thickness of corrugation flange, in mm.

(2) Provided that effective gusset plates are fitted (see Figure 7.9.4.2(2)), when calculating the section modulus of corrugations at the lower end (cross-section ① in Figure 7.9.4.2(2)), the area of flange plates, in cm^2 , may be increased by:

$$7h_g t_f \text{ cm}^2$$

where: h_g — height of gusset plate, in m (see Figure 7.9.4.2(2)), not to be taken greater than 10

$S_{gu}/7$;

S_{gu} — width of gusset plate, in m;

t_f — net thickness of corrugation flange, in m, based on the as-built condition.

The lower stool top plate is assumed to be at 0° angle to horizontal plane for (1) and (2) above.

(3) If the lower stool top plate is sloped and at an angle not less than 45° to the horizontal plane, the corrugation webs are to be considered fully effective when calculating the section modulus of corrugations at the lower end. In case effective gusset plates are fitted, when calculating the section modulus of corrugations the area of flange plates may be increased as specified in (2) above. However, no increase may be permitted in the case where shedder plates are fitted without gussets. If the lower stool top plate is sloped and at an angle less than 45° to the horizontal plane, the effectiveness of corrugation webs is to be obtained by linear interpolation between 30% for 0° and 100% for 45° .

7.9.4.4 Section modulus of corrugations at cross sections other than the lower end

The section modulus is to be calculated with the corrugation webs being considered fully effective and the compression flange having an effective flange width b_{ef} not larger than as given in 7.9.4.6(1).

7.9.4.5 Allowable stress

The normal and shear stresses are not to exceed the allowable values σ_a and τ_a . The allowable stress is given by:

$$\sigma_a = R_{eH}$$

$$\tau_a = 0.5R_{eH}$$

where: R_{eH} — yield stress, in N/mm^2 , of the material.

7.9.4.6 Effective compression flange width and shear buckling check

(1) Effective width of the compression flange of corrugations

The effective width b_{ef} , in m, of the corrugation flange is given by:

$$b_{ef} = C_e a$$

$$\text{where: } C_e = \frac{2.25}{\beta} - \frac{1.25}{\beta^2} \text{ for } \beta > 1.25$$

$$C_e = 1.0 \text{ for } \beta \leq 1.25$$

$$\beta = 10^3 \frac{a}{t_f} \sqrt{\frac{R_{eH}}{E}};$$

t_f — net flange thickness, in mm;

a — width of the corrugation flange, in m;

R_{eH} — yield stress, in N/mm², of the material;

E — modulus of elasticity of the material, in N/mm², to be assumed equal to 2.06×10^5 N/mm² for steel.

(2) Shear

The buckling check is to be performed for the web plates at the corrugation ends.

The shear stress τ is not to exceed the critical value τ_c , in N/mm², obtained by the following:

$$\tau_c = \tau_E \quad \text{for } \tau_E \leq \frac{\tau_s}{2}$$

$$\tau_c = \tau_s \left(1 - \frac{\tau_s}{4\tau_E}\right) \text{ for } \tau_E > \frac{\tau_s}{2}$$

$$\text{where: } \tau_s = \frac{R_{eH}}{\sqrt{3}}$$

R_{eH} — yield stress, in N/mm², of the material;

$$\tau_E = 0.9 k_t E \left(\frac{t}{1000c} \right)^2, \text{ N/mm}^2;$$

E — modulus of elasticity of the material, in N/mm²;

t — net thickness, in mm, of corrugation web;

c — width, in m, of corrugation web (See Figure 7.9.2.3(2)).

7.9.4.7 Net plate thickness

When the thickness of the flange is the same as that of the web, the bulkhead net plate thickness t is given by:

$$t_n = 15.27 s_n \sqrt{\frac{P}{R_{eH}}} \text{ mm}$$

where: s_w — plate width, in m, to be taken equal to the width of the corrugation flange or web, whichever is the greater (see Figure 7.9.2.3(2));

P — resultant pressure, in kN/mm², as defined in 7.9.2.5, at the bottom of each strake of plating;

in all cases, the net thickness of the lowest strake is to be determined using the resultant pressure at the top of the lower stool, or at the inner bottom, if no lower stool is fitted or at the top of shedders, if shedder or gusset/shedder plates are fitted;

R_{eH} — yield stress, in N/mm², of the material.

For built-up corrugation bulkheads, when the thickness of the flange is different from that of the web, the net thickness of the narrow plating is not to be less than t_n , in mm, given by:

$$t_n = 15.27 s_n \sqrt{\frac{P}{R_{eH}}} \quad \text{mm}$$

where: s_n — width of the narrower plating, in m;

R_{eH} — yield stress, in N/mm², of the material.

The net thickness of the wider plating, in mm, is not to be taken less than the maximum of the following:

$$t_{w1} = 15.27 s_w \sqrt{\frac{P}{R_{eH}}} \quad \text{mm}$$

and

$$t_{w2} = \sqrt{462 s_w^2 \frac{P}{R_{eH}} - t_{np}^2} \quad \text{mm}$$

where: t_{np} — less or equal to actual net thickness of the narrower plating and not to be greater than:

$$15.27 s_w \sqrt{\frac{P}{R_{eH}}} \quad \text{mm}$$

R_{eH} — yield stress, in N/mm², of the material.

7.9.5 Corrosion addition and steel renewal

7.9.5.1 The corrosion addition is to be taken equal to 3.5 mm.

7.9.5.2 Steel renewal is required where the gauged thickness is less than $t_{net} + 0.5$ mm. Where the gauged thickness is within the range $t_{net} + 0.5$ mm and $t_{net} + 1.0$ mm, coating or annual gauging may be adopted as an alternative to steel renewal.

SECTION 10 - ALLOWABLE HOLD LOADING CONSIDERING HOLD FLOODING

7.10.1 General requirements

7.10.1.1 This Section applies to non-CSR bulk carriers of 150 m and over in length, intending to carry solid bulk cargoes having a density of 1.0 t/m³, or above, and

(1) single hull, or

(2) double side skin construction in which any part of longitudinal bulkhead is located within $B/5$ or 11.5 m, whichever is less, inboard from the ship's side at right angle to the centreline at the assigned summer load line.

7.10.1.2 The loading in each hold is not to exceed the allowable hold loading in flooded condition, calculated according to 7.10.4 of this Section, using the shear capacity of the double bottom given in 7.10.3 of this Section.

7.10.1.3 In no case is the allowable hold loading, considering flooding, to be taken greater than the design hold loading in intact condition.

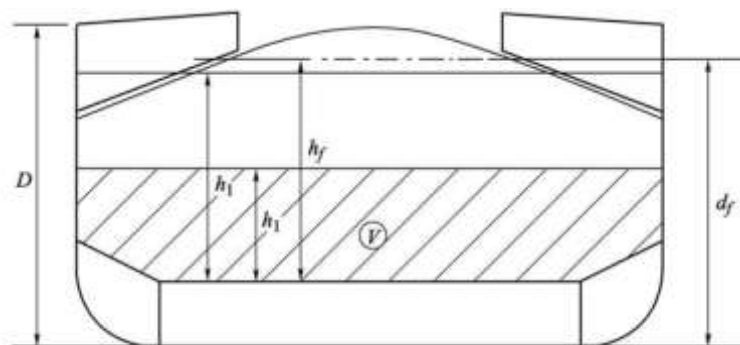
7.10.2 Loading model

7.10.2.1 General requirements

- (1) The loads to be considered as acting on the double bottom are those given by the external sea pressure and the combination of the cargo loads with those induced by the flooding of the hold which the double bottom belongs to.
- (2) The most severe combinations of cargo induced loads and flooding loads are to be used, depending on the loading conditions included in the loading manual:
 - homogeneous loading conditions;
 - non-homogeneous loading conditions;
 - packed cargo conditions (such as steel products).
- (3) For each loading condition, the maximum bulk cargo density to be carried is to be considered in calculation of the allowable hold loading limit.

7.10.2.2 The flooding head h_f (see Figure 7.10.2.2) is the distance, in m, measured vertically with the ship in the upright position, from the inner bottom to a level located at a distance d_f , in m, from the baseline equal to (D being moulded depth):

- (1) In general:
 - D , for the foremost hold;
 - $0.9D$, for the other holds.
- (2) For ships less than 50,000 tons deadweight with Type B freeboard:
 - $0.95D$, for the foremost hold;
 - $0.85D$, for the other holds.



V = Volume of cargo

Figure 7.10.2.2

7.10.3 Shear capacity of double bottom

7.10.3.1 The shear capacity C of the double bottom is defined as the sum of the shear strength at each end of:

- all floors adjacent to both hopper tanks, less one half of the strength of the two floors adjacent to each stool, or transverse bulkhead if no stool is fitted (see Figures 7.10.3.1(1) and 7.10.3.1(2));

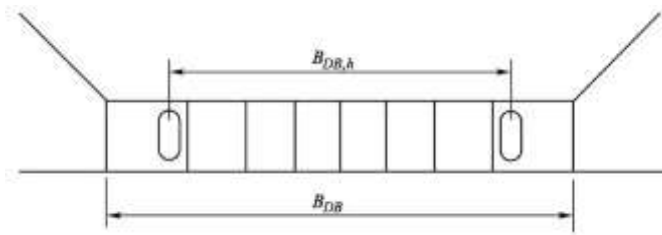


Figure 7.10.3.1(1)

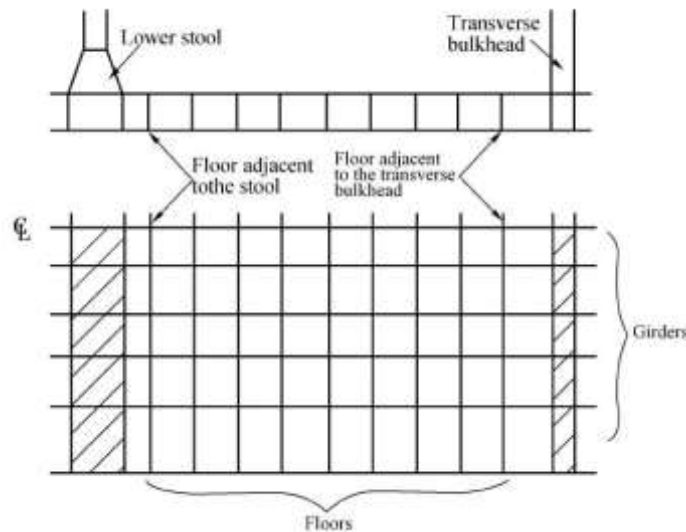


Figure 7.10.3.1(2)

– all double bottom girders adjacent to both stools, or transverse bulkheads if no stool is fitted. Where in the end holds, girders or floors run out or are not directly attached to the boundary stool, their strength is to be evaluated for the end only.

Note that the floors and girders to be considered are those inside the hold boundaries formed by the hopper tanks and stools (or transverse bulkheads if no stool is fitted). The hopper tank girders and the floors below the lower stools (or transverse bulkheads if no stool is fitted) are not to be included.

Where the geometry and or/the structural arrangement of the double bottom are different from those stated above, special consideration is to be given.

In calculation of the shear strength, the net thickness of floors and girders is to be used. The net thickness t_{net} is given by:

$$t_{net} = t - 2.5 \text{ mm}$$

where: t — actual thickness of floors or girders, in mm.

7.10.3.2 The floor shear strength S_{f1} in way of the floor panel adjacent to hopper tanks, in kN, and the floor shear strength S_{f2} in way of the openings in the outmost bay (i.e. that bay which is closer to hopper tank), in kN, are given by the following formulae:

$$S_{f1} = A_f \frac{[\tau]}{\eta_1} \times 10^{-3} \text{ kN}$$

$$S_{f2} = A_{fn} \frac{[\tau]}{\eta_2} \times 10^{-3} \text{ kN}$$

where: A_f — sectional area, in mm^2 , of the floor panel adjacent to hopper tanks;

A_{fh} — net sectional area, in mm^2 , of the floor panels in way of the openings in the outmost bay (i.e. that bay which is closer to hopper tank);

$[\tau]$ — allowable shear stress, in N/mm^2 , to be taken equal to the lesser of

$$[\tau] = \frac{162R_{eH}^{0.6}}{(s/t_{net})^{0.8}} \quad \text{and} \quad \frac{R_{eH}}{\sqrt{3}}$$

For floors adjacent to the stools or transverse bulkheads, $[\tau]$ may be given by

$$[\tau] = \frac{R_{eH}}{\sqrt{3}}$$

where: R_{eH} — yield stress, in N/mm^2 , of the material;

s — spacing of stiffening members, in mm, of panel under consideration;

t_{net} — net thickness, in mm, of floor;

$\eta_1 = 1.10$;

$\eta_2 = 1.20$.

Where appropriate reinforcements are fitted around openings, η_2 may be reduced down to 1.10.

7.10.3.3 The girder shear strength S_{g1} in way of the girder panel adjacent to stools (or transverse bulkheads, if not stool is fitted), in kN, and the girder shear strength S_{g2} in way of the largest opening in the outmost bay (i.e. that bay which is closer to hopper tank), in kN, are given by:

$$S_{g1} = A_g \frac{[\tau]}{\eta_1} \times 10^{-3} \quad \text{kN}$$

$$S_{g2} = A_{gh} \frac{[\tau]}{\eta_2} \times 10^{-3} \quad \text{kN}$$

where: A_g — sectional area, in mm^2 , of the girder panel adjacent to stools (or transverse bulkheads, if no stool is fitted);

A_{gh} — net sectional area, in mm^2 , of the girder panel in way of the largest opening in the outmost bay (i.e. that bay which is closer to stool, or transverse bulkhead, if no stool is fitted);

$[\tau]$ — the same as in 8.10.3.2 of this Section, t_{net} being net thickness of girder in mm;

$\eta_1 = 1.10$;

$\eta_2 = 1.15$, may be reduced down to 1.10 where appropriate reinforcements are fitted around openings.

7.10.4 Allowable hold loading

7.10.4.1 The allowable hold loading is given by:

$$W = \frac{\rho_c V}{F} \quad \text{t}$$

where: F — coefficient, 1.1 in general and 1.05 for steel products;

ρ_c — cargo density, in t/m^3 , for steel products, ρ_c is to be taken as the density of steel;

V — volume, in m^3 , occupied by cargo at a level h_1 , to be obtained by the following formula:

$$h_1 = \frac{X}{9.81\rho_c}$$

X = for bulk cargoes, the lesser of X_1 and X_2 given by:

$$X_1 = \frac{Z + 10(E - h_f)}{1 + \frac{1}{\rho_e}(\text{perm} - 1)}$$

$$X_2 = Z + 10(E - h_f \text{perm})$$

for steel products, X may be taken as X_1 , using $\text{perm} = 0$;

E — ship immersion, in m, for flooded hold condition, to be obtained by:

$$df - 0.1D$$

$d_{f,D}$ — determined according to Figure 7.10.2.2;

h_f — flooding head, in m;

perm — cargo permeability; it need not be taken as greater than 0.3;

Z — the lesser of Z_1 and Z_2 given by:

$$Z_1 = \frac{C_h}{A_{DBh}}$$

$$Z_2 = \frac{C_e}{A_{DBe}}$$

C_h — shear capacity of the double bottom, in kN, considering, for each floor, the lesser of the shear strength S_{f1} and S_{f2} and, for each girder, the lesser of the shear strength S_{g1} and S_{g2} ;

C_e — shear capacity of the double bottom, in kN, considering, for each floor, the shear strength S_{f1} and, for each girder, the lesser of the shear strengths S_{g1} and S_{g2} ;

$$A_{DBh} = \sum_{i=1}^n S_i B_{DBi}$$

$$A_{DBe} = \sum_{i=1}^n S_i (B_{DB} - s_i)$$

n — number of floors between stools (for transverse bulkheads, if no stool is fitted);

S_i — space of i th-floor, in m;

$B_{DBi} = B_{DB} - s_i$, for floors whose shear strength is given by S_{f1} ;

$B_{DBi} = B_{DBh}$, for floors whose shear strength is given by S_{f2} ;

B_{DB} — breadth of double bottom, in m, between hopper tanks (see Figure 7.10.3.1(1));

B_{DBh} — distance, in m, between the two considered openings (see Figure 7.10.3.1(1));

s_i — spacing, in m, of double bottom longitudinals adjacent to hopper tanks.

SECTION 11 - HATCH COVERS OF CARGO HOLDS

7.11.1 General requirements

7.11.1.1 This Section applies to bulk carriers, ore carriers and combination carriers. The hatch covers of cargo holds are to comply with the relevant requirements of Section 20, Chapter 2 of this PART.

SECTION 12 - HARMONIZED NOTATIONS AND CORRESPONDING DESIGN LOADING CONDITIONS FOR BULK CARRIERS

7.12.1 General requirements

7.12.1.1 This Section is not intended to prevent any other loading conditions to be included in the loading manual for which calculations are to be submitted as required, nor is it intended to replace in any way the required loading manual/instrument.

7.12.1.2 A bulk carrier may in actual operation be loaded differently from the design loading conditions specified in the loading manual, provided limitations for longitudinal and local strength as defined in the loading manual and loading instrument onboard and applicable stability requirements are not exceeded.

7.12.2 Application

7.12.2.1 Typical bulk carriers of 150 m or over in length and constructed with single deck, double bottom, topside tanks and hopper tanks in the cargo hold region and of single side skin or double side skin construction are to comply with relevant requirements of this Section. General dry cargo ships intended to carry cargoes in bulk may also be assigned relevant notations provided that relevant requirements of this Section are satisfied.

7.12.2.2 The loading conditions listed in 7.12.4 are to be used for the checking of rules criteria regarding longitudinal strength, local strength, capacity and disposition of ballast tanks and stability. The longitudinal strength is to comply with the requirements of Section 2, Chapter 2 and Section 8, Chapter 7 of this PART. The loading conditions listed in 7.12.5 are to be used for the checking of local strength. Direct calculations are to be carried out for the strength of primary structural members within the cargo area in accordance with the requirements of 7.1.4 of this Chapter.

7.12.2.3 Maximum draught mentioned in this Section is to be taken as moulded summer load line draught.

7.12.2.4 Filling rate mentioned in this Section is the rate of cargo mass to hold cubic capacity. The hold cubic capacity is to be taken up to the top of the hatch coaming in calculation.

7.12.3 Harmonized notations and annotations

7.12.3.1 Bulk carriers complying with this Section are to be assigned one of the following notations:

(1) BC–A: for bulk carriers:

- designed to carry dry bulk cargoes of cargo density 1.0 t/m^3 and above,
- with specified holds empty at maximum draught, and
- in addition to BC–B conditions.

(2) BC–B: for bulk carriers:

- designed to carry dry bulk cargoes of cargo density of 1.0 t/m^3 and above,
- with all cargo holds loaded, and
- in addition to BC–C conditions.

(3) BC–C: for bulk carriers:

- designed to carry dry bulk cargoes of cargo density less than 1.0 t/m^3 .

7.12.3.2 Additional notations:

- (1) {Maximum cargo density x.y t/m^3 }: When the maximum design cargo density is less than 3.0 t/m^3 , for bulk carriers, the limitation is to be given after the harmonized notation, indicating the maximum cargo density allowed to be loaded. This additional notation is only applicable to notations BC–A and BC–B. For general dry cargo ships intended to carry cargoes in bulk, when the maximum density of the bulk cargo designed under the bulk cargo loading condition is less than 3.0 t/m^3 , this notation is assigned to indicate the limitation and the maximum density value of the bulk cargo allowed to be loaded.
- (2) {No MP}: When requirements for loading and unloading in multiple ports have not been raised in accordance with 8.12.5.3 in the design of bulk carrier, the limitation is to be given after the harmonized notation. This additional notation is applicable to all harmonized notations (BC–A, BC–B, BC–C). For general dry cargo ships intended to carry cargoes in bulk, this notation is assigned to show the limitation when the bulk cargo loading condition has not been designed for loading and unloading in multiple ports in accordance with the Rules.
- (3) {Holds a, b, ...may be empty}: When specified empty holds are allowed in the design of bulk carriers, this additional notation is to be given after the harmonized notation. This notation is only applicable to notation BC–A. For general dry cargo ships intended to carry cargoes in bulk, this notation is assigned to specify the empty hold No. when specified empty holds are allowed in the design of bulk cargo loading condition.

7.12.4 Design loading conditions (General)

7.12.4.1 Harmonized notation BC–C is to cover:

Homogeneous cargo loaded condition where the cargo density corresponds to all cargo holds, including hatchways, being 100% full at maximum draught with all ballast tanks empty.

7.12.4.2 Harmonized notation BC–B is to cover:

The condition as required by 8.12.4.1, plus: homogeneous cargo loaded condition with cargo density 3.0 t/m^3 , and the same filling rate in all cargo holds at maximum draught with all ballast tanks empty.

In cases where the cargo density applied for this design loading condition is less than 3.0 t/m^3 , the maximum density of the cargo that the vessel is allowed to carry is to be indicated with the additional notation (Maximum cargo density x.y t/m^3) as specified in 7.12.3.2(1).

7.12.4.3 Harmonized notation BC–A is to cover:

The condition as required by 7.12.4.1 and 7.12.4.2, plus: at least one cargo loaded condition with specified holds empty, with cargo density 3.0 t/m^3 , and the same filling rate in all loaded cargo holds at maximum draught with all ballast tanks empty.

The combination of specified empty holds is to be indicated with the annotation (Holds a, b, ... may be empty). In such cases where the design cargo density applied is less than 3.0 t/m^3 , the maximum density of the cargo that the vessel is allowed to carry is to be indicated within the annotation, e.g. (Maximum cargo density x.y t/m^3 , Holds a, b, ... may be empty).

7.12.4.4 Ballast conditions (applicable to all notations)

(1) Ballast tank capacity and disposition

All bulk carriers are to have ballast tanks of sufficient capacity and so disposed to at least fulfill the following requirements:

① Normal ballast condition for the purpose of this Section is a ballast (no cargo) condition where:

- all cargo holds or holds adapted for the carriage of water ballast at sea are to be empty;
- the ballast tanks may be full, partially full or empty. Where partially full option is exercised, the conditions in 2.2.2.5 of Section 2, Chapter 2 of this PART are to be complied with;
- the propeller is to be fully immersed; and
- the trim is to be by the stern and is not to exceed $0.015L$, where L is the length between perpendiculars of the ship. In the assessment of the propeller immersion and trim, the draughts at the forward and after perpendiculars may be used.

② Heavy ballast condition for the purpose of this Section is a ballast (no cargo) condition where:

- at least one cargo hold adapted for carriage of water ballast at sea, where required or provided, is to be full;
- the ballast tanks may be full, partially full or empty. Where partially full option is exercised, the conditions in 2.2.2.5 of Section 2, Chapter 2 of this PART are to be complied with;
- the propeller immersion I/D is to be at least 0.60 where I = the distance from propeller centerline to the waterline, in m, D = propeller diameter, in m;
- the trim is to be by the stern and is not to exceed $0.015L$, where L is the length, in m, between perpendiculars of the ship; and
- the moulded forward draught in the heavy ballast condition is not to be less than the smaller of $0.03L$ or 8 m.

(2) Strength requirements

① Normal ballast condition:

- the structures of bottom forward are to be strengthened in accordance with the relevant requirements of 2.15.3 of Section 15, Chapter 2 of this PART against slamming for the condition of 7.12.4.4(1) where the lightest forward draught is less than 0.04L;
- the longitudinal strength requirements are to be met for the condition of 7.12.4.4(1); and
- in addition, the longitudinal strength requirements are to be met with all ballast tanks 100% full for the condition of 7.12.4.4(1) where the ballast tanks may be partially full or empty.

② Heavy ballast condition:

- the longitudinal strength requirements are to be met for the condition of 8.12.4.4(1);
- in addition, the longitudinal strength requirements are to be met with all ballast tanks 100% full for the condition of 7.12.4.4(1) where the ballast tanks may be partially full or empty; and
- where more than one hold is adapted and designated for the carriage of water ballast at sea, it will not be required that two or more holds be assumed 100% full simultaneously in the longitudinal strength assessment, unless such conditions are expected in the heavy ballast condition. Unless each hold is individually investigated, the designated heavy ballast hold and any/all restrictions for the use of other ballast hold(s) are to be indicated in the loading manual.

7.12.4.5 Unless otherwise specified, each of the design loading conditions defined in 7.12.4 is to be investigated for the arrival and departure conditions as defined below.

- (1) Departure condition: with bunker tanks not less than 95% full and other consumables 100%;
- (2) Arrival condition: with 10% of consumables.

7.12.5 Design loading conditions (for local strength)

7.12.5.1 The maximum allowable or minimum required cargo mass in a cargo hold, or in two adjacently loaded holds, is related to the net load on the double bottom. The net load on the double bottom is a function of draft, cargo mass in the cargo hold, as well as the mass of fuel oil and ballast water contained in double bottom tanks. For the purpose of the conditions in 7.12.5.2 to 7.12.5.6, the following definitions

apply:

- (1) *M_H*: the actual cargo mass in a cargo hold corresponding to a homogeneously loaded condition at maximum draught;
- (2) *M_{Full}*: the cargo mass in a cargo hold corresponding to cargo with virtual density (homogeneous mass/hold cubic capacity, minimum 1.0 t/m³) filled to the top of the hatch coaming. *M_{Full}* is in no case to be less than *M_H*;
- (3) *M_{HD}*: the maximum cargo mass allowed to be carried in a cargo hold according to design loading condition(s) with specified holds empty at maximum draft.

7.12.5.2 For all ships within the scope of application, the cargo hold is to be checked in accordance

with the following loading conditions.

- (1) Any cargo hold is to be capable of carrying M_{Full} with fuel oil tanks in double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at maximum draught (see Figure 7.12.5.2(1)).

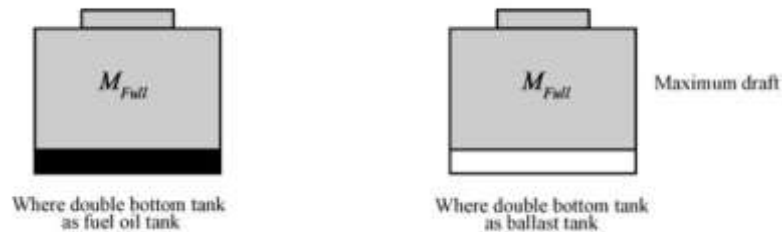


Figure 7.12.5.2(1)

- (2) Any cargo hold is to be capable of carrying minimum 50% of M_H , with all double bottom tanks in way of the cargo hold being empty, at maximum draught (see Figure 7.12.5.2(2)).

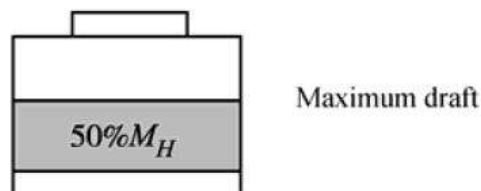


Figure 7.12.5.2(2)

- (3) Any cargo hold is to be capable of being empty, with all double bottom tanks in way of the cargo hold being empty, at the deepest ballast draught (see Figure 7.12.5.2(3)).

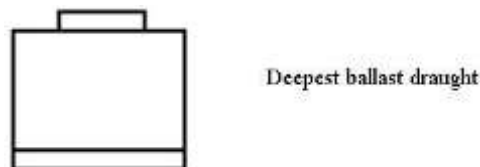


Figure 7.12.5.2(3)

7.12.5.3 For all ships within the scope of application, the cargo hold is to be checked in accordance with the following loading conditions, except when notation (No MP) is assigned

- (1) Any cargo hold is to be capable of carrying M_{Full} with fuel oil tanks in double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67% of maximum draught (see Figure 7.12.5.3(1)).

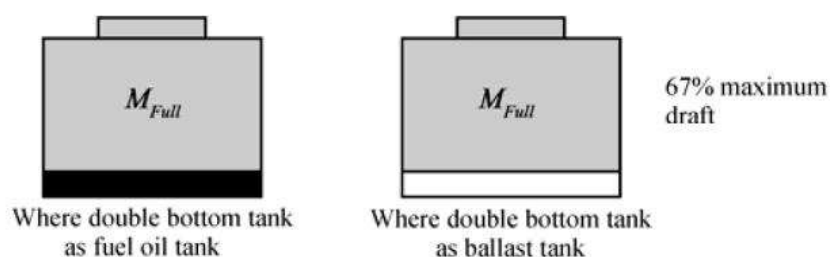


Figure 7.12.5.3(1)

- (2) Any cargo hold is to be capable of being empty with all double bottom tanks in way of the cargo hold being empty, at 83% of maximum draught (see Figure 7.12.5.3(2)).

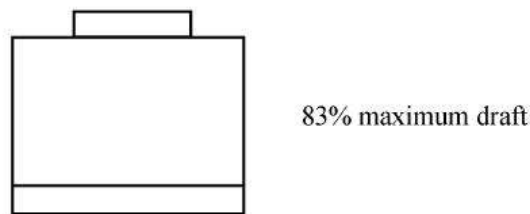


Figure 7.12.5.3(2)

- (3) Any two adjacent cargo holds are to be capable of carrying MFull with fuel oil tanks in double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67% of the maximum draught. This requirement to the mass of cargo and fuel oil in double bottom tanks in way of the cargo hold applies also to the condition where the adjacent hold is filled with ballast, if applicable (see Figure 7.12.5.3(3)).

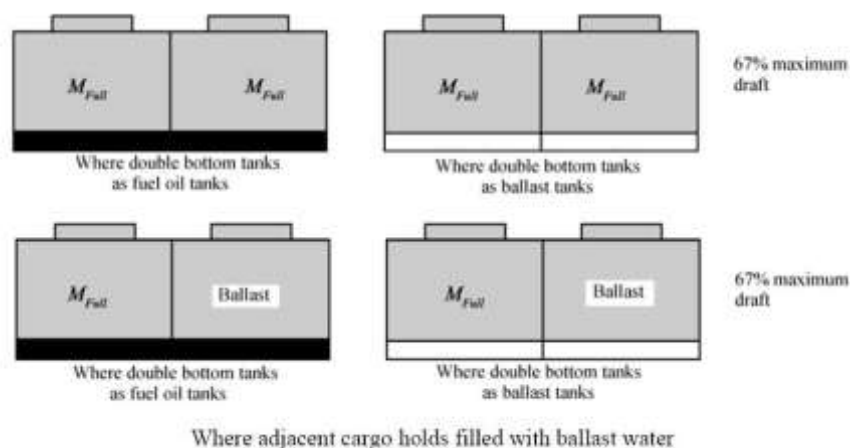


Figure 7.12.5.3(3)

- (4) Any two adjacent cargo holds are to be capable of being empty, with all double bottom tanks in way of the cargo hold being empty, at 75% of maximum draught (see Figure 7.12.5.3 (4)).

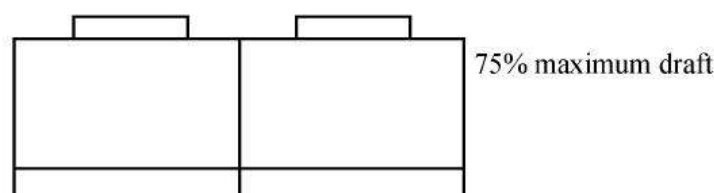


Figure 7.12.5.3(4)

7.12.5.4 Additional requirements for ships where empty holds are allowed in the bulk cargo loading condition

- (1) Cargo holds, which are intended to be empty at maximum draught, are to be capable of being empty with all double bottom tanks in way of the cargo hold also being empty (see Figure 7.12.5.4 (1)).

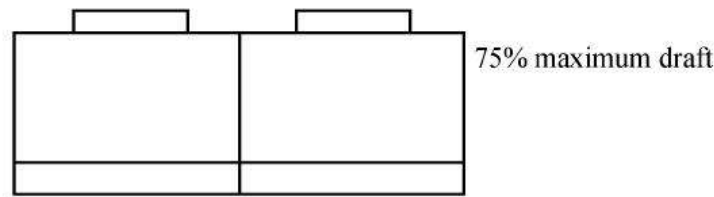


Figure 7.12.5.4(1)

- (2) Cargo holds, which are intended to be loaded with high density cargo, are to be capable of carrying MHD plus 10% of MH, with fuel oil tanks in the double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom being empty in way of the cargo hold, at maximum draught. In operation the maximum allowable cargo mass is to be limited to MHD (see Figure 7.12.5.4 (2)).

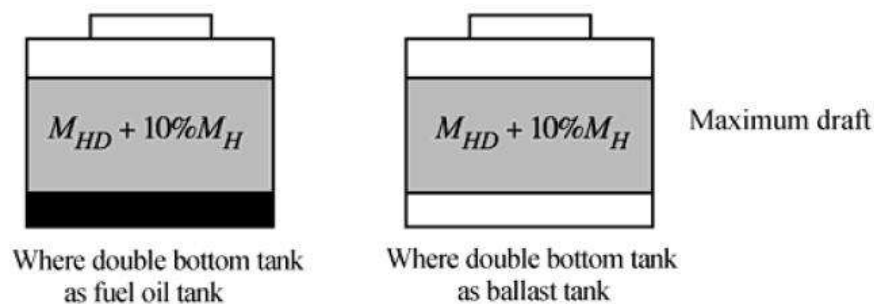


Figure 7.12.5.4(2)

- (3) Any two adjacent cargo holds which according to a design loading condition may be loaded with the next holds being empty, are to be capable of carrying 10% of M_H in each hold in addition to the maximum cargo load M'_{HD} according to that design loading condition, with fuel oil tanks in the double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at maximum draught. In operation the maximum allowable mass is to be limited to the maximum cargo load according to the design loading conditions (see Figure 7.12.5.4 (3)).

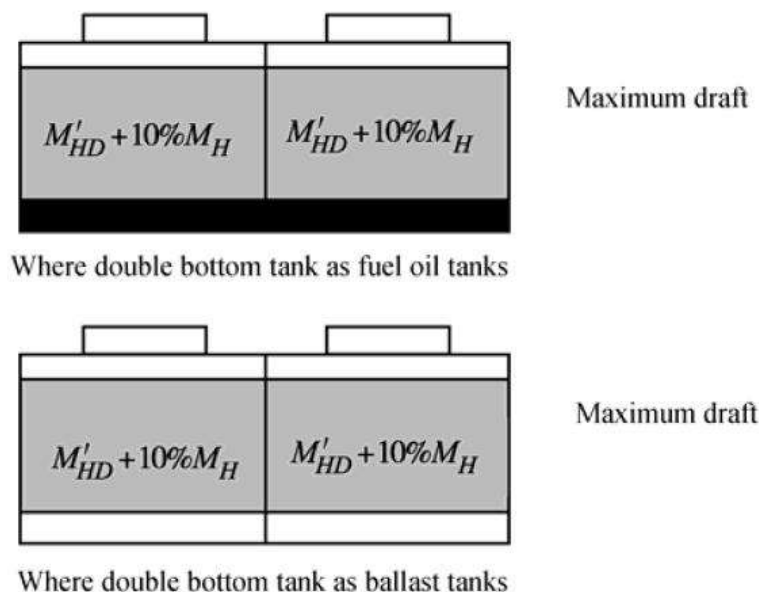


Figure 7.12.5.4(3)

7.12.5.5 Additional conditions applicable for ballast hold(s) only

- (1) Cargo holds, which are designed as ballast water holds, are to be capable of being 100% full of ballast water including hatchways, with all double bottom tanks in way of the cargo hold being 100% full, at any heavy ballast draught. For ballast holds adjacent to topside wing, hopper and double bottom tanks, it is to be strengthwise acceptable that the ballast holds are filled when the topside wing, hopper and double bottom tanks are empty (see Figure 7.12.5.5 (1)).

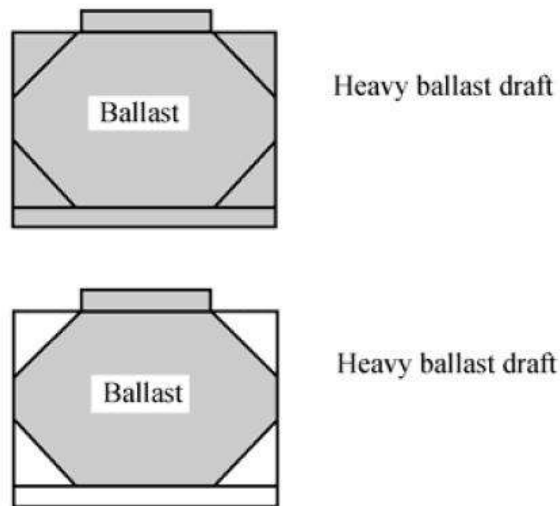


Figure 7.12.5.5(1)

7.12.5.6 Additional conditions applicable during loading and unloading in harbor only

- (1) Any single cargo hold is to be capable of holding the maximum allowable seagoing mass at 67% of maximum draught, in harbor condition (see Figure 7.12.5.6 (1)).

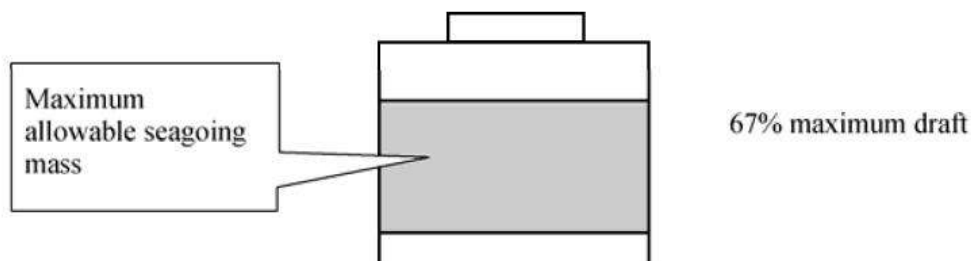


Figure 7.12.5.6(1)

- (2) Any two adjacent cargo holds are to be capable of carrying M_{Full} , with fuel oil tanks in the double bottom in way of the cargo hold, if any, being 100% full and ballast water tanks in the double bottom in way of the cargo hold being empty, at 67% of maximum draught, in harbor condition (see Figure 7.12.5.6(2)).

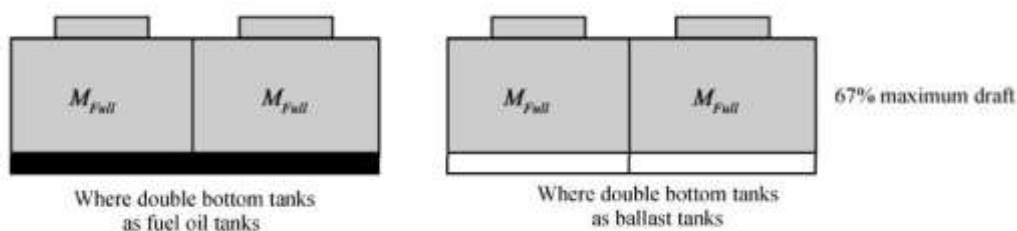


Figure 7.12.5.6(2)

- (3) At reduced draught during loading and unloading in harbor, the maximum allowable mass in a cargo hold may be increased by 15% of the maximum mass allowed at the maximum draught in sea-going condition, but is not to exceed the mass allowed at maximum draught in the sea-going condition. The minimum required mass may be reduced by the same amount.

7.12.5.7 Hold mass curves

- (1) Based on the design loading criteria for local strength, as given in 7.12.5.2 to 7.12.5.6 above, hold mass curves are to be included in the loading manual and the loading instrument, showing maximum allowable and minimum required mass as a function of draught, in sea-going condition as well as during loading and unloading in harbor (see Section 7, Chapter 7 of this PART).
- (2) At other draughts than those specified in the design loading conditions above, the maximum allowable and minimum required mass is to be adjusted for the change in buoyancy acting on the bottom. Change in buoyancy is to be calculated using water plane area at each draught.

SECTION 13 - REQUIREMENTS FOR THE FITTING OF A FORECASTLE

7.13.1 General requirements

7.13.1.1 This Section applies to bulk carriers, ore carriers and combination carriers.

7.13.1.2 Ships to which this Section applies are to be fitted with an enclosed forecastle on the freeboard deck.

7.13.1.3 In addition, structural arrangement and scantlings of the forecastle are to comply with the applicable requirements of Section 17, Chapter 2 of this PART.

7.13.2 Arrangement

7.13.2.1 The forecastle is to be located on the freeboard deck with its aft bulkhead fitted in way or aft of the forward bulkhead of the foremost hold, as shown in Figure 7.13.2.1. However, if this requirement hinders hatch cover operation, the aft bulkhead of the forecastle may be fitted forward of the forward bulkhead of the foremost cargo hold provided the forecastle length is not less than $0.07 L_L$ of ship's length abaft the forward perpendicular, where the ship's length and forward perpendicular are defined in Regulation 3 of Annex I of the International Convention on Load Lines, 1966 and its 1988 amendments.

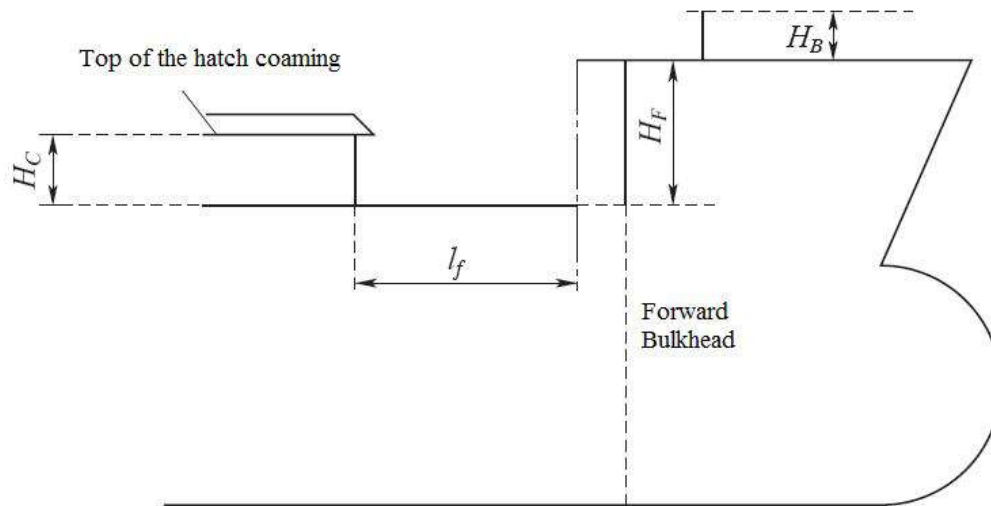


Figure 7.13.2.1

7.13.2.2 The forecastle height H_F above the main deck is not to be less than:

$$HF1 = H_{sh} \text{ m}$$

$$HF2 = H_C + 0.5 \text{ m}$$

where: H_{sh} — the standard height of a superstructure as specified in the International Convention on LoadLines, 1966 and its 1988 amendments;

H_C — the height, in m, of the forward transverse hatch coaming of cargo hold No.1, whichever is the greater.

7.13.2.3 All points of the aft edge of the forecastle deck are to be located at a distance l_f :

$$l_f \leq 5\sqrt{H_F - H_C} \text{ m}$$

from the hatch coaming plate in order to apply the reduced loading to the No.1 forward transverse hatch coaming and No.1 hatch cover in applying 2.20.2.2(2) and 2.20.2.9(2), respectively, of Chapter 2 of this PART.

7.13.2.4 A breakwater is not to be fitted on the forecastle deck with the purpose of protecting the hatch coaming or hatch covers. If fitted for other purposes, it is to be located such that its upper edge at centre

line is not less than $H_B/\tan 20^\circ$ forward of the aft edge of the forecastle deck, where H_B is the height of the breakwater above the forecastle (see Figure 7.13.2.1).

SECTION 14 - DOUBLE SIDE STRUCTURE

7.14.1 General requirements

7.14.1.1 This Section applies to the double side skin construction within the cargo area of bulk carriers.

7.14.1.2 Manholes are to be provided in transverse webs and horizontal girders. The manholes may either be round or elliptical. The long axis of an elliptical manhole is to be vertical to or along the length of the ship. Except access openings, the holes in upper and lower adjacent horizontal girders are not to be on the same vertical line. The manhole edges are to be strengthened.

7.14.2 Structural arrangements of double side skin

7.14.2.1 Where double side skin is provided in the cargo area, the inner shell is to extend as far forward and aft as practicable at the fore and aft ends of the cargo hold and is to be effectively connected and tapered to the structures there. Supporting members within the inner shell are to be provided in double side skin instead of one side of the cargo hold.

7.14.2.2 Cargo loading is not permitted inside double side skin, and the inner shell is to be so arranged that all cargo holds are inboard of double side skin.

7.14.2.3 Where the load line length L_L is 150 m and upwards, the width of double side skin at any transverse section of the hull is not to be less than 1 m. Such width is the distance between the outer shell and the inner shell, measured perpendicular to the side shell.

7.14.2.4 Where the load line length L_L is 150 m and upwards, the structural arrangement of double side skin is to comply with the following:

- (1) the minimum width of the clear passage through the double-side skin space in way of obstructions such as piping or vertical ladders is not to be less than 0.6 m;
- (2) where the inner and outer skins are transversely framed, the minimum clearance between the inner surfaces of the frames is not to be less than 0.6 m;
- (3) where the inner and outer skins are longitudinally framed, the minimum clearance between the inner surfaces of the frames is not to be less than 0.8 m. Outside the parallel part of the cargo hold length, this clearance may be reduced where necessitated by the structural configuration, but not less than 0.6 m.

Consideration over end brackets of frames is not necessary when measuring the clearance, see Figure 8.14.2.4 for the measurement.

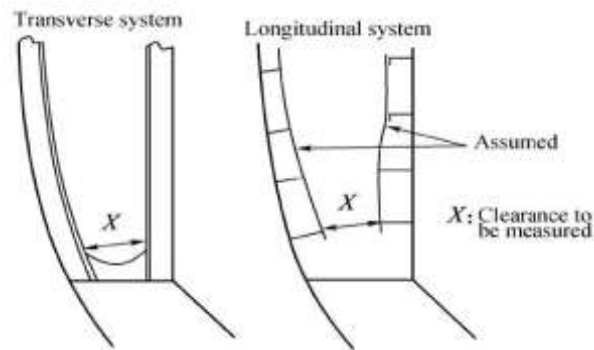


Figure 7.14.2.4

7.14.2.5 Transverse webs are to be provided within double side skin in line with the transverse watertight bulkheads of cargo holds. Otherwise, transverse framing is to be provided and ballast tanks are to be provided with swash bulkheads.

7.14.2.6 Transverse framing or transverse webs, which are to be provided or alternately provided within double side skin in line with double bottom transverses, together with transverse supporting members in topside tanks and hopper tanks and double bottom transverses, form transverse strength framing.

7.14.2.7 Horizontal girders must be provided at bottom of topside tanks and at top of hopper tanks. Manholes may not be provided for the sake of subdivision and stability.

7.14.3 Minimum thickness

7.14.3.1 The minimum thickness t of webs and face plates of primary members, horizontal girders, transverse webs and inner shell plating in double side skin is not to be less than that obtained from the following formula:

$$t = 7.5 + 0.015L, \text{ but need not be greater than } 11 \text{ mm}$$

7.14.3.2 Where specified empty spaces are within double side skin, the minimum thickness as required in 7.14.3.1 may be reduced by 1 mm.

7.14.4 Inner shell plating

7.14.4.1 Where specified empty spaces are within double side skin, in addition to complying with the requirement in 7.14.3 of this Section, the thickness t of inner shell plating is not to be less than that obtained from the following formula:

$$t = 4s\sqrt{hK} \quad \text{mm}$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, measured from the lower edge of the inner shell plating strake to bulkhead deck;

K — material factor.

Where no hopper tank is provided, the thickness obtained of strake at the bottom of the inner shell plating is to be increased by 1 mm, the width is not to be less than 900 mm. Where the thickness of inner shell plating is much less than that of the girder web to which the shell plating is

connected, the thickness of the inner shell plating in way of the connecting area is in general to be increased.

7.14.4.2 Where ballast tanks are within double side skin, in addition to complying with the requirement in 8.14.3 of this Section, the thickness t of inner shell plating is not to be less than that obtained from the following formula:

$$t = 4s\sqrt{hK} + 2.5 \text{ mm}$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, measured from the lower edge of the inner shell plating strake to the top of the ballast tank, or half the distance to the top of the overflow, whichever is the greater;

K — material factor.

Where no hopper tank is provided, the thickness obtained of the lowest strake of inner shell plating is to be increased by 1 mm.

7.14.4.3 Where no topside tank is provided, the thickness of inner shell plating within $0.1D$ of strength deck is not to be less than that obtained from the following formula:

$$t = 4s\sqrt{DK} \text{ mm}$$

where: s — spacing of stiffeners, in m;

D — molded depth, in m;

K — material factor.

However, the thickness of inner shell plating is not to be necessarily greater than that of sheer strakes with same frame spacing.

7.14.4.4 Stiffener spacing of inner shell plating is to be the same as that of side frames or side longitudinals.

7.14.4.5 In specified empty spaces, the section modulus W of inner shell plating stiffeners is not to be less than that obtained from the following formula:

$$W = 3shl^2K \text{ cm}^3$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, measured from the mid-span of the stiffener to upper deck, but not less than 2 m;

l — span of stiffener, in m;

K — material factor.

7.14.4.6 In the ballast tank, the section modulus W and the moment of inertia I of inner shell stiffeners are not to be less than those obtained from the following formulae respectively:

$$W = 8.2shl^2K \text{ cm}^3$$

$$I = 2.3Wl/K \text{ cm}^4$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, measured from the mid-span of the stiffener to tank top, or half the distance to the top of the overflow, whichever is the greater;

l — span of stiffener, in m;

K — material factor.

7.14.4.7 In ships over 150 m in length or where higher tensile steel is used for horizontal stiffeners, horizontal stiffeners of inner shell plating within $0.1D$ from bottom and strength deck are to pass continuously through watertight transverse webs. Where horizontal stiffeners are cut at watertight transverse webs, they are to be bracketed to transverse webs.

7.14.4.8 Tripping brackets are to be provided at both ends of vertical stiffeners.

7.14.4.9 Scantlings of tripping brackets are to comply with the requirements in 1.2.6 of Chapter 1 of this PART.

7.14.5 Transverse webs

7.14.5.1 Where watertight transverse webs in double side skin constitute boundaries of specified empty spaces, their scantlings are to comply with the requirements in 8.14.4.1 and 8.14.4.5 of this Section.

7.14.5.2 Where watertight transverse webs in double side skin constitute boundaries of ballast tanks, their scantlings are to comply with the requirements in 8.14.4.2 and 8.14.4.6 of this Section.

7.14.5.3 Stiffeners are to be provided in between side longitudinals and inner shell horizontal stiffeners in way of transverse webs.

7.14.5.4 Where longitudinal framing is provided inside double side skin, non-watertight transverse webs supporting side longitudinals and inner shell horizontal stiffeners are to be provided or alternately provided at the same frame of bottom transverse in double side skin. The thickness of non-watertight transverse webs is to comply with the requirements in 8.14.3 of this Section. The side longitudinals and inner shell horizontal stiffeners are to pass through the non-watertight transverse webs.

7.14.6 Platform in deep tanks

7.14.6.1 The platform in deep tanks is to comply with the relevant requirements of Section 13, Chapter 2 of this PART.

SECTION 15 - ADDITIONAL REQUIREMENTS FOR STIFFENING STRUCTURAL MEMBERS

7.15.1 General requirements

7.15.1.1 This Section applies to bulk carriers of 150 m in load line length and upwards, carrying solid bulk cargoes having a density of 1 t/m^3 and above, as defined in SOLAS Regulation XII/1.

7.15.2 Materials

7.15.2.1 For ships with single side structures, the steel grade is not to be less than grade D or DH for:

- (1) the lower bracket of side frames;
- (2) side shell plate between two points located to $0.125l$ above and $0.125l$ below the intersection of side shell and bilge hopper sloping plate or inner bottom plate, l being the span of the side frame.
- (3) In case of side frames built with multiple spans, the above requirements are to apply to the lower part only, see Figure 7.15.2.1.

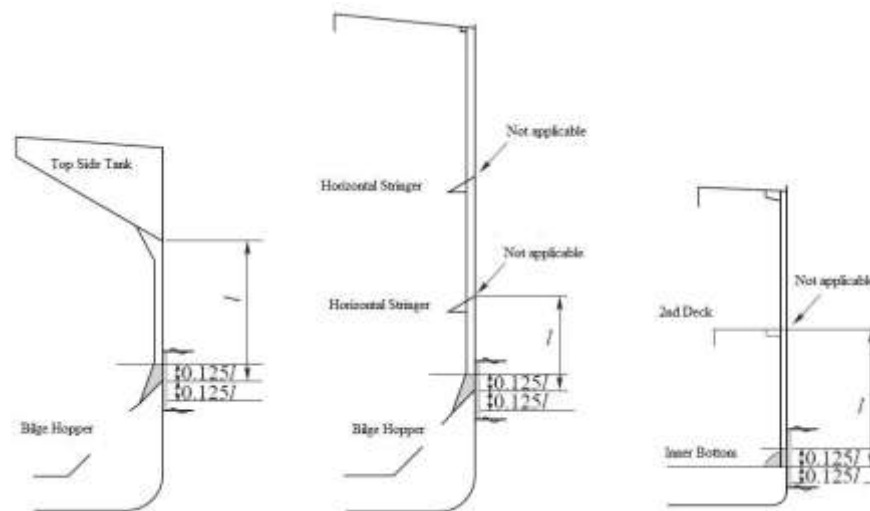


Figure 7.15.2.1

7.15.3 Lateral buckling of stiffeners

7.15.3.1 Scope of check

The lateral buckling of longitudinal and transverse stiffeners in the following areas within cargo areas are to be checked:

- (1) hatchway coaming;
- (2) inner bottom;
- (3) sloped stiffened panel of topside tanks and hopper tanks (if any);
- (4) inner side (if any);
- (5) top stool and bottom stool of transverse bulkhead (if any);
- (6) stiffened transverse bulkhead (if any);
- (7) side shell (if directly bounding the cargo hold).

7.15.3.2 Design loads

- (1) Design loads are to be based on the loading conditions under intact stability as specified in

the loading manual. The loads and loading conditions, for which the strength requirements in 7.15.3.1 are applicable, are given in 7.15.3.2(2).

(2) Loads and load cases

① The following types of loads, if applicable, are to be considered:

- (a) normal stress σ_n due to bending of hull girder, see ② below;
- (b) shear stress τ_{SF} , see ③ below;
- (c) lateral pressure applied to the member in loading conditions under intact stability as specified in the loading manual, see ④ below.

② Normal stress σ_n — the normal stress σ_n considered for each of the mutually exclusive load cases is the maximum compressive stress in the sagging or hogging condition as calculated according to 2.2.5.5 of Chapter 2 of this PART.

③ Shear stress, τ_{SF} — the shear stress, τ_{SF} considered for each of the mutually exclusive load cases is the shear stress calculated according to 2.2.6.4 of Chapter 2 of this PART.

If the value of the permissible still water shear force is not available at the preliminary design stage, the following value, in kN, may be used: $F_S = 0.3CLB(C_B + 0.7)$

④ Lateral pressure p — the lateral pressure for each of the mutually exclusive load cases is to be selected according to 1.5.3, 1.5.4 and 1.5.5 of Section 5 of Chapter 1 of this PART. The lateral pressure of hatch coaming stiffeners is to be calculated according to 2.20.2.2 of Chapter 2 of this PART.

⑤ The load calculation point for normal stress, shear stress and lateral pressure of stiffener and its attached plating is defined in Section 7, Chapter 3 of PART 9-1 of the Rules.

⑥ The lateral buckling strength is to be checked for the following two stress combinations:

- (a) stress combination 1: 100% of the normal stress as defined in 7.15.3.2(2) and 70% of the shear stress as defined in 7.15.3.2(2);
- (b) stress combination 2: 70% of the normal stress as defined in 7.15.3.2(2) and 100% of the shear stress as defined in 7.15.3.2(2).

7.15.3.3 Methods and criteria for check of buckling strength

The lateral buckling capacity of stiffeners is to be calculated according to 2.1 and 2.3 of Section 5, Chapter 8 of Part 9-1 of the Rules, with the safety factor S being taken as 1.15 (i.e. the allowable utilization factor being 0.87). The standard thickness deduction specified in Table 2.2.7.4 of Chapter 2 of this PART is to be deducted in calculation. The buckling strength of stiffeners is to be checked according to the criteria specified in 3.3.1 of Section 3, Chapter 8 of Part 9-1.

APPENDIX 1

DIRECT STRENGTH CALCULATION OF BULK CARRIERS

1 General

1.1 General requirements

1.1.1 This Appendix applies to the direct strength calculation of bulk carriers as required by this Chapter.

1.1.2 For those not covered in this Appendix, the relevant requirements of Section 5, Chapter 1 of this PART are to be complied with.

2 Design Loads

2.1 General requirements

2.1.1 Unless otherwise specified in this Appendix, the design loads are to be referred to in Section 5, Chapter 1 of this PART.

2.1.2 Unless otherwise specified in this Appendix, the still water bending moment in the global loadcondition is to be taken as the permissible value $\overline{M}_s$ provided by the designer, and the wave bending moment M_w is to be calculated according to 1.5.6.1(2) of Section 5, Chapter 1 of this PART.

2.1.3 For harbour conditions, the effect of wave loads (pressure and bending moment) is not considered; the allowable still water bending moment $\overline{M}_{sp}$ is determined by the designer, but it is to envelop the design still water bending moment under the loading and unloading conditions in harbour given in the loading manual. The sequence of loading and unloading is to be indicated in the loading manual.

3 Loading Conditions

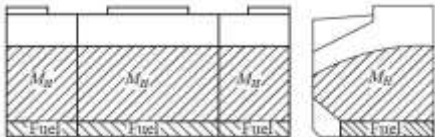
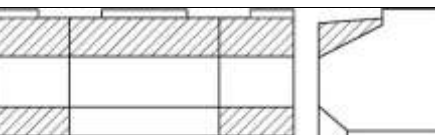
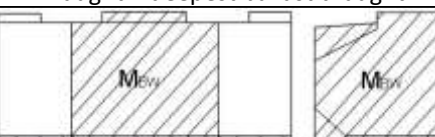
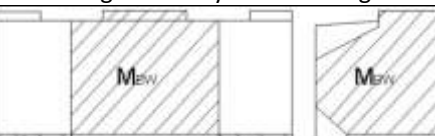
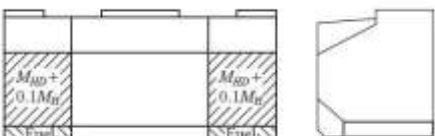
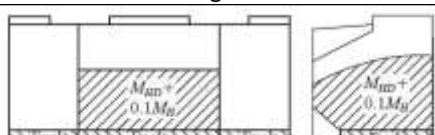
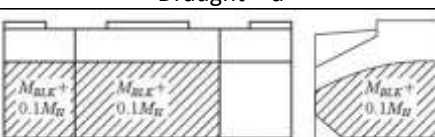
3.1 General requirements

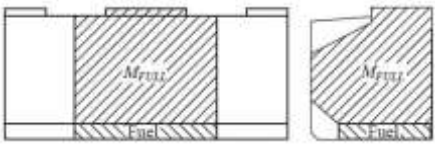
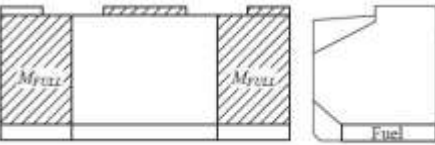
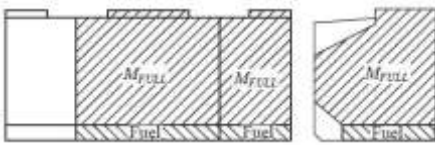
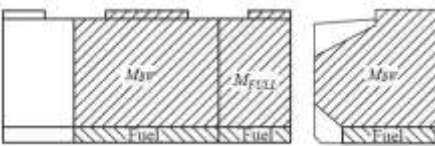
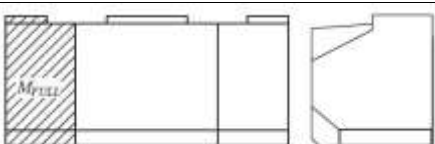
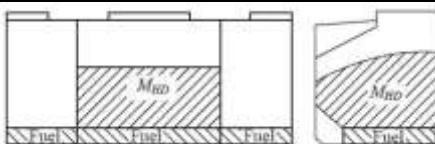
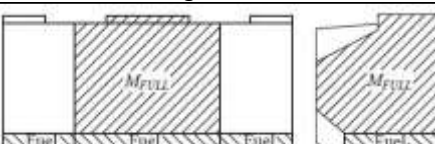
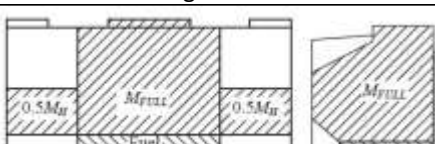
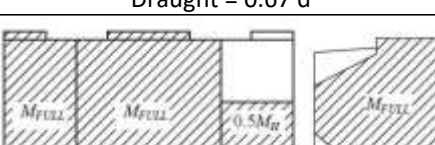
3.1.1 Normally, the loading conditions under consideration are to cover the most severe condition in ship design. The corresponding loading conditions are to be selected from Table 3.2.1 of this Appendix for check. For more severe loading conditions in the loading manual which are not covered by the Table, direct strength analysis is also to be carried out.

3.2 Loading conditions

3.2.1 The finite element analysis for holds is to be carried out in accordance with the applicable loading conditions in Table 3.2.1.

Table 3.2.1 - Loading Conditions

Type of Loading Condition	Loading Condition No.	Condition Considered	Mode of Loading	Still Water Bending Moment	Wave Bending Moment
Full Load	1	Full load	 Draught = d	M_s	M_w
	2	Full load	 Draught = d	M_s	M_w
	3	Non-homogeneous full load	 Draught = d	(1.1 M_s , but need not be greater than M_s ; taken as M_s if there is no such loading)	M_w
Ballast	4	Normal ballast	 Draught = deepest ballast draught	M_s	M_w
	5	Heavy ballast	 Draught = heavy ballast draught	M_s	M_w
	6	Heavy ballast	 Draught = heavy ballast draught	M_s	M_w
Alternate Load	7	Alternate load	 Draught = d	M_s	M_w
	8	Alternate load	 Draught = d	M_s	M_w
	9	Alt-block load	 Draught = d	M_s	M_w

Loading / Unloading in Multiple Ports	10	Multi port - 1	 Draught = 0.67 d	M_s	M_w
	11	Multi port - 2	 Draught = 0.83 d	M_s	M_w
	12	Multi port – 3a	 Draught = 0.67 d	M_s	M_w
	13	Multi port – 3b	 Draught = 0.67 d	M_s	M_w
	14	Multi port - 4	 Draught = 0.75 d	M_s	M_w
Loading / Unloading in Harbour	15	Harbour condition -1a	 Draught = 0.67 d	M_v	—
	16	Harbour condition -1b	 Draught = 0.67 d	M_v	—
	17	Harbour condition -1c	 Draught = 0.67 d	M_v	—
	18	Harbour condition -2	 Draught = 0.67 d	M_v	—

Notes:

 M_a — actual still water bending moment in the corresponding condition, in kN·m; M_H — actual cargo mass in a cargo hold corresponding to a homogeneously loaded condition at maximum draught, in

t;

M_{FULL} — cargo mass in a cargo hold corresponding to cargo with virtual density filled to the top of the hatch coaming, in t, i.e.:

$$M_{FULL} = V_{FULL} \cdot \max (M_H / V_{FULL}, 1.0)$$

M_{HD} — maximum cargo mass allowed to be carried in a cargo hold according to design loading condition with specified holds empty at maximum draught, in t;

M_{BW} — maximum ballast water mass in cargo holds, in t;

M_{BLK} — maximum cargo mass under packed cargo conditions, in t;

V_H — volume, in m^3 , of cargo hold excluding the volume enclosed by hatch coaming;

V_{FULL} — volume, in m^3 , of cargo hold including the volume enclosed by hatch coaming;

ρ_w — density of sea water, to be taken as 1.025 t/m^3 .

4 Structural Modeling

4.1 General requirements

4.1.1 Unless otherwise specified in this Appendix, the requirements for structural modeling are to be referred to in Section 5, Chapter 1 of this PART (for typical finite element model, see Figure 4.1.1).

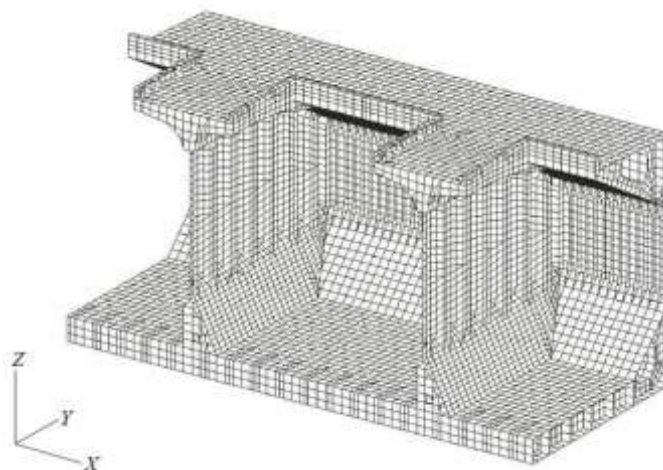


Figure 4.1.1 Finite Element Model

4.2 Boundary conditions

4.2.1 Boundary condition with the structures symmetrical to longitudinal centerline section

4.2.1.1 If a half-breadth FE model is used, the displacements in transverse direction of nodes on the longitudinal centerline section and the rotation around the two coordinate axes on the longitudinal centerline section are restrained, i.e.: $\delta_x = \theta_y = \theta_z = 0$.

4.2.1.2 If a full-breadth FE model is used, the displacements in transverse direction of intersection G of the longitudinal centerline section in way of forward and aft bulkheads of midship cargo holds and bottom plating are restrained, i.e.: $\delta = 0$.

4.2.2 Boundary conditions for local loads (see Table 4.2.2)

4.2.2.1 Symmetrical boundary conditions are applied respectively to end planes A and B, and

the displacements in longitudinal direction of nodes within the end plane and the rotations around the two coordinate axes within the end plane are restrained, i.e.: $\delta_x = \theta_y = \theta_z = 0$.

4.2.2.2 Vertical spring elements are to be provided at intersections of side shell plating and inner hull plating with forward and aft transverse bulkheads in midship holds. The coefficient of elasticity of spring elements is to be distributed evenly and calculated by the following formula:

$$K = \frac{5GA}{6l_H n} \quad \text{N/mm}$$

where: G — shear modulus of elasticity of material, $G = 0.792 \times 10^5$ N/mm² for steel;

A — shearing area of side shell plating and inner hull plating in way of forward and aft bulkheads, in mm²;

l_H — length of midship hold, in mm;

n — number of nodes on vertical intersections of side shell plating and inner hull plating.

Table 4.2.2 - Boundary Conditions for Local Loads

Position	Displacement Constraint			Rotation Constraint		
	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Longitudinal centerline section (half-breadth model)	—	Constraint	—	Constraint	—	Constraint
Node G (full-breadth model)	—	Constraint	—	—	—	—
End planes A, B	Constraint	—	—	—	Constraint	Constraint
Intersection line C	—	—	Spring	—	—	—

4.2.3 Boundary conditions for global load (see Table 4.2.3)

4.2.3.1 An independent point H is to be set in way of intersection of the neutral axis with the longitudinal centerline section within end planes A and B , the longitudinal bending moment is to be applied on the point H , and the degrees of freedom δ , δ_y and δ_z of each member node for end planes is linked to independent point.

4.2.3.2 The displacements of the independent point H within end planes A and B in transverse direction, vertical direction, and the rotation around longitudinal axes are restrained, i.e.: $\delta_y = \delta_z = \theta_x = 0$; the displacement of the independent point H within the end plane A in longitudinal direction are restrained, i.e.: $\delta_x = 0$.

Table 4.2.3 - Boundary Conditions for Global Load

Position	Displacement Constraint			Rotation Constraint		
	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Longitudinal centerline section (half-breadth model)	—	Constraint	—	Constraint	—	Constraint
Node G (full-breadth model)	—	Constraint	—	—	—	—
End planes A, B	Link	Link	Link	—	—	—
Independent point H (end plane A)	Constraint	Constraint	Constraint	Constraint	Bending moment	—

Independent point H (end plane B)	–	Constraint	Constraint	Constraint	Bending moment	–

4.2.4 For boundary conditions of the model, see Figure 4.2.4.

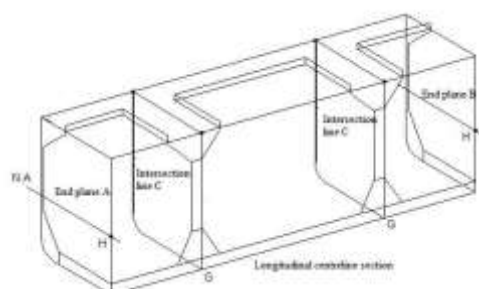


Figure 4.2.4 Boundary Conditions

5 Yield Strength Evaluation

5.1 Allowable stresses

5.1.1 Strength evaluation is to be carried out for all primary members in the cargo holds amidships (including bulkheads) within the longitudinal extent. The stress evaluated is to be the combined one due to local load case and global load case in accordance with 1.5.1.9(2) of Chapter 1 of this PART.

5.1.2 The allowable stresses for each primary structural member are given in Table 5.1.2.

Table 5.1.2 - Allowable Stresses

Type of Structure	Allowable Stress (N/mm ²)	
	[σ] _e	[τ]
Deck	220/K	–
Bottom shell plating, inner bottom plating	220/K	–
Side shell plating, inner skin plating, horizontal girder in double hulls	220/K	115/K
Hopper and topside tank sloping plating	220/K	115/K
Bottom girder	235/K	115/K
Double bottom floor	175/K	95/K
Transverse bulkhead	175/K	95/K
Side plating of lower and upper stools	195/K	95/K
Transverse web frame	195/K	95/K
Deck between hatchways	175/K	–
Other	195/K	–

Note: K— material factor.

6 Buckling Strength Evaluation

6.1 Buckling safety factors

6.1.1 The standard thickness deduction of members is given in Table 6.1.1.

Table 6.1.1 - Standard Thickness Deduction

Position	Standard Thickness Deduction (mm)
Within 1.5 m below weather deck	
– One side connected to ballast water	1
– Two sides connected to ballast water	2
Elsewhere	1

6.1.2 The safety factor λ against plate panel buckling is not to be less than the minimum one in Table 6.1.2.

Table 6.1.2 - Minimum Buckling Safety Factor

Structural Member	Minimum Buckling Safety Factor	Structural Member	Minimum Buckling Safety Factor
Deck, deck between hatchways	0.8	Double bottom girder, horizontal girder in double hulls	1
Bottom shell plating, inner bottom plating	0.8	Double bottom floor, transverse web frame	1
Side shell plating, inner skin plating	0.8	Transverse bulkhead, lower stool, upper stool	0.8
Hopper and topside tank sloping plating	0.8		

APPENDIX 2 HOLD MASS CURVES

Symbols

h : vertical distance from the top of inner bottom plating to upper deck plating at the ship's centerline section, in m;

h_a : vertical distance from the top of inner bottom plating to upper deck plating at the ship's centerline section of aft cargo holds under the alt-block loading condition, in m;

h_f : vertical distance from the top of inner bottom plating to upper deck plating at the ship's centerline section of forward cargo holds under the alt-block loading condition, in m;

M_H : see Appendix 1 of this Chapter;

M_{FULL} : see Appendix 1 of this Chapter;

M_{HD} : see Appendix 1 of this Chapter;

M_D : maximum cargo mass given for each cargo hold, in t;

M_{BLK} : see Appendix 1 of this Chapter;

T_{HB} : maximum ballast draught, in m;

T_i : draught in loading condition No. i at mid-hold position of cargo hold length l_H , in m;

d : draught, in m;

V_H : volume, in m^3 , of cargo hold excluding the volume enclosed by hatch coaming;

V_f, V_a : volume, in m^3 , of forward or aft cargo hold excluding the volume enclosed by hatch coaming;

T_{min} : 0.75 d or draught in ballast conditions with the two adjacent cargo holds empty, whichever

is greater, in m;

Σ : sum of mass of two adjacent cargo holds.

1 General Requirements

1.1 Application

1.1.1 This Appendix applies to ships of 150 m or over in length.

1.1.2 This Appendix describes the procedure to be used for determination of:

- (1) the maximum and minimum masses of cargo in each cargo hold as a function of the draught at mid-hold position of cargo hold;
- (2) the maximum and minimum mass of cargo in any two adjacent holds as a function of the mean draught in way of these holds.

1.1.3 The calculation results are to be included in the loading manual.

2 Maximum and Minimum Masses of Cargo in Each Hold

2.1 Maximum permissible mass and minimum required mass of single cargo hold in sea-going condition

2.1.1 The cargo mass curves of single cargo hold in sea-going condition are defined in 2.1.2 to 2.1.5 of this Appendix. However, if the ship structure is checked for more severe loading conditions than the ones considered in Appendix 1 of this Chapter, the minimum required cargo mass and maximum permissible cargo mass may be based on those more severe loading conditions.

2.1.2 Ships with alternate load under multi-port condition

For loaded holds, the maximum permissible cargo mass ($W_{max} (T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{max} (T_i) = M_{HD} + 0.1M_H - 1.025V_H \frac{(d - T_i)}{h}$$

$W_{max} (T_i)$ in no case to be greater than M_{HD} .

For loaded holds, the minimum required cargo mass ($W_{min} (T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$\begin{aligned} W_{min} (T_i) &= 0 & \text{for } T_i \leq 0.83d \\ W_{min} (T_i) &= 1.025V_H \frac{(T_i - 0.83d)}{h} & \text{for } d \geq T_i > 0.83d \end{aligned}$$

For empty holds which may be empty at the maximum draught, the maximum permissible cargo mass ($W_{max} (T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

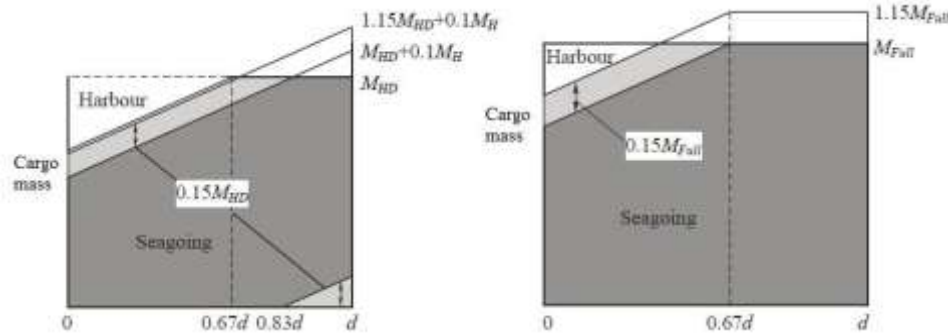
$$\begin{aligned} W_{max} (T_i) &= M_{Full} & \text{for } d \geq T_i \geq 0.67d \\ W_{max} (T_i) &= M_{Full} - 1.025V_H \frac{(0.67d - T_i)}{h} & \text{for } T_i < 0.67d \end{aligned}$$

For loaded holds, the minimum required cargo mass ($W_{min} (T_i)$) at various draughts (T_i) is

obtained, in t, by the following formula:

$$W_{\min}(T_i) = 0 \text{ for } T_i \leq d$$

Mass curves of loaded cargo hold and cargo hold which may be empty at the maximum draught for ships with alternate load under multi-port condition are shown in Figure 2.1.2.



(a) Loaded hold (b) Cargo hold which may be empty at the maximum draught
Figure 2.1.2 Mass Curve for Ships with Alternate Load under Multi-port Condition

2.1.3 Ships with alternate load under no multi-port condition

For cargo holds, the maximum permissible cargo mass ($W_{\max}(T_i)$) at various draughts (T_i), in t, is the same as specified in 2.1.2.

For cargo holds, the minimum required cargo mass ($W_{\min}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{\min}(T_i) = 0 \quad \text{for } T_i \leq T_{HB}$$

$$W_{\min}(T_i) = \min \left\{ \begin{array}{ll} 1.025V_H \frac{(T_i - T_{HB})}{h} & \text{for } d \geq T_i > T_{HB} \\ 0.5M_H - 1.025V_H \frac{(d - T_i)}{h} \geq 0 & \text{for } d \geq T_i \end{array} \right.$$

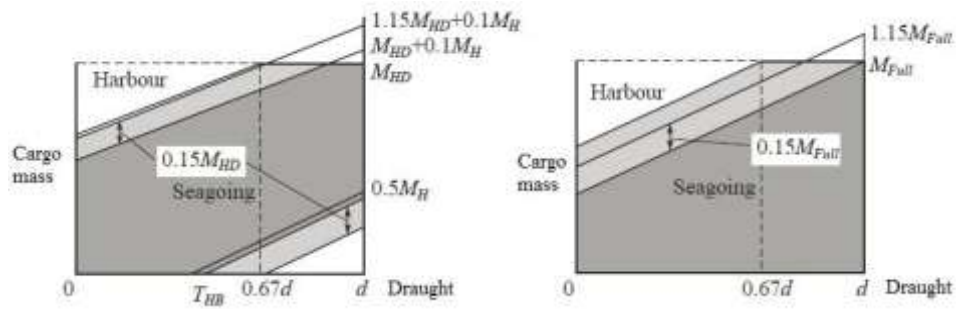
For empty hold which may be empty at the maximum draught, the maximum permissible cargo mass ($W_{\max}(T_i)$) at various draught (T_i) is obtained, in t, by the following formula:

$$W_{\max}(T_i) = M_{Full} - 1.025V_H \frac{(d - T_i)}{h}$$

For empty hold which may be empty at the maximum draught, the minimum required cargo mass ($W_{\min}(T_i)$) at various draught (T_i) is obtained, in t, by the following formula:

$$W_{\min}(T_i) = 0 \quad \text{for } T_i \leq d$$

Mass curves of loaded cargo hold and cargo hold which may be empty at the maximum draught for ships with alternate load under no multi-port condition are shown in Figure 2.1.3.



(a) Loaded hold (b) Cargo hold which may be empty at the maximum draught

Figure 2.1.3 Mass Curve for Ships with Alternate Load under no Multi-port Condition

2.1.4 Ships with homogeneous load under multi-port condition

The maximum permissible cargo mass ($W_{max}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{max}(T_i) = M_{Full} \quad \text{for } d \geq T_i \geq 0.67d$$

$$W_{max}(T_i) = M_{Full} - 1.025V_H \frac{(0.67d - T_i)}{h} \quad \text{for } T_i < 0.67d$$

The minimum required cargo mass ($W_{min}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{min}(T_i) = 0 \quad \text{for } T_i \leq 0.83d$$

$$W_{min}(T_i) = 1.025V_H \frac{(T_i - 0.83d)}{h} \quad \text{for } d \geq T_i > 0.83d$$

Mass curves of loaded cargo hold for ships with homogeneous load under multi-port condition are shown in Figure 2.1.4.

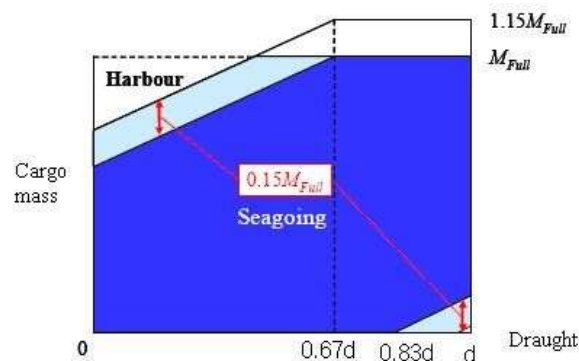


Figure 2.1.4 Mass Curve for Ships with Homogeneous Load under Multi-port Condition

2.1.5 Ships with homogeneous load under no multi-port condition

The maximum permissible cargo mass ($W_{max}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formula:

$$W_{max}(T_i) = M_{Full} - 1.025V_H \frac{(d - T_i)}{h}$$

The minimum required cargo mass ($W_{min}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{min}(T_i) = 0 \quad \text{for } T_i \leq T_{HB}$$

$$W_{min}(T_i) = \min \begin{cases} 1.025V_H \frac{(T_i - T_{HB})}{h} \geq 0 & \text{for } d \geq T_i > T_{HB} \\ 0.5M_H - 1.025V_H \frac{(d - T_i)}{h} \geq 0 & \text{for } d \geq T_i \end{cases}$$

Mass curves of loaded cargo hold for ships with homogeneous load under no multi-port condition are shown in Figure 2.1.5.

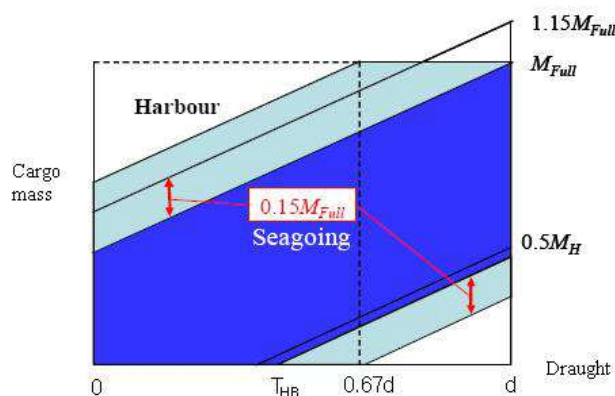


Figure 2.1.5 Mass Curve for Ships with Homogeneous Load under No Multi-port Condition

2.2 Maximum permissible mass and minimum required mass of single cargo hold in harbour condition

2.2.1 The cargo mass curves of single cargo hold in harbour condition are defined in 2.2.2 of this Appendix. However, if the ship structure is checked for more severe loading conditions than the ones considered in Appendix 1 of this Chapter, the minimum required cargo mass and maximum permissible cargo mass may be based on those more severe loading conditions.

2.2.2 For all ships, the maximum permissible cargo mass and the minimum required cargo mass corresponding to draught for loading/unloading conditions in harbour may be increased or decreased by 15% of the maximum permissible mass at the maximum draught for the cargo hold in sea-going condition. Maximum permissible cargo mass is in no case to be greater than the maximum permissible cargo mass at designed maximum load draught for each cargo hold.

2.2.3 Ships with alternate load under multi-port condition

During the loading/unloading in harbour, the maximum permissible cargo mass ($W_{max}(T_i)$), in t, at various draughts (T_i) is to be checked by the following formulae, in addition to the requirements of 2.1.2 of this Appendix:

For cargo hold,

$$\begin{aligned}
 W_{\max}(T_i) &= M_{HD} && \text{for } T_i \geq 0.67d \\
 W_{\max}(T_i) &= M_{HD} - 1.025V_H \frac{(0.67d - T_i)}{h} && \text{for } T_i < 0.67d
 \end{aligned}$$

2.2.4 Ships with alternate load under no multi-port condition

During the loading/unloading in harbour, the maximum permissible cargo mass ($W_{\max}(T_i)$), in t, at various draughts (T_i) is to be checked by the following formulae, in addition to the requirements of 2.1.3 of this Appendix:

For empty hold which may be empty at the maximum draught,

$$\begin{aligned}
 W_{\max}(T_i) &= M_{FULL} && \text{for } T_i \geq 0.67d \\
 W_{\max}(T_i) &= M_{FULL} - 1.025V_H \frac{(0.67d - T_i)}{h} && \text{for } T_i < 0.67d
 \end{aligned}$$

2.2.5 Ships with homogeneous load under no multi-port condition

During the loading/unloading in harbour, the maximum permissible cargo mass ($W_{\max}(T_i)$), in t, at various draughts (T_i) is to be checked by the following formulae, in addition to the requirements of 2.2.2 of this Appendix:

$$\begin{aligned}
 W_{\max}(T_i) &= M_{FULL} && \text{for } d \geq T_i > 0.67d \\
 W_{\max}(T_i) &= M_{FULL} - 1.025V_H \frac{(0.67d - T_i)}{h} && \text{for } T_i < 0.67d
 \end{aligned}$$

3 Maximum and Minimum Cargo Masses of Two Adjacent Holds

3.1 Maximum permissible cargo mass and minimum required cargo mass of two adjacent holds in sea-going condition

3.1.1 The cargo mass curves of two adjacent cargo holds in sea-going condition are defined in

3.1.2 of this Appendix. However, if the ship structure is checked for more severe loading conditions than the ones considered in Appendix 1 of this Chapter, the minimum required cargo mass and maximum permissible cargo mass may be based on those more severe loading conditions.

3.1.2 Ships with alternate load of bulk goods under multi-port condition

The maximum permissible mass cargo ($W_{\max}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{\max}(T_i) = \sum (M_{BLK} + 0.1M_H) - 1.025 \left(\frac{V_f}{h_f} + \frac{V_a}{h_a} \right) (d - T_i)$$

or

$$W_{\max}(T_i) = \sum M_{FULL} - 1.025 \left(\frac{V_f}{h_f} + \frac{V_a}{h_a} \right) (0.67d - T_i)$$

$W_{\max}(T_i)$ is not greater than $\sum M_{BLK}$.

The minimum required cargo mass ($W_{\min}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{\min}(T_i) = 0 \quad \text{for } T_i \leq 0.75d$$

$$W_{\min}(T_i) = 1.025 \left(\frac{V_f}{h_f} + \frac{V_a}{h_a} \right) (T_i - 0.75d) \quad \text{for } d \geq T_i > 0.75d.$$

3.1.3 Ships with alternate load of packed cargo under no multi-port condition

The maximum permissible cargo mass ($W_{\max}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{\max}(T_i) = \sum (M_{BLK} + 0.1M_H) - 1.025 \left(\frac{V_f}{h_f} + \frac{V_a}{h_a} \right) (d - T_i)$$

$$W_{\max}(T_i) \text{ is not greater than } \sum M_{BLK}.$$

The minimum required cargo mass ($W_{\min}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{\min}(T_i) = 0 \quad \text{for } T_i \leq T_{HB}$$

$$W_{\min}(T_i) = 1.025 \left(\frac{V_f}{h_f} + \frac{V_a}{h_a} \right) (T_i - T_{HB}) \quad \text{for } d \geq T_i > T_{HB}.$$

Mass curves of loaded cargo hold for ships with alternate load of packed cargo are shown in Figure 3.1.3.

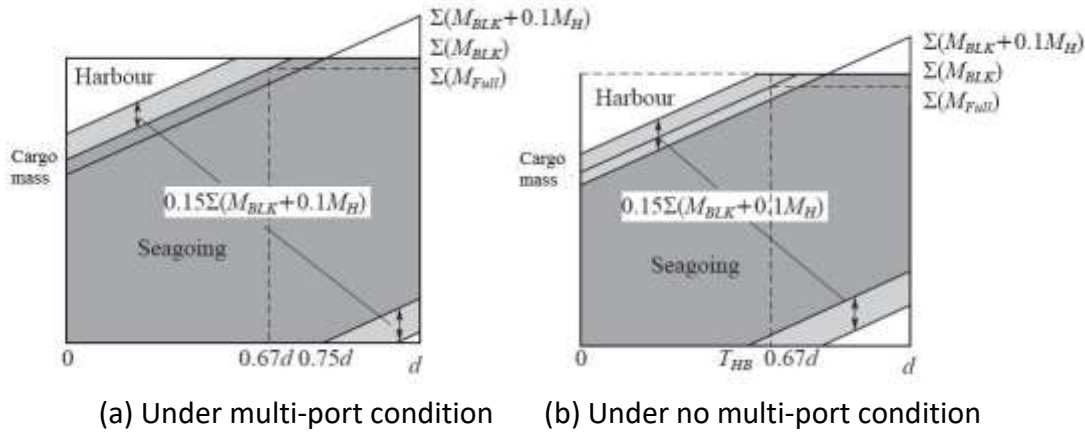


Figure 3.1.3 Mass Curve of Loaded Cargo Hold for Ships with Alternate Load of Packed Cargo

3.1.4 Ships with alternate load without packed cargo under multi-port condition and ships with homogeneous load

The maximum permissible mass cargo ($W_{\max}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{\max}(T_i) = \sum M_{FULL} \quad \text{for } d \geq T_i \geq 0.67d$$

$$W_{\max}(T_i) = \sum M_{FULL} - 1.025 \left(\frac{V_f}{h_f} + \frac{V_a}{h_a} \right) (0.67d - T_i) \quad \text{for } T_i < 0.67d$$

The minimum required cargo mass ($W_{\min}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{\min}(T_i) = 0 \quad \text{for } T_i \leq 0.75d$$

$$W_{\min}(T_i) = 1.025 \left(\frac{V_f}{h_f} + \frac{V_a}{h_a} \right) (T_i - 0.75d) \quad \text{for } d \geq T_i > 0.75d$$

3.1.5 Ships with alternate load without packed cargo under no multi-port condition and

ships with homogeneous load

The maximum permissible mass cargo ($W_{max}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formula:

$$W_{max}(T_i) = \sum M_{FULL} - 1.025 \left(\frac{V_f}{h_f} + \frac{V_a}{h_a} \right) (d - T_i) \quad \text{for } T_i < d$$

The minimum required cargo mass ($W_{min}(T_i)$) at various draughts (T_i) is obtained, in t, by the following formulae:

$$W_{min}(T_i) = 0 \quad \text{for } T_i \leq T_{HB}$$

$$W_{min}(T_i) = 1.025 \left(\frac{V_f}{h_f} + \frac{V_a}{h_a} \right) (T_i - T_{HB}) \quad \text{for } d \geq T_i > T_{HB}$$

Mass curves of loaded cargo hold for ships with alternate load without packed cargo are shown in Figure 3.1.5.

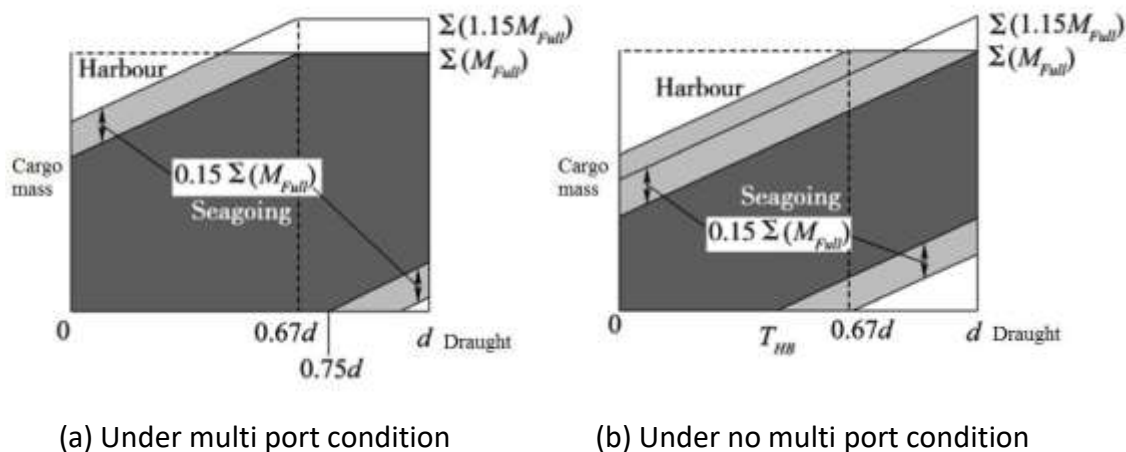


Figure 3.1.5 Mass Curve of Loaded Cargo Hold for Ships with Alternate Load without Packed Cargo and Ships with Homogeneous Load

3.2 Maximum permissible cargo mass and minimum required cargo mass in two adjacent holds in harbour condition

3.2.1 The cargo mass curves of two adjacent cargo holds in harbour condition are defined in 3.2.2 of this Appendix. However, if the ship structure is checked for more severe loading conditions than the ones considered in Appendix 1 of this Chapter, the minimum required cargo mass and maximum permissible cargo mass may be based on those more severe loading conditions.

3.2.2 For all ships, the maximum permissible cargo mass and the minimum required cargo mass corresponding to draught for loading/unloading conditions in harbour may be increased or decreased by 15% of the maximum permissible mass at the maximum draught for the cargo hold in sea-going condition. Maximum permissible cargo mass is in no case to be greater than the maximum permissible cargo mass at designed maximum load draught for each cargo hold.

3.2.3 Ships with alternate load of packed cargo under no multi-port condition

During the loading/unloading in harbour, the maximum permissible cargo mass ($W_{max}(T_i)$), in t, at various draughts (T_i) is to be checked by the following formulae, in addition to the requirements of 3.1.3 of this Appendix:

$$W_{max}(T_i) = \sum M_{FULL} - 1.025 \left(\frac{V_f}{h_f} + \frac{V_a}{h_a} \right) (0.67d - T_i)$$

$$W_{max}(T_i) \leq M_{BLK}$$

3.2.4 Ships with alternate load without packed cargo under no multi-port condition and ships with homogeneous load

During the loading/unloading in harbour, the maximum permissible cargo mass ($W_{max}(T_i)$), in t, at various draughts (T_i) is to be checked by the following formulae, in addition to the requirements of 3.1.5 of this Appendix:

$$W_{max}(T_i) = M_{FULL} \quad \text{for } d \geq T_i \geq 0.67d$$

$$W_{max}(T_i) = \sum M_{FULL} - 1.025 \left(\frac{V_f}{h_f} + \frac{V_a}{h_a} \right) (0.67d - T_i) \quad \text{for } T_i < 0.67d$$

CHAPTER 8

ROLL ON-ROLL OFF SHIPS, PASSENGER SHIPS, RO-RO PASSENGER SHIPS AND FERRIES

SECTION 1 GENERAL PROVISIONS

8.1.1 Application

8.1.1.1 This Chapter applies to roll on-roll off ships, passenger ships, ro-ro passenger ships and ferries defined as follows:

- (1) A roll on-roll off ship is a ship specially designed and constructed for the carriage of vehicles, and cargo in pallet form or in containers, and loaded/unloaded by wheeled vehicles;
- (2) A passenger ship is a ship which carries more than twelve passengers;
- (3) Ro-ro passenger ship means a passenger ship with ro-ro cargo spaces or special category spaces;
- (4) Ferries are the ships specially designed for the carriage of passengers (without sleeping berths) and/or vehicles engaged on regular voyages between two sides of straits or islands. Ferries carrying more than 12 passengers are ferry passenger ships.

8.1.1.2 Ro-ro spaces are spaces not normally subdivided in any way and normally extending to either a substantial length or the entire length of the ship, in which motor vehicles with fuel in their tanks for their own propulsion or goods (packaged or in bulk, in or on rail or road cars, vehicles (including road or rail tankers), trailers, containers, pallets, demountable tanks or in or on similar stowage units or other receptacles) can be loaded and unloaded normally in a horizontal direction.

8.1.1.3 Special category spaces are those enclosed vehicle spaces above and below the bulkhead deck, into and from which vehicles can be driven and to which passengers have access. Special category spaces may be accommodated on more than one deck provided that the total overall clear height for vehicles does not exceed 10 m.

8.1.1.4 Those not specified in this Chapter are to comply with the relevant requirements of Chapter 2 of this PART.

8.1.2 Class notations

8.1.2.1 Ships complying with the requirements of this Chapter will be eligible to be assigned one of the following class notations:

- (1) Roll on-roll off ships: RO-RO Ship; (2) Passenger ships: Passenger Ship;
- (3) Ro-ro passenger ships carrying only road vehicles: RO-RO Passenger Ship;
- (4) Ro-ro passenger ships carrying railway vehicles: Train/RO-RO Passenger Ship; (5) Ferries: Ferry;
- (6) Ferry Passenger Ship.

8.1.3 Plans and documents

8.1.3.1 In addition to the plans and documents required in Section 1, Chapter 2 of this PART, the following plans and documents are to be submitted for approval:

- (1) Structural arrangement of ramps (appropriate strength calculations are submitted for information);
- (2) Structural arrangements of bow doors, inner doors, stern doors and side doors and their operating and maintenance manual (appropriate strength calculations are submitted for information);
- (3) Structural arrangement of movable platforms (appropriate strength calculations are submitted for information);
- (4) Structural arrangement of sloping vehicle ramps (appropriate strength calculations are submitted for information).

8.1.3.2 Direct strength calculations for vehicle deck (where available), direct calculations of transverse strength for hull (where applicable), the arrangement of wheel prints for the carriage of vehicles and the data related to design loading, e.g. loads and axle loads, are to be provided for information.

SECTION 2 - HULL STRUCTURE

8.2.1 General requirements

8.2.1.1 The structural arrangements of the hull are to comply with the relevant requirements of Section 12, Chapter 1 of this PART.

8.2.1.2 The basic structural configuration is to be a single deck or multi-deck hull, and in some cases wing tanks up to the freeboard deck or bulkhead deck may be fitted.

8.2.1.3 Where the number of transverse bulkheads is not in accordance with the requirements in Section 12, Chapter 2 of this PART, partial transverse bulkheads, or web frames and deck transverses are to be fitted to provide equivalent transverse strength.

8.2.1.4 Longitudinal framing is, in general, to be adopted at the strength deck and at the bottom for ships greater than 65 m in length.

8.2.1.5 Web frames and deck transverses within vehicle spaces above the bulkhead deck may be connected with continuous rounded corners or by cross joints without brackets, see Figure

8.2.1.5(1) and (2). The radius R of the rounded corners is not to be less than the web depth of web frame or deck transverse, whichever is greater. The web thickness t_3 of the joint of cross connection without brackets (between web frame and deck transverse) is not to be less than the greater of the values obtained by the following formulas, nor less than the web thickness of web frame or deck transverse, whichever is greater.

$$t_3 = \frac{1}{K} \left(\frac{\sigma_1 A_1}{d_{w2}} - \frac{t_2 \tau_2}{100} \right) \quad \text{mm}$$

$$t_3 = \frac{1}{K} \left(\frac{\sigma_2 A_2}{d_{w1}} - \frac{t_1 \tau_1}{100} \right) \quad \text{mm}$$

where: A_1, A_2 — sectional area of faceplate respectively of web frame and deck transverse, in cm^2 ;

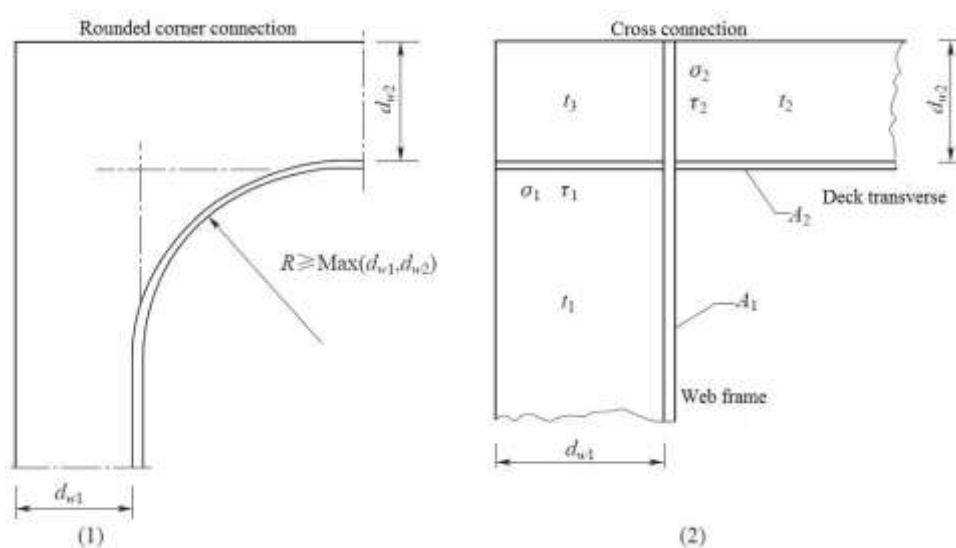
d_{w1}, d_{w2} — web depth respectively of web frame and deck transverse, in mm;

t_1, t_2 — web thickness respectively of web frame and deck transverse adjacent to cross connection joint, in mm;

σ_1, σ_2 — bending stress respectively of web frame and deck transverse adjacent to cross connection joint, in N/mm^2 ;

τ_1, τ_2 — shear stress respectively of web frame and deck transverse adjacent to cross connection joint, in N/mm^2 ;

K — material factor.



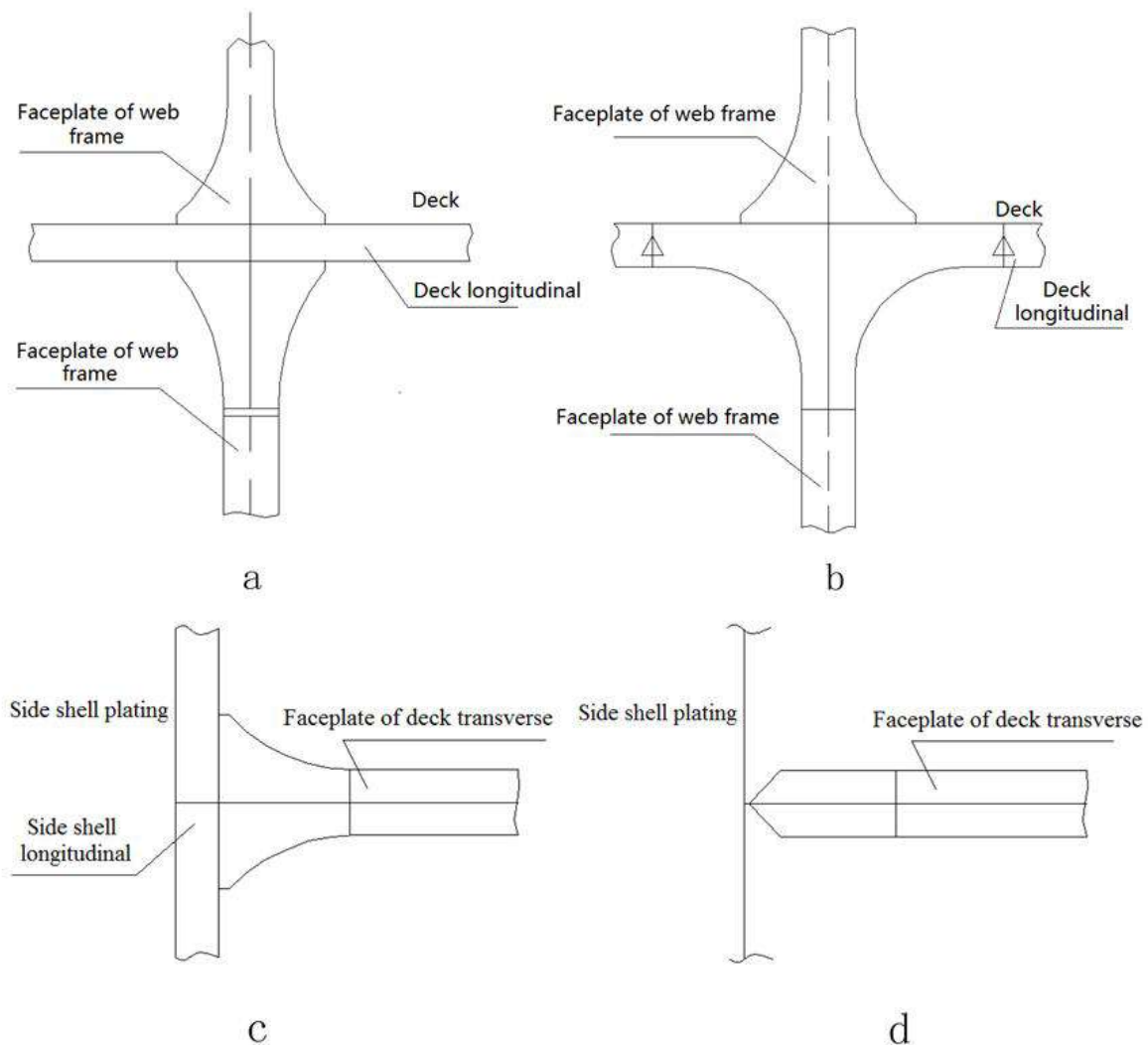


Figure 8.2.1.5

The faceplate of web frames and deck transverse, which are cross-connected without brackets, is to be continuous to deck plating and side shell and to be well transitioned, see Figure 8.2.1.5(3) for typical types of joints.

8.2.1.6 Where necessary, the structures in way of securing devices of vehicles and securing points of the hull are to be locally strengthened as appropriate.

8.2.1.7 The scantlings of stabilizing tanks and balancing tanks are to comply with the requirements of Section 13, Chapter 2 of this PART for deep tanks. The scantlings of those members, which may be subject to sloshing loads, are to be increased by 10%.

8.2.2 Longitudinal strength

8.2.2.1 The longitudinal strength is to comply with the requirements of Section 2, Chapter 2 of this PART. Where large openings are cut in side shell below strength deck and this significantly reduces shear force transmission from side shell to strength deck, the contribution of longitudinal continuous members within the area of strength deck and openings below to the longitudinal

strength may be determined by finite element direct calculations.

8.2.3 Transverse strength

8.2.3.1 For roll on-roll off ships, ro-ro passenger ships and ferries carrying vehicles, the transverse strength of the hull is to be checked in accordance with the relevant requirements of Section 7 of this Chapter.

8.2.4 Superstructure deck

8.2.4.1 Where superstructure deck is strength deck, the thickness of deck plating, excluding that of the forecastle, is to comply with the requirements of 2.17.5.4 in Section 17, Chapter 2 of this PART and the buckling strength requirements in respect to longitudinal strength in Section 2 of the same Chapter, but not less than 6 mm.

8.2.4.2 Where superstructure deck is strength deck, the framing of superstructure deck is to comply with the relevant requirements in Section 8, Chapter 2 of this PART and the buckling strength requirements in respect to longitudinal strength in Section 2 of the same Chapter.

8.2.5 Side framing

8.2.5.1 Side framing is to comply with the relevant requirements of Section 7, Chapter 2 of this PART. When calculating the scantlings of primary members of side framing below freeboard deck, however, the design pressure head may be measured to freeboard deck at side.

8.2.6 Vehicle deck

8.2.6.1 The structure of vehicle deck is to comply with the requirements of Section 21, Chapter 2 of this PART.

8.2.6.2 The strength of primary supporting members of vehicle deck is to comply with relevant requirements in Section 7 of this Chapter.

8.2.7 Train deck

8.2.7.1 Rails on the deck are to be fitted in way of deck girders or longitudinals. The effects of rails on the structural strength are not to be considered.

8.2.7.2 The thickness of deck plating is to be in accordance with the relevant requirements in Section 4, Chapter 2 of this PART.

8.2.7.3 The longitudinals or beams of deck framing are to be in accordance with the relevant requirements in Section 8, Chapter 2 of this PART, and the design head h is to be taken as $0.14p$, p being design cargo load, in kPa. Deck longitudinals supporting rails are to comply with the relevant requirements of Section 21, Chapter 2 of this PART.

8.2.7.4 The girders and transverses of deck framing are to be in accordance with 2.21.2.3 in Section

21, Chapter 2 of this PART. Where the deck framing is fitted with transverses and girders, their scantlings may be determined by direct calculations in accordance with the relevant requirements in Section 7 of this Chapter. The load of train wheels and the concentrated static load at supporting points of lifting jacks are to be taken into account respectively.

8.2.7.5 Where the train deck is intended to carry road vehicles, the relevant requirements in this Chapter for vehicle decks are to be complied with.

8.2.7.6 Where jacks are used to secure trains, the supporting points of the jacks are to be arranged as far as practicable in way of primary supporting members of the deck structure, otherwise the structure in this area is to be locally strengthened as appropriate.

8.2.8 Deck framing within area of deckhouses in accommodation spaces

8.2.8.1 The section modulus W of deck longitudinals or beams within the area of deckhouses is not to be less than the value obtained as follows:

$$W = 5shl^2K \text{ cm}^3, \text{ and not less than } 25s$$

where: s — spacing of deck longitudinals or beams, in m;

l — span of deck longitudinals or beams, in m;

h — design head, in m, taken as 0.45 m and for portions exposed to weather, increased by

$h_0 - 1.2$ m, where h_0 is to be calculated according to 2.8.1.1 of Chapter 2 of this PART;

K — material factor.

The scantlings of deck girders and transverses within the area of deckhouses are to be calculated in accordance with the relevant requirements in Section 8, Chapter 2 of this PART, while the design head is to be taken as 0.45 m and the web thickness of deckhouse girders is not to be less than 1% of web depth plus 2 mm, nor less than 4 mm.

8.2.9 Deck framing within area of deckhouses in baggage and storage spaces

8.2.9.1 For deck framing within the area of deckhouses, calculations are to be in accordance with the requirements in Section 8, Chapter 2 of this PART for cargo decks not exposed to weather.

SECTION 3 - MOVABLE PLATFORMS AND SLOPING VEHICLE RAMPS

8.3.1 Movable platforms

8.3.1.1 Movable platforms are generally to be constructed as pontoons comprising a web structure with top decking.

8.3.1.2 Positive means of control are to be provided to secure the platform in the lowered position.

8.3.1.3 The supporting members of movable platforms are to have sufficient strength. For the design of movable platform, the strength of the fittings or members at the following supports is to be checked on the basis of the imposed loads (including the weight of the platform):

(1) Flexible supports: the permissible load for fittings such as chains and steel hawsers is to be

taken as 1/5 of the breaking strength;

(2) Rigid supports: the allowable stresses are to be as follows:

Allowable bending stress $[\sigma] \leq 85/K \text{ N/mm}^2$;

Allowable shear stress $[\tau] \leq 43/K \text{ N/mm}^2$;

Allowable equivalent stress $[\sigma_e] = [\sigma_e] = \sqrt{\sigma^2 + 3\tau^2} \leq 160/K \text{ N/mm}^2$;

where: K — material factor.

(3) Buckling is to be checked for the pressured members.

8.3.1.4 The thickness of the movable platform plating is to be calculated as that of the vehicle decks.

8.3.1.5 Where the movable platforms are intended for handling cargo with forklifts, the scantlings of the stiffeners are to comply with the requirements for deck beams or longitudinals in Section 21, Chapter 2 of this PART.

8.3.1.6 The section modulus W of the stiffeners of movable platforms designed exclusively for the carriage of vehicles is not to be less than that obtained from the following formula:

$$W = 1.39J_1P/K \text{ cm}^3$$

where: J_1 , P and l — see 2.21.2.2(2) of Chapter 2 of this PART;

K — material factor.

8.3.1.7 The scantlings of girders of movable platforms may be determined by a direct calculation on the basis of the following criteria:

Allowable bending stress: $[\sigma] \leq 128/K \text{ N/mm}^2$;

Allowable shear stress: $[\tau] \leq 64/K \text{ N/mm}^2$;

Allowable equivalent stress: $[\sigma_e] = [\sigma_e] = \sqrt{\sigma^2 + 3\tau^2} \leq 160/K \text{ N/mm}^2$;

Deflection: $f \leq l/400 \text{ mm}$.

where: K — material factor; l — distance between the supporting points of stiffeners, in mm.

8.3.2 Sloping vehicle ramps

8.3.2.1 Fixed sloping vehicle ramps are to comply with the requirements for vehicle decks in Section 21, Chapter 2 of this PART.

8.3.2.2 Movable sloping vehicle ramps are to comply with the requirements for vehicle ramps in Section 6 of this Chapter, and their rigid supports are to comply with 8.3.1.3(2) of this Section.

SECTION 4 - BOW DOORS AND INNER DOORS

8.4.1 General requirements

8.4.1.1 Application

(1) This Section applies to the arrangement, strength and securing of bow doors and inner doors leading to a complete or long forward enclosed superstructure, or to a long non-enclosed superstructure which is fitted to attain minimum bow height equivalence.

(2) This Section is applicable to the following two types of bow doors:

- ① Visor doors opened by rotating upwards and outwards about a horizontal axis through two or more hinges located near the top of the door and connected to the primary structure of the door by longitudinally arranged lifting arms;
 - ② Side-opening doors opened either by rotating outwards about a vertical axis through two or more hinges located near the outboard edges or by horizontal translation by means of linking arms arranged with pivoted attachments to the door and the ship. It is anticipated that side-opening bow doors are arranged in pairs.
- Other types of bow door will be specially considered.

8.4.1.2 Arrangement

- (1) Bow doors are to be situated above the freeboard deck. A watertight recess in the freeboard deck located forward of the collision bulkhead and above the deepest waterline, fitted for arrangement of ramps or other related mechanical devices, may be regarded as a part of the freeboard deck for the purpose of this requirement.
- (2) An inner door is to be fitted. The inner door is to be part of the collision bulkhead. The inner door need not be fitted directly above the bulkhead, provided it is located within the limits specified for the position of the collision bulkhead (1.12.3.1 or 1.12.3.2 of Section 12, Chapter 1 of this PART). A vehicle ramp may be arranged for this purpose at the position specified in 1.12.3.1 or 1.12.3.2 of Section 12, Chapter 1 of this PART. If this is not possible, a separate inner weathertight door is to be installed, as far as practicable, within the limits specified for the position of the collision bulkhead.
- (3) Bow doors are to be so fitted as to ensure tightness consistent with operational conditions and to give effective protection to inner doors. Inner doors forming part of the collision bulkhead are to be weathertight over the full height of the cargo space and arranged with fixed sealing supports on the aft side of the doors.
- (4) Bow doors and inner doors are to be arranged so as to preclude the possibility of the bow door causing structural damage to the inner door or to the collision bulkhead in the case of damage to or detachment of the bow door. If this is not possible, a separate inner weathertight door is to be installed, as indicated in 8.4.1.2(2) of this Section.
- (5) The requirements for inner doors are based on the assumption that vehicles are effectively lashed and secured against movement in stowed position.

8.4.1.3 Definitions

- (1) **Securing device:** a device used to keep the door closed by preventing it from rotating about its hinges;
- (2) **Supporting device:** a device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the ship's structure;
- (3) **Locking device:** a device that locks a securing device in the closed position;
- (4) **Ro-ro passenger ship:** see 8.1.1.1(3) of Section 1 of this Chapter;

- (5) **Ro-ro spaces:** see 8.1.1.2 of Section 1 of this Chapter;
 (6) **Special category spaces:** see 8.1.1.3 of Section 1 of this Chapter.

8.4.2 Strength criteria of primary structures and securing and supporting devices

8.4.2.1 Scantlings of the primary members, securing and supporting devices of bow doors and inner doors are to be determined to withstand the design loads defined in 8.4.3 of this Section, using the following permissible stresses:

Permissible bending stress $[\sigma] = 120/K \text{ N/mm}^2$

Permissible shear stress $[\tau] = 80/K \text{ N/mm}^2$

Permissible equivalent stress $[\sigma_e] = \sqrt{\sigma^2 + 3\tau^2} = 150/K \text{ N/mm}^2$

where: K – material factor, but not to be taken less than 0.72 (unless a fatigue analysis is carried out).

8.4.2.2 The buckling strength of primary members is to be verified as being adequate.

8.4.2.3 For steel to steel bearings in securing and supporting devices, the nominal bearing pressure calculated by dividing the design force by the projected bearing area is not to exceed $0.8R_{eH}$, where R_{eH} is the yield stress of the bearing material. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer's specification.

8.4.2.4 The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces. The maximum tension in way of threads of bolts not carrying support forces is not to exceed $125/K$, in N/mm^2

8.4.3 Design loads

8.4.3.1 Bow doors

- (1) The design external pressure P_e , in kN/m^2 , which is to be considered for the scantlings of primary members, securing and supporting devices of bow doors, is not to be less than that obtained from the following formula:

$$P_e = 2.75 \lambda C_H (0.22 + 0.15 \tan \alpha) (0.4V \sin \beta + 0.6 \sqrt{L})^2 \text{ kN/m}^2$$

where: V — contractual ship's speed, in kn;

L — ship's length, in m, but need not be taken greater than 200 m;

λ — coefficient depending on the intended service of the ship:

$\lambda = 1$ for ships intended for unrestricted service;

C_H — coefficient, to be determined as follows:

$C_H = 0.0125L$ for $L < 80 \text{ m}$;

$C_H = 1$ for $L \geq 80 \text{ m}$;

α — flare angle at the point considered, defined as the angle between a vertical line and the tangent to the side shell, measured in a vertical plane normal to the horizontal tangent to the outer shell of the door, with the considered point being on the bow door, $l/2$ aft of the stem line on the plane $h/2$ above the bottom of the door, see Figure

9.4.3.1(1);

- l — length of the door on the plane $h/2$ above the bottom of the door, in m, see Figure 9.4.3.1(1);
- β — entry angle at the point considered, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane, with the considered point being the same as that of angle α , see Figure 8.4.3.1(1);
- h — height, in m, of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, whichever is the lesser.

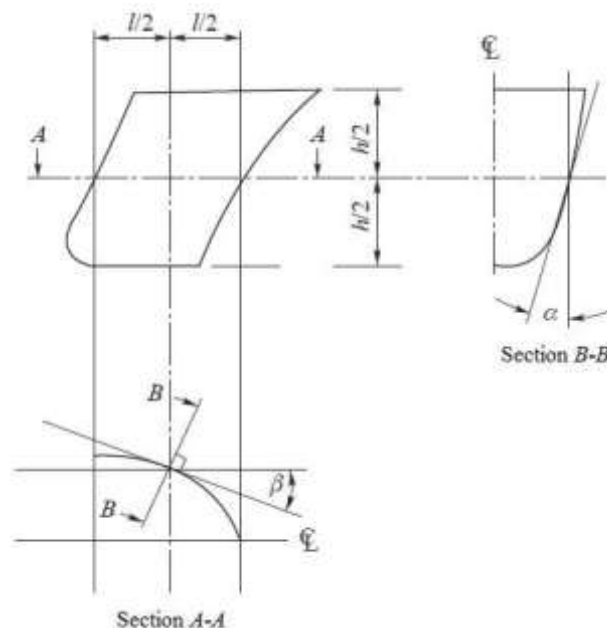


Figure 8.4.3.1(1)

- (2) The design external forces, in kN, considered for the scantlings of securing and supporting devices of bow doors are to be determined by the following formulae:

$$F_x = P_e A_x \text{ kN}$$

$$F_y = P_e A_y \text{ kN}$$

$$F_z = P_e A_z \text{ kN}$$

where: A_x — area, in m^2 , of the transverse vertical projection of the bow door between the levels of the bottom of the door and the top of the upper deck bulwark, or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is lesser. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the

upper deck or to the top of the door, whichever is lesser. In determining the height from the bottom of the door to the upper deck or to the top of the door, the bulwark is to be excluded. See Figure 8.4.3.1(2);

A_y — area, in m^2 , of the longitudinal vertical projection of the bow door between the levels

of the bottom of the door and the top of the upper deck bulwark, or between the bottom of the door

and the top of the door, including the bulwark, where it is part of the door, whichever is lesser. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser. See Figure 8.4.3.1(2);

A_z — area, in m^2 , of the horizontal projection of the bow door between the bottom of the door and the top of the upper deck bulwark, or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is the lesser. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser. See Figure 8.4.3.1(2).

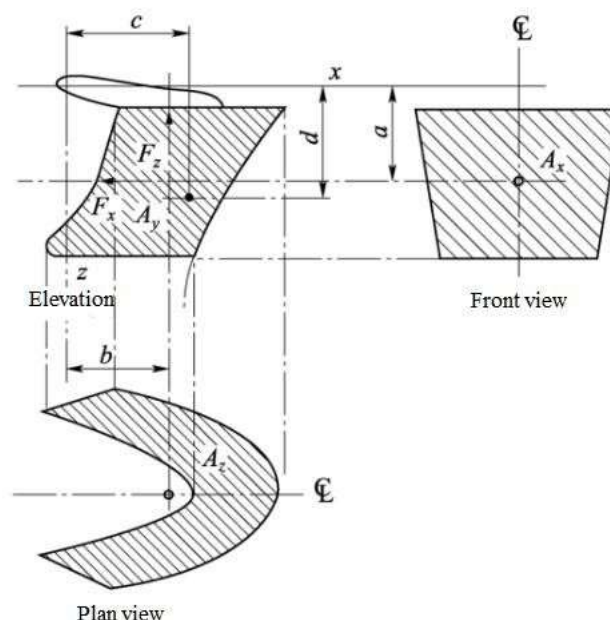


Figure 8.4.3.1(2)

For bow doors, including bulwark, of unusual form or proportions, e.g. ships with a rounded nose and large stem angles, the areas and angles used for determination of the design values of external forces are to be specially considered.

- (3) For visor doors the closing moment M_y under external loads, in $kN \cdot m$, is to be taken as:

$$M_y = F_x a + 10Wc - F_z b \text{ kN} \cdot \text{m}$$

where: F_x, F_z — to be obtained in accordance with 8.4.3.1(2);

W — mass of the visor door, in t;

a — vertical distance, in m, from visor pivot to the centroid of the transverse vertical projected area of the visor door, as shown in Figure 8.4.3.1(2);

b — horizontal distance, in m, from visor pivot to the centroid of the horizontal projected area of the visor door, as shown in Figure 8.4.3.1(2);

c — horizontal distance, in m, from visor pivot to the centre of gravity of visor mass, as shown in Figure 8.4.3.1(2).

- (4) Moreover, the lifting arms of a visor door and its supports are to be dimensioned for the static and dynamic forces applied during the lifting and lowering operations, and a minimum wind pressure of 1.5 kN/m^2 is to be taken into account.

8.4.3.2 Inner doors

- (1) The design external pressure considered for the scantlings of primary members, securing and supporting devices and surrounding structure of inner doors is to be taken as the greater of p_e , external pressure and p_h , hydrostatic pressure:

$$p_e = 0.45L \text{ kN/m}^2$$

$$p_h = 10h \text{ kN/m}^2$$

where: L — the ship's length, in m, need not be taken as greater than 200 m;

h — the distance, in m, from the load point under consideration to the top of the cargo space.

- (2) The design internal pressure p_i considered for the scantlings of securing devices of inner doors is not to be less than 25 kN/m^2 .

8.4.4 Scantlings of bow doors

8.4.4.1 General requirements

- (1) The strength of bow doors is to be commensurate with that of the surrounding structure.
- (2) Bow doors are to be adequately stiffened and means are to be provided to prevent lateral or vertical movement of the doors when closed. For visor doors, adequate strength for the opening and closing operations is to be provided in the connections of the lifting arms to the door structure and to the ship structure.

8.4.4.2 Plating and stiffeners

- (1) The thickness of the bow door plating is not to be less than that required for the side shell plating, using bow door stiffener spacing, but in no case less than the minimum required thickness of fore end shell plating.
- (2) The section modulus of horizontal or vertical stiffeners is not to be less than that required for end framing. Consideration is to be given, where necessary, to differences in fixity between ship's frames and bow door stiffeners.
- (3) The stiffener webs are to have a net sectional area A not less than:

$$A = \frac{QK}{10} \text{ cm}^2$$

where: Q — shear force, in kN, in the stiffener, calculated by using uniformly distributed external pressure p_e as given in 8.4.3.1(1);

K — material factor.

8.4.4.3 Primary structure

- (1) The bow door stiffeners are to be supported by primary members constituting the main stiffening elements of the door.
- (2) The primary members of the bow door and the hull structure in way are to have sufficient stiffness to ensure the integrity of the boundary support of the door.
- (3) Scantlings of the primary members are generally to be supported by direct strength calculations in association with the external pressure given in 8.4.3.1(1) of this Section and permissible stresses given in 8.4.2.1 of this Section. Normally, formulae for simple beam theory may be applied to determine the bending stress, with members being considered to have simply supported end connections.

8.4.5 Scantlings of inner doors

8.4.5.1 General requirements

- (1) Scantlings of the primary members are generally to be supported by direct calculations in association with the external pressure given in 8.4.3.2(1) and permissible stresses given in 9.4.2.1 of this Section. Normally, formulae for simple beam theory may be applied.
- (2) Where inner doors also serve as vehicle ramps, the scantlings are to comply with Section 6 of this Chapter.
- (3) The distribution of the forces acting on the securing and supporting devices is generally to be supported by direct calculations taking into account the flexibility of the structure and the actual position and stiffness of the supports.

8.4.6 Securing and supporting of bow doors

8.4.6.1 General requirements

- (1) Bow doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure. The hull supporting structure in way of the bow doors is to be suitable for the same design loads and design stresses as the securing and supporting devices. Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered. Maximum design clearance between securing and supporting devices is generally not to exceed 3 mm.

A means is to be provided for mechanically fixing the door in the open position.

- (2) Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small or flexible devices, such as cleats, intended to provide load compression of the packing material are generally not to be included in the calculations called for in 8.4.6.2(5) of this Section.

The number of securing and supporting devices are generally to be the minimum practical whilst taking into account the requirements for redundant provision given in 8.4.6.2(6) and 8.4.6.2(7) of this Section and the available space for adequate support in the hull structure.

- (3) For visor doors opening outwards, the pivot arrangement is generally to be such that the visor is self-closing under external loads, that is $M_y > 0$. Moreover, the closing moment M_y as given

in 8.4.3.1(3) is not to be less than:

$$M_y = 10Wc + 0.1 \sqrt{(a^2 + b^2)(F_x^2 + F_z^2)} \quad \text{kN} \cdot \text{m}$$

where: F_x , F_z — to be obtained in accordance with 9.4.3.1(2);

W — mass of the visor door, in t;

a — vertical distance, in m, from visor pivot to the centroid of the transverse vertical projected area of the visor door, as shown in Figure 8.4.3.1(2);

b — horizontal distance, in m, from visor pivot to the centroid of the horizontal projected area of the visor door, as shown in Figure 8.4.3.1(2);

c — horizontal distance, in m, from visor pivot to the centre of gravity of visor mass, as shown in Figure 8.4.3.1(2).

8.4.6.2 Scantlings

- (1) Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the permissible stresses given in 8.4.2.1.
- (2) For visor doors, the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self-weight of the door: Case 1: F_x and F_z ;
- (3) Case 2: $0.7F_y$ acting on each side separately together with $0.7F_x$ and $0.7F_z$.

For side-opening doors, the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self-weight of the door:

Case 1: F_x , F_y and F_z acting on both doors;

Case 2: $0.7F_x$ and $0.7F_z$ acting on both doors and $0.7F_y$ acting on each door separately.

F_x , F_y and F_z in (2) and (3) above are determined as indicated in 8.4.3.1(2) and applied at the centroid of projected areas.

- (4) The support forces as determined according to 8.4.6.2(2) and (3) (Case 1) are generally to give rise to a zero moment about the transverse axis through the centroid of the area A_x (see Figure 8.4.3.1(2)). For visor doors, longitudinal reaction forces of pin and/or wedge supports at the door base contributing to this moment are not to be of the forward direction.
- (5) The distribution of the reaction forces acting on the securing and supporting devices may require to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports.
- (6) The arrangement of securing and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable of withstanding the reaction forces without exceeding by more than 20% the permissible stresses as given in 8.4.2.
- (7) For visor doors, two securing devices are to be provided at the lower part of the door, each capable of providing the full reaction force required to prevent opening of the door within the permissible stresses given in 8.4.2.1 of this Section. The opening moment M_0 to be balanced by this reaction force is not to be taken less than:

$$M_0 = 10Wd + 5A_x a \text{ kN}\cdot\text{m}$$

where: A_x — to be obtained from 8.4.3.1(2) of this Section;

W — mass of the visor door, in t;

a — vertical distance, in m, from visor pivot to the centroid of the transverse vertical projected area of the visor door, as shown in Figure 8.4.3.1(2);

d — vertical distance, in m, from the hinge axis to the centre of gravity of the door, as shown in Figure 8.4.3.1(2).

- (8) For visor doors, the securing and supporting devices excluding the hinges should be capable of resisting the vertical design force:

$$F_z = 10W, \text{ in kN, within the permissible stresses given in 8.4.2.1}$$

where: F_z — to be obtained from 8.4.3.1(2);

W — mass of the visor door, in t.

- (9) All load transmitting elements in the design load path, from door through securing and supporting devices into the ship structure, including welded connections, are to be to the same strength standard as required for the securing and supporting devices. These elements include pins, supporting brackets and back-up brackets.
- (10) For side-opening doors, a thrust bearing has to be provided in way of girder ends at the closing of the two leaves to prevent one leaf to shift towards the other one under the effect of unsymmetrical pressure (see example of Figure 8.4.6.2). Each part of the thrust bearing has to be kept secured on the other part by means of securing devices. Any other arrangement serving the same purpose may be proposed.

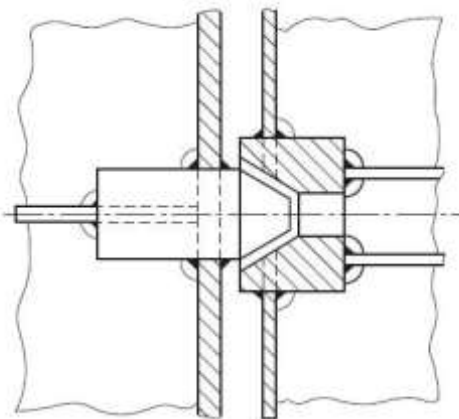


Figure 8.4.6.2

8.4.7 Securing and locking arrangements

8.4.7.1 Systems for operation

- (1) Securing devices are to be simple to operate and easily accessible. Securing devices are to be equipped with mechanical locking arrangement (self-locking or separate arrangement), or to be of the gravity type.
- (2) The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

Bow doors and inner doors giving access to vehicle decks are to be provided with an arrangement for remote control, from a position above the freeboard deck, of:

- ① the closing and opening of the doors; and
- ② associated securing and locking devices for every door.

Indication of the open/closed position of every door and every securing and locking device is to be provided at the remote control stations. The operating panels for operation of doors are to be inaccessible to unauthorized persons. A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

- (3) Where hydraulic securing devices are applied, the system is to be mechanically lockable in closed position. This means that, in the event of loss of the hydraulic fluid, the securing devices remain locked. The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits, when in closed position.

8.4.7.2 For indication/monitoring systems of doors, refer to the relevant requirements in Section 9, Chapter 2 of PART FOUR of the Rules.

8.4.8 Operating and maintenance manual

8.4.8.1 An Operating and Maintenance Manual for the bow door and inner door is to be provided on board and is to contain necessary information on:

- (1) Main particulars and design drawings:
 - Special safety precautions; Details of ship;
 - Equipment and design loading (for ramps); Key plan of equipment (doors and ramps);
 - Manufacturer's recommended testing for equipment;
 - Description of equipment: bow doors, inner bow doors, bow ramp/doors, side doors, stern doors, central power pack, bridge panel, engine control room panel.
- (2) Service conditions:
 - Limiting heel and trim of ship for loading/unloading; Limiting heel and trim for door operations;
 - Doors/ramps operating instructions;
 - Doors/ramps emergency operating instructions.
- (3) Maintenance:
 - Schedule and extent of maintenance;
 - Trouble shooting and acceptable clearances; Manufacturer's maintenance procedures.
- (4) Register of inspections, including inspection of locking, securing and supporting devices, repairs and renewals.

It is to be ensured that the abovementioned items are contained in the OMM and that the maintenance part includes the necessary information with regard to inspections, troubleshooting and acceptance/rejection criteria.

8.4.8.2 Documented operating procedures for closing and securing the bow door and inner door are to be kept on board and posted at appropriate place.

SECTION 5 - SIDE SHELL AND STERN DOORS

8.5.1 General requirements for side and stern doors

8.5.1.1 This Section applies to the arrangement, strength and securing of side shell doors, abaft the collision bulkhead, and of stern doors leading to enclosed spaces.

8.5.1.2 Stern doors for passenger ships are to be situated above the freeboard deck. Stern doors for ro-ro cargo ships and side shell doors may be either below or above the freeboard deck.

8.5.1.3 Side shell doors and stern doors are to be so fitted as to ensure tightness and structural integrity commensurate with their location and the surrounding structure.

8.5.1.4 Where the sill of any side shell door is below the uppermost load line, the arrangement is to be specially considered, i.e. an inner door of equivalent strength and watertightness is to be fitted in the place. In that case a leakage detection device is to be provided in the compartment between the two doors. Further, drainage of this compartment to the bilges controlled by an easily accessible screw-down valve is to be arranged.

8.5.1.5 The doors are to preferably open outwards.

8.5.1.6 Definitions

- (1) Securing device means a device used to keep the door closed by preventing it from rotating about its hinges or about pivoted attachments to the ship.
- (2) Supporting device and locking device, ro-ro passenger ship, ro-ro space and special category space are as defined in 8.4.1.3, Section 4 of this Chapter.

8.5.2 Strength criteria of side shell doors and stern doors

8.5.2.1 Scantlings of the primary members, securing and supporting devices of side shell doors and stern doors are to be determined to withstand the design loads defined in 9.5.3, using the following permissible stresses:

Permissible bending stress $[\sigma] = 120/K \text{ N/mm}^2$

Permissible shear stress $[\tau] = 80/K \text{ N/mm}^2$

Permissible equivalent stress $[\sigma_e] = [\sigma_e] = \sqrt{\sigma^2 + 3\tau^2} = 150/K \text{ N/mm}^2$

where: K — material factor, not to be taken less than 0.72 unless a direct strength analysis with regard to relevant modes of failures is carried out.

8.5.2.2 The buckling strength of primary members is to be verified as being adequate.

8.5.2.3 For steel to steel bearings in securing and supporting devices, the nominal bearing pressure calculated by dividing the design force by the projected bearing area is not to exceed $0.8ReH$, where ReH is the yield stress of the bearing material. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer's specification.

8.5.2.4 The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces. The maximum tension in way of threads of bolts not carrying support forces is not to exceed $125/K$, in N/mm^2 , with K defined in 8.5.2.1 above.

8.5.3 Design loads of side shell doors and stern doors

8.5.3.1 The design forces, considered for the scantlings of primary members, securing and supporting devices of side shell doors and stern doors are not to be less than:

(1) Design forces for securing or supporting devices of doors opening inwards:

$$\text{External } F_e = AP_e + F_p \quad \text{kN}$$

$$\text{Internal force: } F_i = F_o + 10W \quad \text{kN}$$

(2) Design forces for securing or supporting devices of doors opening outwards:

$$\text{External } F_e = AP_e \quad \text{kN}$$

$$\text{Internal force: } F_i = F_o + 10W + F_p \quad \text{kN}$$

(3) Design forces for primary members:

$$\text{External force: } F_e = Ape \quad \text{kN}$$

$$\text{Internal force: } F_i = F_o + 10W \quad \text{kN}$$

where: A — area, in m^2 , of the door opening;

W — mass of door, in t;

F_p — total packing force in kN; packing line pressure is normally not to be taken less than 5 N/mm;

F_o — the greater of F_c and $5A$, in kN;

F_c — accidental force, in kN, due to loosening of cargo, etc., to be uniformly distributed over the area A and not to be taken less than 300 kN. For small doors such as bunker doors and pilot doors, the value of F_c may be appropriately reduced. However, the value of F_c may be taken as zero, provided an additional structure such as an inner ramp is fitted, which is capable of protecting the door from accidental forces due to loose cargoes, etc.;

P_e — external design pressure, in kN/m^2 , determined at the centre of gravity of the door opening and not taken less than:

$$P_e = 10(T - ZG) + 25 \quad kN/m^2, \text{ for } ZG < d$$

$$P_e = 25 \quad kN/m^2, \text{ for } ZG \geq d$$

Moreover, for stern doors of ships fitted with bow doors, P_e is not to be taken less than:

$$P_e = 0.6\lambda C_H (0.8 + 0.6\sqrt{L})^2 \text{ kN/m}^2$$

- where: d — draught, in m, at the highest subdivision load line, in m;
 Z_G — height of the centre of area of the door, in m, above the baseline;
 λ — coefficient depending on the area where the ship is intended to be operated:
 $\lambda = 1$ for ships intended for unrestricted service;
 C_H — coefficient, to be determined as follows:
 $C_H = 0.0125L$ for $L < 80$ m;
 $C_H = 1$ for $L \geq 80$ m;
 L — the ship's length, in m, need not be taken as greater than 200 m.

8.5.4 Scantlings of side shell doors and stern doors

8.5.4.1 The strength of side shell doors and stern doors is to be commensurate with that of the surrounding structure.

8.5.4.2 Side shell doors and stern doors are to be adequately stiffened and means are to be provided to prevent any lateral or vertical movement of the doors when closed. Adequate strength is to be provided in the connections of the lifting/manoeuvring arms and hinges to the door structure and to the ship's structure.

8.5.4.3 Where doors also serve as vehicle ramps, the design of the hinges should take into account the ship angle of trim and heel which may result in uneven loading on the hinges.

8.5.4.4 Shell door openings are to have well-rounded corners and adequate compensation is to be arranged with web frames at sides and stringers or equivalent above and below and they are to comply with the relevant requirements in 2.3.7 of Section 3, Chapter 2 of this PART.

8.5.4.5 The thickness of the door plating is not to be less than the required thickness for the side shell plating, using the door stiffener spacing, but in no case less than the minimum required thickness of shell plating. Where doors serve as vehicle ramps, the plating thickness is to comply with Section 6 of this Chapter.

8.5.4.6 The section modulus of horizontal or vertical stiffeners is not to be less than that required for side framing. Consideration is to be given, where necessary, to differences in fixity between ship's frames and door stiffeners. Where doors serve as vehicle ramps, the stiffener scantlings are to comply with Section 6 of this Chapter.

8.5.4.7 The secondary stiffeners are to be supported by primary members constituting the main stiffening elements of the door.

8.5.4.8 The primary members and the hull structure in way are to have sufficient stiffness to ensure structural integrity of the boundary of the door.

8.5.4.9 Scantlings of the primary members are generally to be supported by direct strength calculations in association with the design forces given in 8.5.3.1 of this Section and permissible stresses given in 8.5.2.1 of this Section. Normally, formulae for simple beam theory may be applied to determine the bending stresses. Members are to be considered to have simply supported end connections.

8.5.5 Securing and supporting of doors

8.5.5.1 Side shell doors and stern doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure. The hull supporting structure in way of the doors is to be suitable for the same design loads and design stresses as the securing and supporting devices.

Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered.

Maximum design clearance between securing and supporting devices is generally not to exceed 3 mm.

A means is to be provided for mechanically fixing the door in the open position.

8.5.5.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide local compression of the packing material are generally not to be included in the calculations called for in 8.5.5.4. The number of securing and supporting devices are generally to be the minimum practical whilst taking into account the requirement for redundant provision given in 8.5.5.5 and the available space for adequate support in the hull structure.

8.5.5.3 Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the permissible stresses given in 8.5.2.1.

8.5.5.4 The distribution of the reaction forces acting on the securing devices and supporting devices may be supported by direct calculations taking into account the flexibility of the hull structure and the actual position of the supports.

8.5.5.5 The arrangement of securing devices and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable of withstanding the reaction forces without exceeding by more than 20% the permissible stresses as given in 8.5.2.1.

8.5.5.6 All load transmitting elements in the design load path, from the door through securing and supporting devices into the ship's structure, including welded connections, are to be to the same strength standard as required for the securing and supporting devices. These elements include pins, support brackets and back-up brackets.

8.5.6 Securing and locking arrangement and systems for operation

8.5.6.1 Securing devices are to be simple to operate and easily accessible.

Securing devices are to be equipped with mechanical locking arrangement (self-locking or separate arrangement), or are to be of the gravity type. The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

8.5.6.2 Doors which are located partly or totally below the freeboard deck with a clear opening area greater than 6 m² are to be provided with an arrangement for remote control, from a position above the freeboard deck, of the closing and opening of the doors and associated securing and locking devices. For doors which are required to be equipped with a remote control arrangement, indication of the open/closed position of the door and the securing and locking device is to be provided at the remote control stations. The operating panels for operation of doors are to be inaccessible to unauthorized persons. A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

8.5.6.3 Where hydraulic securing devices are applied, the system is to be mechanically lockable in closed position. This means that, in the event of loss of the hydraulic fluid, the securing devices remain locked. The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits, when in closed position.

8.5.6.4 For the indicating/monitoring systems of doors, see the relevant requirements in Section 9, Chapter 2 of PART FOUR of the Rules.

8.5.7 Operating and Maintenance Manual

8.5.7.1 An Operating and Maintenance Manual for the side shell and stern doors is to be provided on board and is to contain the necessary information on:

(1) Main particulars and design drawings

Special safety precautions; Details of ship;

Equipment and design loading (for ramps);

Key plan of equipment (doors and ramps);

Manufacturer's recommended testing for equipment;

Description of equipment: bow doors, inner bow doors, bow ramp/doors, side doors, stern doors, central power pack, bridge panel, engine control room panel.

(2) Service conditions

Limiting heel and trim of ship for loading/unloading; Limiting heel and trim for door operations;

Doors/ramps operating instructions;

Doors/ramps emergency operating instructions.

(3) Maintenance

Schedule and extent of maintenance;

Trouble shooting and acceptable clearances; Manufacturer's maintenance procedures.

(4) Register of inspections and repairs

Including inspection of locking, securing and supporting devices, repairs and renewals.

It is to be ensured that the above mentioned items are contained in the OMM and that the maintenance part includes the necessary information with regard to inspections, troubleshooting and acceptance/rejection criteria.

8.5.7.2 Documented operating procedures for closing and securing side shell and stern doors are to be kept on board and posted at the appropriate places.

SECTION 6 - VEHICLE RAMPS**8.6.1 Structural strength of vehicle ramps**

8.6.1.1 The relevant requirements of Section 21, Chapter 2 of this PART are to be complied with.

8.6.2 Framing of vehicle ramps

8.6.2.1 The strength is to be checked in accordance with the following requirements:

- (1) the ramp is in a lowered position;
- (2) the design vehicle load multiplied by coefficient 1.1 is the load acting on the ramp at its worst position and the mass of the ramp is also to be considered;
- (3) allowable bending stress $[\sigma] = 141/K$, in N/mm^2 , with K being the material factor; allowable deflection $[f] = l/200$ mm, with l being the distance between the supporting points of primary structures of vehicle ramps, in mm.

8.6.3 Connecting hinges of vehicle ramps

8.6.3.1 The following requirements are to be complied with:

- (1) The diameter d of the axial pin is to comply with the following:

$$d \geq d_0$$

- (2) The size of the central eye plate of hinges is to comply with the following:

$$\frac{F}{2b_0t_0} \leq [\tau], \quad b_0 \geq d_0$$

- (3) The size of the eye plates on both sides of hinges is to comply with the following:

$$\frac{F}{4t_1t_2} \leq [\tau], \quad t_1 \geq d_0 / 2$$

where: d_0 — minimum required diameter of the axial pin, $d_0 = 0.92 \sqrt{\frac{F}{[\tau]}}$ mm;

F — maximum force transmitted by the hinge, in N;

t_1, t_2, b_0, t_0, d — size of hinge parts, in mm, see Figure 8.6.3;

$[\tau]$ — allowable shear stress, to be taken as $[\tau] = 81.6/K$, in N/mm^2 , K being the material factor.

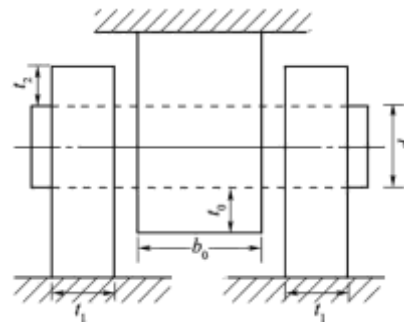


Figure 8.6.3

SECTION 7 - DIRECT CALCULATIONS

8.7.1 General requirements

8.7.1.1 This Section specifies the methods to be used in direct calculations for the strength of transverses and girders of vehicle deck framing and for the transverse strength of hull structure.

8.7.2 Design loads and loading conditions

8.7.2.1 For the acceleration of ship motions, see the relevant requirements of Section 5, Chapter 1 of this PART

8.7.2.2 For direct strength calculation of vehicle deck structure, the deck load is to be calculated as follows:

Vertical load	$P_h = (g + 0.5a_v)M$	kN
Uniformly distributed load	$P_{d_h} = (g + 0.5a_v)p$	kN/m ²
Deck weight load	$P_{s_h} = (g + 0.5a_v)m_s$	kN/m ²

where: g — acceleration due to gravity, to be taken as 9.81 m/s²;

a_v — vertical composite acceleration, in m/s², see 8.7.2.1 of this Section;

M — design vehicle mass, in t;

p — design uniformly distributed load of vehicle deck, in t/m², not to be less than 0.25 t/m²;

m_s — deck weight, in t/m².

8.7.2.3 For direct calculation of transverse strength, the ship is assumed to heel to maximum heeling angle (if hull structures are not symmetrical to the longitudinal centerline, rolling towards portside and rolling towards starboard are to be considered separately) and the design load is to be calculated as follows:

(1) Vertical load and transverse load of vehicle deck are to be respectively calculated as follows:

Vertical load of vehicle	$P_{r_v} = (g \cos \varphi_m + 0.5a_v)M$	kN
Transverse load of vehicle	$P_{r_t} = (g \sin \varphi_m + 0.5a_t)M$	kN
Uniformly distributed vertical load	$P_{d_{r_v}} = (g \cos \varphi_m + 0.5a_v)p$	kN/m ²
Uniformly distributed transverse load	$P_{d_{r_t}} = (g \sin \varphi_m + 0.5a_t)p$	kN/m ²

Deck weight vertical load	$p_{s\_r\_v} = (g \cos \varphi_m + 0.5a_v)m_s$ kN/m ²
Deck weight transverse load	$p_{s\_r\_t} = (g \sin \varphi_m + 0.5a_t)m_s$ kN/m ²

where: g — acceleration due to gravity, to be taken as 9.81 m/s²;

φ_m — maximum heeling angle, in rad, see 8.7.2.1 of this Section, to be taken not less than 0.35 rad;

a_v — vertical composite acceleration, in m/s², see 8.7.2.1 of this Section;

a_t — transverse composite acceleration, in m/s², see 8.7.2.1 of this Section;

M — design vehicle mass, in t;

p — design uniformly distributed load of vehicle deck, in t/m², not to be less than 0.25 t/m²;

m_s — deck weight, in t/m².

(2) Vertical load and transverse load of superstructure deck and deckhouse deck are to be respectively calculated as follows:

$$\begin{array}{ll} \text{Vertical load} & p_{u\_r\_v} = (g \cos \varphi_m + 0.5a_v)m_0 \quad \text{kN/m}^2 \\ \text{Transverse load} & p_{u\_r\_t} = (g \sin \varphi_m + 0.5a_t)m_0 \quad \text{kN/m}^2 \end{array}$$

where: g — acceleration due to gravity, to be taken as 9.81 m/s²;

φ_m — maximum heeling angle, in rad, see 8.7.2.1 of this Section, to be taken not less than 0.35 rad;

a_v — vertical composite acceleration, in m/s², see 8.7.2.1 of this Section;

a_t — transverse composite acceleration, in m/s², see 8.7.2.1 of this Section;

m_0 — design load including deck weight, in t/m², not to be less than 0.25 t/m².

(3) The hydrostatic pressure p_{hs} , which is to be calculated in accordance with 1.5.3.2 of Section 5 of Chapter 1, is to be taken as the external sea pressure.

8.7.2.4 Calculation conditions are given in Tables 8.7.2.4.

Table 8.7.2.4 - Calculations conditions

Condition	Load Area	Direction Calculations of Vehicle Deck Strength	Direction Calculations of Transverse Strength
1	Vehicle Deck	Vehicle load: Ph Deck weight load: ps_h	Vehicle vertical load: Pr_v Vehicle transverse load: Pr_t Deck weight vertical load: ps_r_v Deck weight transverse load: ps_r_t
	Superstructure and Deckhouse	—	Vertical load: pu_r_v Transverse load: pu_r_t
	External	—	Hydrostatic pressure: p_{hs}
2	Vehicle Deck	Uniformly distributed load: Pd_h Deck weight load: ps_h	Uniformly distributed vertical load: pd_r_v Uniformly distributed transverse load: pd_r_t Deck weight vertical load: ps_r_v Deck weight transverse load: ps_r_t
	Superstructure and Deckhouse	—	Vertical load: pu_r_v Transverse load: pu_r_t
	External	—	Hydrostatic pressure: p_{hs}

8.7.3 Model and boundary conditions for strength calculation of vehicle deck structure

8.7.3.1 A 2- or 3-dimensional beam or plate/beam model may be used for direct strength calculations of vehicle deck structure, and the extent of the model is usually based on the following principles: Girders and transverses of the vehicle deck are to be taken as main objects of analysis, covering at least half the longitudinal length of the deck. Alternatively, a typical portion of the deck structure may be taken for modelling according to specific conditions of load distribution, deck structure and its supporting structures (e.g. pillars, bulkheads). Regardless of the length of the model, the whole tier of deck is to be considered for the selection of loads.

8.7.3.2 To minimize the effects of boundary constraints on the results of vehicle deck structure strength calculations, the boundary conditions are preferably to be applied at a suitable distance above and/or below the vehicle deck plane. For the fore and aft end planes of the model, the displacement in the longitudinal direction and the rotation about the coordinate axis perpendicular to the longitudinal direction are to be taken as zero.

8.7.4 Model and boundary conditions for transverse strength calculation

8.7.4.1 A 2- or 3-dimensional beam or plate/beam model may be used for direct transverse strength calculations, and the extent of the model is usually based on the following principles: Primary members of the deck and their supporting structures (e.g. pillars, bulkheads, side structures and transverse webs) are to be taken as main objects of analysis, covering at least in the vertical direction all tiers of decks and their supporting structures starting from baseline to the uppermost deck, in the transverse direction the entire breadth of the ship, and in the longitudinal direction at least the length of 5 strength frame rings or one design length of a vehicle amidships, whichever is the greater.

8.7.4.2 For the fore and aft end planes of the model, the displacement in the longitudinal direction and the rotation about the coordinate axis perpendicular to the longitudinal direction are to be taken as zero; For intersection lines AA' , BB' , CC' , DD' of side ring frame or web frame and side shell plating, the displacement in vertical direction is to be taken as zero. For the intersection line $A'B'$ of inner bottom and portside shell plating, the displacement in transverse direction is to be taken as zero. Where inner bottom is not provided, the constraint of displacement in transverse direction may be applied to the intersection line EF of centre keelson and bottom plating (or similar position), see Figure 8.7.4.2.

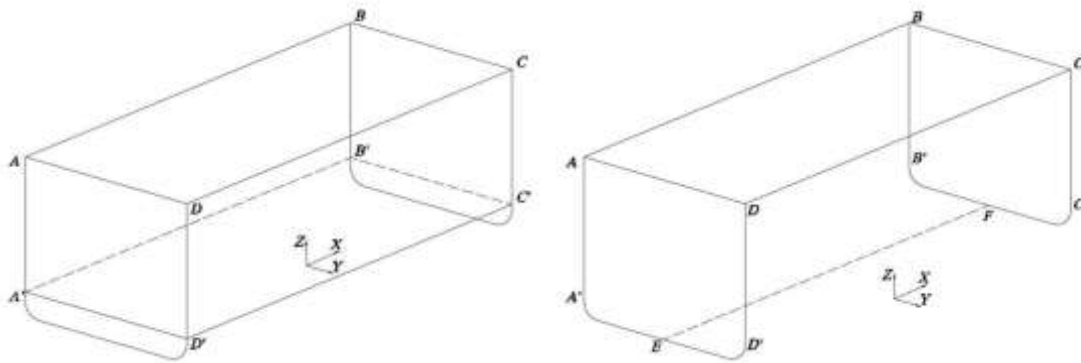


Figure 8.7.4.2

8.7.5 Permissible stresses

8.7.5.1 Permissible stresses for the 2- or 3-dimensional beam model:

Permissible bending stress $[\sigma]$ is to be: $[\sigma] = 165/K$, in N/mm^2

but $[\sigma]$ may be taken as $180/K$, in N/mm^2 , for primary transverse members;

Permissible shear stress $[\tau]$ is to be: $[\tau] = 94/K$, in N/mm^2

where: K — material factor;

σ — bending stress, in N/mm^2 ;

τ — shear stress, in N/mm^2 .

8.7.5.2 Permissible stress for plate/beam model

Permissible shear stress $[\tau]$ is to be: $[\tau] = 94/K$, in N/mm^2 ;

Permissible equivalent stress $[\sigma_e]$ is to be: $[\sigma_e] = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3\tau_{xy}^2} = 180/K$, N/mm^2

where: K — material factor;

σ_x — normal stress of the element in X direction under plane stress, in N/mm^2 ;

σ_y — normal stress of the element in Y direction under plane stress, in N/mm^2 ;

τ_{xy} — shear stress of the element in X direction under plane stress, in N/mm^2 .

SECTION 8 - EXTERNAL GLASS BALUSTRADES

8.8.1 General

8.8.1.1 The requirements of this Section apply solely to external glass balustrades. External glass balustrades are barriers constructed with glass that are used on exposed decks.

8.8.1.2 Glass balustrades, in lieu of bulwark or guard rails (see Section 19, Chapter 2 of this PART), may be accepted on exposed decks above position 2 specified in 1.1.2.22, Section 1, Chapter 1 of this PART, except on mooring deck and in way of lifeboats and life rafts and embarkation stations.

8.8.1.3 Glass is to be manufactured in accordance with a recognised National or International Standard.

7.15.3.3 The detailed arrangement, applicable loads and structural strength calculations are to be submitted to ISC.

7.15.3.4

8.8.2 Arrangement requirements

8.8.2.1 External glass balustrades are to be not less than 1 m in height.

8.8.2.2 In general, openings (e.g. the gaps between panels or the gap between the deck and the bottom of a panel) are not to be greater than 76 mm unless required for water freeing.

8.8.2.3 If a well is formed, the necessary drainage port is to be provided. Openings for water freeing are not to be greater than 230 mm.

8.8.3 Design pressure

8.8.3.1 For the lowest weather deck, the minimum design pressure P_W of glass balustrades is to be calculated as follows: $P_W = 9.81h$, kN/m²

where: h —head in 2.17.2, Section 17, Chapter 2 of this PART.

8.8.3.2 For higher exposed decks, the minimum design pressure P_W of glass balustrades is to be calculated as follows:

(1) Below 1.7C m above the scantling draught, $P_W = 5 \text{ kN/m}^2$, where C is the coefficient as specified in 2.2.3.1, Section 2, Chapter 2 of this PART;

(2) For other locations, $P_W = 2.5 \text{ kN/m}^2$.

8.8.4 Minimum scantling requirements

8.8.4.1 External glass balustrades using monolithic glass are to comply with the following requirements:

(1) Minimum thickness of glass is not to be less than 6.0 mm;

- (2) Top rail is required, with a minimum section modulus of 17 cm³;
 (3) Stanchions is to be fitted, not more than 1.5 m apart, with minimum section modulus of 20 cm³.

8.8.4.2 External glass balustrades using laminated glass are to comply with the following requirements:

- (1) Minimum thickness for each glass pane is not to be less than 4 mm;
 (2) Top rail is required, with a minimum section modulus of 17 cm³;
 (3) Stanchions is to be fitted, not more than 1.5 m apart, with minimum section modulus of 20 cm³.

8.8.4.3 The section modulus requirements in 8.8.4.1 and 8.8.4.2 above are based on steel. For other metallic materials, equivalent section modulus is to be calculated.

8.8.4.4 The glass panes are to be supported at minimum two opposite sides by metallic mounting frames. The glass panes can be fixed to the metal frame by mechanical means or adhesive. If the metal mounting frames are connected to the stanchion by bolts, there is to be no less than two force bolts on one side.

8.8.4.5 The overlap between the glass panes and metallic frames is not to be less than 10 mm or $b/75$ mm, whichever is greater, but not more than 20 mm, b is the breadth of the glass pane, in mm.

8.8.4.6 In public areas, laminated glass panes are required for external glass balustrades.

8.8.5 Glass thickness

8.8.5.1 For monolithic toughened glass, the thickness is to be less than the value obtained from the following formula: $t = b\sqrt{\beta P} / 200$ mm

where: b — length of the shorter side of the glass, in mm;

P — load for calculation,

$P = 0.5P_w$, in kN/m²;

P_w — design pressure, in kN/m², see 9.8.3 of this Section;

β — coefficient, to be taken as follows:

- 1) glass with firm support on all sides : $\beta = 0.54A_R - 0.078A_R^2 - 0.17$ for $A_R \leq 3.6$
 $\beta = 0.7645$ for $A_R > 3.6$

- 2) glass with firm support on two sides only: $\beta = 0.7645$

where: A_R — aspect ratio of rectangle window, to be taken as follows

$$A_R = a / b$$

a — length of the longer side of the glass, in mm;

b — length of the shorter side of the glass, in mm.

8.8.5.2 For laminated toughened glass, the equivalent thickness is to be less than the value obtained from 8.8.5.1. The equivalent thickness is calculated according to the following formula:

$$t_e = \sqrt{\sum_{i=1}^n t_i^2} \quad \text{mm}$$

where: n — number of glass layers;

t_i — thickness of the i^{th} layer glass.

8.8.6 Balustrade stanchions

8.8.6.1 For balustrade stanchions below 1.7C m above the scantling draught, the section modulus W at the bottom is not to be less than:

$$W = 655 \frac{P S l^2}{R_{eH}} \quad \text{cm}^3$$

where: S — distance between stanchions, in m;

l — height of the stanchion, in m;

P — load for calculation, $P = P_w$, in kN/m²;

P_w — design pressure, in kN/m², see 8.8.3 of this Section;

R_{eH} — yield stress of material, in N/mm².

8.8.6.2 For balustrade stanchions below 1.7C m above the scantling draught, the shear area A at the bottom is not to be less than:

$$A = 22.7 \frac{P S l}{R_{eH}} \quad \text{cm}^2$$

where: S — distance between stanchions, in m;

l — height of the stanchion, in m;

P — load for calculation, $P = P_w$, in kN/m²;

R_{eH} — yield stress of material, in N/mm².

CHAPTER 9 TUGS

SECTION 1 - GENERAL PROVISIONS

9.1.1 Application

9.1.1.1 The provisions of this Chapter apply to ships intended exclusively for towing.

9.1.1.2 Those not covered in this Chapter are to comply with the relevant requirements of Chapter 2 of this PART.

9.1.1.3 For the determination of scantlings of tugs, the draught d used is not to be less than 85% of the moulded depth.

9.1.1.4 For the calculation of rudder force, the design speed V of the ship is not to be taken as less than 10 kn.

9.1.2 Class notation

9.1.2.1 Tugs complying with the requirements of this Chapter are eligible to be assigned the class notation of Tug.

9.1.3 Plans and documents

9.1.3.1 In addition to those specified in Section 1, Chapter 2 of this PART, the following plan is to be submitted for approval:

- (1) Supporting structure of towing equipment (appropriate strength calculations are submitted for information).
- (2) Towing arrangement.
- (3) Fender (structure) arrangement.

SECTION 2 - HULL FRAMING

9.2.1 Web beam

9.2.1.1 A web beam is to be arranged throughout in way of the mid-portion of the long opening for the machinery space.

9.2.2 Side strengthening outside the fore peak

9.2.2.1 Where the side is framed transversely, the side framing outside the fore peak is to be strengthened in compliance with the requirements of 2.15.2, Chapter 2 of this PART, and the strengthened region is to be extended to $0.3L$ from the F.P. Within the region of strengthening, the section moduli of the main and 'tween deck frames are to be 20% greater than those required in Section 7, Chapter 2 of this PART.

SECTION 3 - MACHINERY CASINGS

9.3.1 Machinery casings

9.3.1.1 The height of exposed machinery casings is not to be less than 900 mm. The stiffeners of the casings are to be spaced not more than 750 mm apart. The thickness of casing wall is to be increased by 20 % over that required in 2.17.9.3, Chapter 2 of this PART, while the section modulus of the stiffeners is to be increased by 50 % over that required in 2.17.9.3, Chapter 2 of this PART.

SECTION 4 - BULWARKS AND FENDERS

9.4.1 Bulwarks

9.4.1.1 Tugs are to be provided with tumble-home bulwarks and the thickness t of bulwark plating is to comply with the following requirements:

$$t = 5 \text{ mm} \quad \text{for } L \leq 30 \text{ m};$$

$$t = 6 \text{ mm} \quad \text{for } 30 < L < 50 \text{ m};$$

$$t = 7 \text{ mm} \quad \text{for } L \geq 50 \text{ m}.$$

where: L — length of ship, in m.

9.4.1.2 The bulwarks are to be supported by stays with a flange or face plate. The stays are to be spaced not more than two frame spaces apart and are to be in line with the beams.

9.4.2 Fenders

9.4.2.1 Fenders are to be fitted along the deck line at side over the full length of the tug and are to have a thickness equal to that of side shell plating at $0.4L$ amidships. Stiffeners are to be arranged inside the fenders.

SECTION 5 - TOWING ARRANGEMENTS AND SUPPORTING STRUCTURE

9.5.1 Towing hooks and towing winches

9.5.1.1 Towing hooks or the position of fixed towing guide point are normally to be situated at 5% to 10% of the ship's length abaft amidships, but in no case are they to be sited forward of the longitudinal centre of gravity of the tug in any anticipated condition of loading. In addition, they are to be located as low as practicable in order to minimize heeling moments arising in normal working conditions.

9.5.1.2 Towing winches and its members are to undertake the breaking loads of the towline selected by the tug and without permanent deformation. Towing hooks are to undertake the testing loads and without permanent deformation. The breaking loads of towlines and the testing loads of towing hooks may be determined according to ISC Guidelines for Towage at Sea.

9.5.2 Releasing arrangements

9.5.2.1 Towing hooks are to have reliable slip arrangements which facilitate towline releasing regardless of the direction of the towing line or the angle of heel and can avoid any inadvertent slipping.

9.5.2.2 The operating position of the slip arrangements is to be such as to ensure free visibility of the towing hook. It is recommended that the slip arrangements also be operable from the bridge.

9.5.3 Supporting structure

9.5.3.1 Pillars or pillar bulkheads are to be provided as far as possible under towing arrangements.

9.5.3.2 The design load for the supporting structure in way of towing arrangements is not to be less than the breaking loads of the towline selected by the tug.

9.5.3.3 The scantlings of primary members of the supporting structure are to be determined by direct calculations using the following allowable stresses:

Allowable shear stress: $[\tau] = 87/K$ N/mm²;

Allowable bending stress: $[\sigma] = 150/K$ N/mm²;

Allowable equivalent stress: $[\sigma_e] = \sqrt{\sigma^2 + 3\tau^2} = 213/K$ N/mm².

where: K — material factor.

SECTION 6 - TOWING WINCH EMERGENCY RELEASE SYSTEMS

9.6.1 Scope and definitions

9.6.1.1 This Section defines minimum safety standards for winch emergency release systems provided on towing winches that are used on towing ships within close quarters, ports or terminals, including those ships normally not intended for towing operation in transverse direction.

9.6.1.2 This Section is not intended to cover towing winches on board ships used solely for long distance ocean towage, anchor handling or similar offshore activities.

9.6.1.3 This Section applies to ships contracted for construction on or after 1 January 2020.

9.6.1.4 The purpose of this section is to provide requirements to prevent the capsize of a tug when in the act of towage as a result of the towline force acting transversely to the tug (in beam direction) as a consequence of an unexpected event (could be loss of propulsion/steering or otherwise), whereby the resulting couple generated by offset and opposing transverse forces (towline force is opposed by thrust or hull resistance force) causes the tug to heel and, ultimately, to capsize, see Figure 10.6.1.4.

9.6.1.5 For the purposes of this Section, definitions are as follows:

- (1) Emergency release system refers to the mechanism and associated control arrangements that are used to release the load on the towline in a controlled manner under both normal and black out conditions.
- (2) Maximum design load is the maximum load that can be held by the winch as defined by the manufacturer (the manufacturer's rating).
- (3) Fleet angle is the angle between the applied load (towline force) and the towline as it is wound onto the winch drum, see Figure 10.6.1.5.

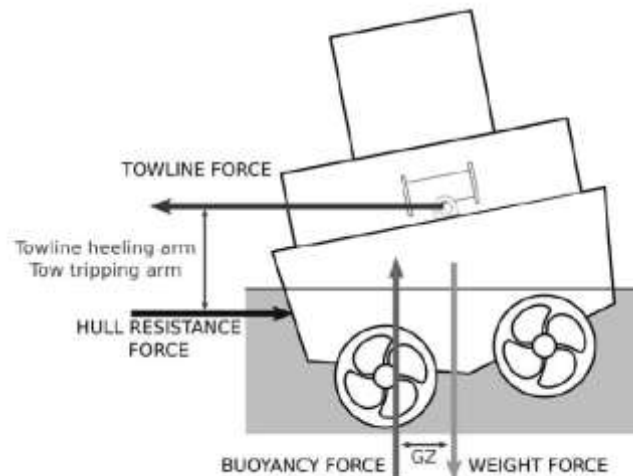


Figure 9.6.1.4 Forces during towing

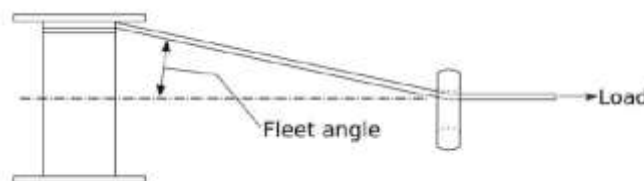


Figure 9.6.1.5 Towline fleet angle

9.6.2 General requirements

9.6.2.1 The in-board end of the towline is to be attached to the winch drum with a weak link or similar arrangement that is designed to release the towline at low load.

9.6.2.2 All towing winches are to be fitted with an emergency release system.

9.6.3 Performance requirements for emergency release system

9.6.3.1 The emergency release system is to operate across the full range of towline load, fleet angle and ship heel angle under all normal and reasonably foreseeable abnormal conditions (these may include, but are not limited to, the following: vessel electrical failure, variable towline load (for example due to heavy weather), etc.).

9.6.3.2 The emergency release system shall be capable of operating with towline loads up to at least 100 per cent of the maximum design load.

9.6.3.3 The emergency release system is to function as quickly as is reasonably practicable and within a maximum of three seconds after activation.

9.6.3.4 The emergency release system is to allow the winch drum to rotate and the towline to pay out in a controlled manner such that, when the emergency release system is activated, there is sufficient resistance to rotation to avoid uncontrolled unwinding of the towline from the drum. Spinning (free, uncontrolled rotation) of the winch drum is to be avoided, as this could cause the towline to get stuck and disable the release function of the winch.

9.6.3.5 Once the emergency release is activated, the towline load required to rotate the winch drum is to be no greater than:

- (1) the lesser of five tonnes or five per cent of the maximum design load when two layers of towline are on the drum, or
- (2) 15 per cent of the maximum design load where it is demonstrated that this resistance to rotation does not exceed 25 per cent of the force that will result in listing sufficient for the immersion of the lowest unprotected opening.

9.6.3.6 Emergency release of the towline is to be possible in the event of a blackout. For this purpose, where additional sources of energy are required, such sources are to comply with 9.6.3.7.

9.6.3.7 The alternative source of energy required by 9.6.3.6 of this Section is to be sufficient to achieve the most onerous of the following conditions (as applicable):

- (1) sufficient for at least three attempts to release the towline (i.e. three activations of the emergency release system). Where the system provides energy for more than one winch it is to be sufficient for three activations of the most demanding winch connected to it.
- (2) Where the winch design is such that the drum release mechanism requires continuous application of power (e.g. where the brake is applied by spring tension and released using hydraulic or pneumatic power) sufficient power is to be provided to operate the emergency release system (e.g. hold the brake open and allow release of the towline) in the event of a blackout for a minimum of five minutes. This may be reduced to the time required for the full length of the towline to feed off the winch drum at the load specified in 10.6.3.5 if this is less than five minutes.

9.6.4 Operational requirements for emergency release system

9.6.4.1 Emergency release operation must be possible from the bridge and from the winch control station on deck. The winch control station on deck is to be in a safe location. A position in close proximity to the winch is not regarded as safe location, unless it is documented that the position is at least protected against towline break or winch failure.

9.6.4.2 The emergency release control is to be located close to an emergency stop button for winch operation, if provided, and shall be clearly identifiable, clearly visible, easily accessible and positioned to allow safe operability.

9.6.4.3 The emergency release function is to take priority over any emergency stop function. Activation of the winch emergency stop from any location is not to inhibit operation of the emergency release system from any location.

9.6.4.4 Emergency release system control buttons are to require positive action to cancel, the positive action may be made at a different control position from the one where the emergency release was activated.

It must always be possible to cancel the emergency release from the bridge regardless of the activation location and without manual intervention on the working deck.

9.6.4.5 Controls for emergency use are to be protected against accidental use.

9.6.4.6 Indications are to be provided on the bridge for all power supply and/or pressure levels related to the normal operation of the emergency release system. Alarms are to activate automatically if any level falls outside of the limits within which the emergency release system is fully operational.

9.6.4.7 Wherever practicable, control of the emergency release system is to be provided by a hard-wired system, fully independent of programmable electronic systems.

9.6.4.8 Computer based systems that operate or may affect the control of emergency release systems are to meet the requirements for Category III systems of Section 6, Chapter 2 of PART SEVEN of the Rules.

9.6.4.9 Components critical for the safe operation of the emergency release system are to be identified by the manufacturer.

9.6.5 Test requirements for emergency release system

9.6.5.1 General requirements

(1) All testing defined within this Section is to be witnessed by a ISC surveyor.

(2) For each emergency release system or type thereof, the performance requirements of 9.6.3 of this Section are to be verified either at the manufacturer's works or as part of the commissioning of the towing winch when it is installed on board. Where verification solely through testing is impracticable (e.g. due to health and safety), testing may be combined with inspection, analysis or demonstration in agreement with ISC.

(3) The performance capabilities, as well as instructions for operation of the emergency release system are to be documented by the manufacturer and made available on board the ship on which the winch has been installed.

(4) Instructions for surveys of the emergency release system are to be documented by the manufacturer, when agreed, and made available on board the ship on which the winch has been installed.

(5) Where necessary for conducting the annual and special surveys of the winch, adequately sized

strong points are to be provided on deck.

9.6.5.2 Installation trials

(1) The full functionality of the emergency release system is to be tested as part of the shipboard commissioning trials to the satisfaction of the surveyor. Testing may be conducted either during a bollard

pull test or by applying the towline load against a strong point on the deck of the tug that is certified to the appropriate load.

(2) Where the performance of the winch in accordance with 9.6.3 of this Section has previously been verified, the load applied for the installation trials is to be at least the lesser of 30% of the maximum design load or 80% of vessel bollard pull.

CHAPTER 10 OFFSHORE SUPPLY SHIPS

SECTION 1 - GENERAL PROVISIONS

10.1.1 Application

10.1.1.1 This Chapter applies to offshore supply ships specially designed and constructed for the carriage of specialized stores and cargoes to mobile or fixed offshore installations, and also to offshore tug/supply ships and offshore anchoring handling/tug/supply ships.

10.1.1.2 Those not covered in this Chapter are to comply with the relevant requirements of Chapter 2 of this PART.

10.1.1.3 This Chapter applies to supply ships having the accommodation and bridge erections in the forward part of the vessel and an exposed deck in the after part for the handling of cargo at sea.

10.1.1.4 In addition to the requirements of this Chapter, tug/supply ships are to comply with the relevant requirements as specified in Section 5, Chapter 9 of this PART. A tug/supply ship, when engaged in towing operations, is in general not to carry deck cargo.

10.1.2 Class notations

10.1.2.1 Ships complying with the requirements of this Chapter are eligible to be assigned one of the following class notations:

- (1) Offshore Supply Ship for offshore supply ships; or
- (2) Offshore Tug/Supply Ship for offshore tug/supply ships.

10.1.3 Plans and documents

10.1.3.1 In addition to the plans and documents required in Section 1, Chapter 2 of this PART, plans covering the following items are to be submitted for approval:

- (1) Independent cargo tanks and their foundations and securing arrangements;
- (2) Drawing of the deck(s) showing the details of loads, the points where they apply and lashing arrangement;
- (3) Towing arrangement;
- (4) Supports and foundations for towing winches, stern towing bollards and for stern rollers of anchor handling/supply ships (appropriate strength calculations are submitted for information);
- (5) Movable decks, including the stowing arrangements for portable components;
- (6) Freeing arrangement;
- (7) Fender arrangement (structure).

SECTION 2 - CARGO CONTAINMENT AND OTHER FITTINGS

10.2.1 Cargo containment

10.2.1.1 Means are to be provided to enable deck cargoes to be adequately secured and protected. In general, suitable inner bulwarks, rails, bins or storage racks of substantial construction are to be provided and properly secured to adequately strengthened parts of the hull structure.

10.2.1.2 Properly designed locking equipment or efficient means for lashing the deck cargoes are to be fitted where appropriate.

10.2.1.3 Small hatches (including escape hatches), control valves, ventilators, air pipes, etc., are to be situated clear of the cargo containment areas and fitted in protected positions.

10.2.2 Doors and accesses

10.2.2.1 If possible, the accesses to machinery spaces are to be arranged in forecastle. Any accesses to machinery spaces from weather cargo decks are to be provided with two weathertight closing appliances. The accesses to spaces below the weather cargo decks are to be preferably from a position on or above the superstructure deck as far as possible.

10.2.2.2 Doors leading directly to and hatches on the open cargo deck are to be kept closed during navigation. These doors are to be clearly marked to indicate that they are to be kept closed except for access.

10.2.3 Side scuttles, windows and skylights

10.2.3.1 Side scuttles, windows and skylights are to comply with the relevant requirements of Section 12, Chapter 1 of this PART.

10.2.3.2 Windows are only allowed to be fitted in the following locations and side scuttles are to be fitted in other positions.

(1) Second tier and higher above the freeboard deck:

- ① in the aft end bulkheads of deckhouses and superstructures;
- ② in the sides of deckhouses and superstructures which are not part of the shell plating;

(2) Third tier and higher above the freeboard deck:

- ① in the forward facing bulkheads of deckhouse and superstructures, except that in the first tier of the front bulkhead above the weather deck, only side scuttles will be accepted.

10.2.3.3 Permanently attached deadlights are to be provided as follows:

(1) Side scuttles:

- ① in the side shell plating;
- ② in the forward facing bulkheads of superstructures and deckhouses;

- ③ in the sides of deckhouses and superstructures up to and including the third tier above the freeboard deck;
- ④ in the after end bulkheads of superstructures, deckhouses, casings and companionways in the first and second tiers above the freeboard deck.

(2) Windows:

- ① in the sides of deckhouses and superstructures in the second and third tiers above the freeboard deck;
- ② in the after end bulkheads of superstructures, deckhouses, casings and companionways in the second tier above the freeboard deck.

10.2.3.4 On windows in the second tier and higher above the freeboard deck, hinged storm covers may be fitted in lieu of deadlights, provided there is safe access for closing.

10.2.3.5 Windows in the wheelhouse front are to have deadlights or storm covers. For storm covers, an arrangement for easy and safe access is to be provided, (e.g. gangway with railing). However, for practical purposes, the deadlights or storm covers may be portable if stowed adjacent to the window for quick fitting. At least two of the deadlights or storm covers are to have the means of providing a clear view.

10.2.3.6 Deadlights for side scuttles, and for windows not mentioned in 10.2.3.4 and 10.2.3.5, are to be internally hinged.

10.2.3.7 The thickness of toughened glass for windows is not to be less than the value calculated by the following formula, and the minimum is not to be less than 10 mm.

$$t = b\sqrt{\varphi\beta\eta h} \quad \text{mm}$$

where: φ — coefficient, taken as 2 for fronts, 1.2 for sides and aft ends;
 η — coefficient, taken as 223 for fronts and sides on the forth tier or above, 125 for aft ends on the forth tier or above, 500 for other cases;
 h — design head of window, calculated according to 2.17.2, Chapter 2 of this PART;
 β — coefficient, to be calculated by the following:
 $\beta = 0.54A_R - 0.078A_R^2 - 0.17$ for $A_R \leq 3.6$
 $\beta = 0.7645$, for $A_R > 3.6$

where: AR — aspect ratio factor of window, calculated by the following equation:

$$AR = a/b$$

a — length of long edge of window, in m;

b — length of short edge of window, in m.

10.2.3.8 Skylights, where fitted, are to be of substantial construction. The height of coamings of skylights is not to be less than 600 mm when situated on open freeboard decks, and raised quarter decks and open superstructure decks forward of $1/4L$ from F.P., and 450 mm when situated on open superstructure decks abaft of $1/4L$ from F.P. The thickness of glass in skylights is to be equal

to that required for side scuttles or windows at the same position. Skylights are to be provided with strong storm covers.

10.2.3.9 For laminated toughened glass, the equivalent thickness is not to be less than that calculated according to 10.2.3.7. The equivalent thickness is to be calculated by the following formula and the thickness of single layer of glass is not to be less than 4 mm.

$$t_e = \sqrt{\sum_{i=1}^n t_i^2}$$

where: n — the number of layer of glass; t_i — the thickness of the i^{th} layer of glass.

10.2.4 Air pipes, ventilators and freeing ports

10.2.4.1 Air pipes situated on the exposed cargo and forecastle decks are to be provided with automatic closing devices.

10.2.4.2 Machinery space ventilators are to be arranged above the superstructure deck, or above an equivalent level if no superstructure deck is fitted.

10.2.4.3 The area of the freeing ports in the side bulwarks on the cargo deck is to be suitably increased above that required in 1.12.6.2, Chapter 1 of this PART. The disposition of the freeing ports is to be carefully considered to ensure the most effective drainage of water trapped in deck cargoes or in recesses in the after end bulkhead of the forecastle.

In ships operating in areas where icing is likely to occur, no shutters are to be fitted in the freeing ports.

10.2.4.4 Engine exhaust outlets are to be located as high as practicable above the deck and are to be fitted with spark arresters.

SECTION 3 - SHELL AND DECK PLATING

10.3.1 Shell plating

10.3.1.1 The thickness of side shell is to be in accordance with the relevant requirements of Section 3, Chapter 2 of this PART, but is in no case to be less than 9 mm.

10.3.1.2 The side shell in way of the stern rollers immediately adjacent to high duty mooring bollards and in other high load areas of anchor handling/supply ships is to be suitably reinforced.

10.3.2 Decks

10.3.2.1 The minimum thickness t of deck plating is not to be less than that obtained from the following formula:

$$t = 0.025L + 7 \text{ mm}$$

where: L — length of ship, in m.

In the deck cargo area, the thickness t of deck plating is, in addition, in no case to be less than that obtained from the following formula:

$$t = 4.8s\sqrt{hK} + 2.5 \text{ mm}$$

where: s — spacing of beams or longitudinals, in m;

h — design head, in m, to be determined from $h = 0.14p$ (p being the load of deck, in kPa), but not to be less than 3.5 m;

K — material factor.

10.3.2.2 The deck plating near the stern and that subject to concentrated loads are to be suitably increased in thickness.

SECTION 4 - HULL ENVELOPE FRAMING

10.4.1 Deck framing

10.4.1.1 The scantlings of cargo decks are to be suitable for the specified loadings, but in no case is a head less than 3.5 m to be used.

10.4.1.2 Additional local increases in scantlings is to be required where specific cargoes are likely to induce concentrated loads.

10.4.2 Side framing

10.4.2.1 Efficient fenders are to be fitted to the ship's side above the waterline, and are to have a thickness equal to that of side shell. Stiffeners are to be arranged inside the fenders. If fenders are not provided, the thickness of the shell plating at least 600 mm below the deck is to be increased by 5 mm.

10.4.2.2 The section moduli of the main and 'tween deck frames are to be 25% greater than those required in Section 7 of Chapter 2 of this PART. Frames are not to be scalloped.

10.4.3 Bottom framing

10.4.3.1 The flat bottom in way of stern is to be suitably strengthened.

SECTION 5 - SUPERSTRUCTURES AND DECKHOUSES

10.5.1 Scantlings

10.5.1.1 The section modulus of the frames in superstructures is to be 25% greater than that required in Section 7, Chapter 2 of this PART. The scantlings of the end bulkheads of superstructures are not to be less than those as specified in Table 10.5.1.2 of this Section.

10.5.1.2 The scantlings of deckhouses situated on the forecastle deck and above are to comply with the requirements of Table 10.5.1.2.

Table 10.5.1.2 - Plate thickness, Stiffener Modulus and Depth of Deckhouses

Position	Thickness t of plating (mm)	Section modulus W of stiffeners (cm^3)	Depth of stiffeners (mm)
Fronts	The greater of $12s$ or 8.0	$34s l^2$	Not less than 100
Sides	The greater of $10s$ or 6.5	$27s l^2$	Not less than 75
Aft ends	The greater of $8s$ or 6.5	$27s l^2$	Not less than 65

Note: s and l are respectively spacing and span of stiffeners, in m.

10.5.2 End connection

10.5.2.1 Both ends of the stiffeners in superstructures and deckhouses are to be bracketed or connected by other effective means on all tiers.

CHAPTER 11 BARGES

SECTION 1 - GENERAL PROVISIONS

11.1.1 Application

11.1.1.1 The barges defined in this Chapter are non-self-propelled ships pushed or towed by other ships and divided into the following types:

- (1) Barges carrying general dry cargo in cargo holds;
- (2) Barges carrying cargo oil in cargo tanks;
- (3) Shipborne barges carrying general dry cargo in cargo holds and carried on board a barge carrier;
- (4) Specially designed pontoons for the carriage of cargo on deck;
- (5) Barges dedicated to transporting marine engineering jacket structure and landing jacket into water by the stern for launching of jacket;
- (6) Barges carrying chemicals in cargo tanks;
- (7) Barges carrying liquefied gas in cargo tanks.

11.1.1.2 Where not covered by this Chapter, barges carrying cargo oil in bulk in cargo tanks are to comply with the relevant requirements of Chapter 4 or 5 of this PART according to its structural configuration; barges carrying chemicals in cargo tanks are to comply with the relevant requirements of Chapter A4, PART TWO of ISC Rules for Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk; barges carrying liquefied gas in cargo tanks are to comply with the relevant requirements of Appendices 1 and 2, PART TWO of ISC Rules for Construction and Equipment of Ships Carrying Liquefied Gas in Bulk and other barges are to comply with the relevant requirements of Chapter 2 of this PART.

11.1.1.3 For pontoons regarded as one of offshore floating facilities, the structure may be in accordance with the requirements of this Chapter for pontoon barges.

11.1.2 Class notations

11.1.2.1 Barges complying with the requirements of this Chapter are eligible to be assigned

one of the following class notations:

- (1) Barges: the notation Barge is to be assigned to the barges as defined in 11.1.1.1(1);
- (2) Oil barges: the notation Oil Barge is to be assigned to the barges as defined in 11.1.1.1(2);
- (3) Shipborne barges: the notation Shipborne Barge is to be assigned to the barges as defined in 11.1.1.1(3);
- (4) Pontoon barges: the notation Pontoon Barge is to be assigned to the barges as defined in 11.1.1.1(4);
- (5) Launch Barge: the notation Launch Barge is to be assigned to the barges as defined in 11.1.1.1(5);
- (6) Chemical Barge: the notation Chemical Barge is to be assigned to the barges as defined in 11.1.1.1(6);
- (7) Gas Barge: the notation Gas Barge is to be assigned to the barges as defined in 11.1.1.1(7).

11.1.3 Plans and documents

11.1.3.1 In addition to the plans and documents required in Section 1, Chapter 2 of this PART, plans and documents covering the following are to be submitted for approval:

- (1) Details of structure and fittings to which deck cargo securing lashings, etc. are attached;
- (2) Details of bollards and their supporting structure;
- (3) Where pusher tugs or integral tug/barge systems are proposed, full details and data of the attachment and support arrangements;
- (4) Longitudinal strength (appropriate strength calculations are submitted for information) and lifting arrangements for shipborne barges.

11.1.4 Structural configuration

11.1.4.1 For barges with large deck openings, deck and bottom are in general to be longitudinally framed.

11.1.4.2 Barges are to be fitted with a collision bulkhead extending intact to the strength/weather deck and, in general, this is to be located in accordance with Table 12.1.4.2. Greater distance between the collision bulkhead and the forward perpendicular may be accepted if assessed by damage stability calculation.

Table 11.1.4.2

Length L of ship (m)	Distance between collision bulkhead and forward perpendicular (m)	
	Minimum	Maximum
≤ 150	0.05 L	0.05 L + 4.5
> 150	0.05 L or 10, whichever is lesser	0.08 L

11.1.4.3 Where the ends of the barge are identical both in structural arrangement and in shape so that its fore and after ends are not distinguishable, collision bulkheads are to be fitted at both ends.

11.1.4.4 Pusher barges are in general to be fitted with a collision bulkhead at the aft end.

11.1.4.5 The total number of watertight bulkheads is in general not to be less than required in Table 11.1.4.5. For ships of over 190 m in length, this is to be determined by direct calculation. Attention is to be paid to reasonable and even arrangement of transverse watertight bulkheads.

Table 11.1.4.5 - Total Number of Transverse Watertight Bulkheads

Length L (m)	L ≤ 60	60 < L ≤ 85	85 < L ≤ 105	105 < L ≤ 145	145 < L ≤ 165	165 < L ≤ 190
Total number of watertight bulkheads	3	4	5	6	7	8

11.1.4.6 Pontoon barges are in general to be fitted with longitudinal bulkheads extending fore and aft in accordance with Table 11.1.4.6, the scantlings of which are to be calculated as required for watertight longitudinal bulkheads. Attention is to be paid to reasonable arrangement of longitudinal bulkheads. For pontoon barges with B/D greater than 6, this is to be determined by direct calculation.

Table 11.1.4.6 - Total Number of Longitudinal Bulkheads

B/D	B/D ≤ 2.5	2.5 < B/D ≤ 3	3 < B/D ≤ 4	4 < B/D ≤ 5	5 < B/D ≤ 6
Total number of longitudinal bulkheads	0	1	2	3 ^①	3

Note: ① Centre longitudinal bulkheads may be replaced by longitudinal trusses.

11.1.4.7 For pontoon barges with B/D equal to or greater than 3, the transverse strength is to be checked by direct calculation (see Appendix 1 of this Chapter).

SECTION 2 - LONGITUDINAL STRENGTH

11.2.1 General requirements

11.2.1.1 The longitudinal strength of barges is to comply with the relevant requirements of Section 2, Chapter 2 of this PART, with the exception of the requirements for loading instruments.

11.2.1.2 For shipborne barges intended to be lifted on board by crane, longitudinal strength calculations

for a condition “fully loaded barge suspended by crane” are to be made with the following permissible stresses:

Permissible bending stress $[\sigma] = 150/K$ N/mm²

Permissible shear stress $[\tau] = 100/K$ N/mm²

where: K — material factor.

11.2.1.3 For barges having large deck openings, torsional strength is to be checked in accordance with Chapter 6 of this PART.

11.2.1.4 Where the transverse watertight bulkheads and longitudinal bulkheads of pontoon barges are fitted in compliance with the requirements for structural arrangement in Section 1

of this Chapter, their proportions may exceed those specified in 2.2.1.2 of Section 2, Chapter 2 of this PART when the requirements for longitudinal strength in Section 2, Chapter 2 of this PART are applied, provided that the following condition is met:

$$\begin{aligned} L/B &> 3 \\ B/D &\leq 6.0 \end{aligned}$$

11.2.1.5 For pontoon barges not meeting the condition in 11.2.1.4 above, this is generally to be determined by direct calculation. See 2.2.9 of Chapter 2 for direct calculation of wave loads.

SECTION 3 - SHELL AND DECK PLATING

11.3.1 General requirements

11.3.1.1 In addition to the requirements of this Section, the shell and deck plating of barges carrying cargo oil in cargo tanks are to comply with the relevant requirements of Chapter 5 of this PART and those of other barges are to comply with the relevant requirements of Chapter 2 of this PART.

11.3.2 Shell plating Decks

11.3.2.1 On barges with two chines each side, the thickness of bilge plating is to be calculated from the bottom plating formulae. On hard chine barges, flanged chines will not, in general, be approved, but where a chine is formed by knuckling the shell plating, the radius of curvature, measured on the inside of the plate, is not to be less than 10 times the plate thickness. Where a solid round chine bar is fitted, the bar diameter is not to be less than 3 times the thickness of the thickest abutting plate. Where welded chines are used, the welding is to be built up as necessary to ensure that the shell plating thickness is maintained across the weld.

11.3.2.2 For barges of less than 100 m in length and without dead rise, the thickness of plate keel is to be calculated from the bottom plating formulae.

11.3.3 Decks

11.3.3.1 For barges with large deck openings, the half sectional area a of the strength deck within $0.4L$ amidships is not to be less than that obtained from the following formula:

$$a = \frac{1}{4.3} B(L + 30) \text{ cm}^2$$

where: L — length of ship, in m;
 B — breadth of ship, in m.

The half sectional area of deck means the sum of sectional areas of the continuous longitudinal members outside the line of openings and on one side of the longitudinal centreline, such as deck plating, deck longitudinals and deck girders.

11.3.3.2 For pontoons, the thickness of deck plating in the deck cargo area is, in addition, not

to be less than that obtained from the following formula:

$$t = 4.5s\sqrt{hK} \text{ mm, but not less than 6 mm}$$

where: s — spacing of beams or longitudinals, in m;

h — design head, in m, to be taken as $0.14p + 0.3$, p being the design load, in kPa;

K — material factor.

11.3.3.3 Where vehicles are to be carried on deck, the deck plating is also to comply with the relevant requirements of Section 21, Chapter 2 of this PART.

SECTION 4 - HULL ENVELOPE FRAMING

11.4.1 General requirements

11.4.1.1 The hull envelope framing of barges carrying dry cargo in cargo holds are to comply with the relevant requirements of Chapter 2 of this PART. The hull envelope framing of barges carrying cargo oil in cargo tanks are to comply with the relevant requirements of Chapter 5 of this PART. The hull envelope framing of pontoon barges are to comply with the relevant requirements of this Section.

11.4.1.2 In way of deck and bottom primary transverse members, a web frame is to be fitted so that the bottom, side and deck transverses are connected into a transverse ring system to ensure sufficient transverse strength.

11.4.1.3 Pontoon barges are in general longitudinally framed. If they are framed transversely, transverse ring systems or transverse trusses are to be suitably fitted to ensure sufficient transverse strength.

11.4.1.4 Figure 11.4.1.4 shows the longitudinally framed structure of pontoon barges.

11.4.1.5 Figure 11.4.1.5 shows the transversely framed structure of pontoon barges.

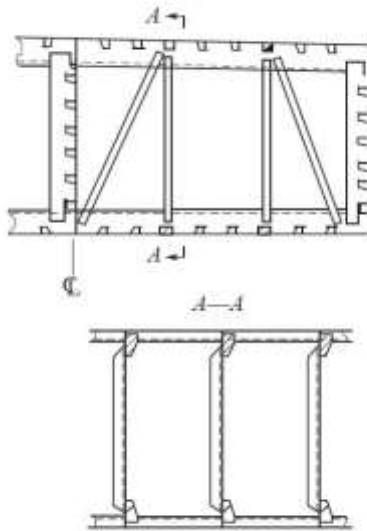


Figure 11.4.1.4

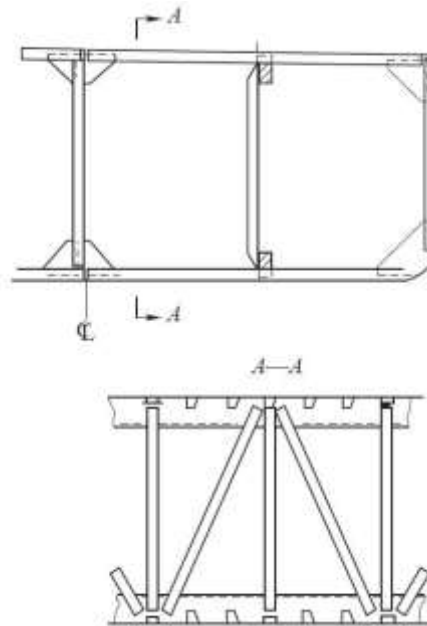


Figure 11.4.1.5

11.4.2 Bottom framing of pontoons

11.4.2.1 Where transversely framed, bottom frames are to be fitted at every frame, and their section modulus W is not to be less than that obtained from the following formula:

$$W = 9.5sDl^2K \text{ cm}^3$$

where: s — spacing of bottom frames, in m;

D — moulded depth, in m;

l — span of bottom frames, in m; supporting structures of bottom frames are to be ship side, longitudinal bulkheads or bottom stringers;

K — material factor.

11.4.2.2 Where longitudinally framed, the section modulus W of bottom longitudinals is not to be less than that obtained from the following formula:

$$W = CsDl^2K \text{ cm}^3$$

where: s — spacing of longitudinals, in m;

D — moulded depth, in m;

l — span of longitudinal, in m; supporting structures of bottom longitudinals are to be transverse bulkheads or bottom webs;

C — coefficient, taken as:

$C = 12$, for rake-ended bow of pontoon barges;

$C = 10.5$, for others;

K — material factor.

11.4.2.3 The section modulus W of bottom stringers (including bottom chords of longitudinal trusses) is not to be less than that obtained from the following formula:

$$W = 9.5SDl^2K \text{ cm}^3$$

where: S — average width of areas supported by bottom stringers, in m;
 D — moulded depth, in m;
 l — span of bottom stringers, in m; supporting structures of bottom stringers are to be transverse bulkheads, truss pillars;
 K — material factor.

11.4.2.4 The section modulus W of bottom webs (including bottom chords of transverse trusses) is not to be less than that obtained from the following formula:

$$W = CSD^2K \text{ cm}^3$$

where: S — average width of areas supported by bottom webs, in m;
 D — moulded depth, in m;
 l — span of bottom web, in m; supporting structures of bottom webs are to be ship side, longitudinal bulkheads or truss pillars;
 C — coefficient, taken as:
 $C = 11$, for rake-ended bow of pontoon barges;
 $C = 9.5$, for others;
 K — material factor.

11.4.2.5 Primary bottom members (bottom stringers and webs) are to comply with the following requirements:

(1) The web depth h of primary members is not to be less than 2 times the depth of the slot for the passage of secondary members (bottom frames and longitudinals), and not to be less than that obtained from the following formula:

$$h = 125/l \text{ mm}$$

where: l — span of primary member, in m.

(2) The web thickness t of primary members is not to be less than that obtained from the following formula:

$$t = h/100 + 3 \text{ mm, not less than 7 mm}$$

where: h — web depth of primary member, in mm.

11.4.3 Side framing of pontoons

11.4.3.1 The section modulus W of frames is not to be less than that obtained from the following formula:

$$W = 9.5shl^2K \text{ cm}^3$$

where: s — spacing of frames, in m;
 l — span of frame, in m;
 h — head taken in calculation, in m; vertical distance measured from the midpoint of span of the frame to deck at side, but not to be less than $0.01L + 0.7$ m, L being length of ship, in m;
 K — material factor.

11.4.3.2 The section modulus W of side longitudinals is not to be less than that obtained from the following formula:

$$W = Cshl^2K \text{ cm}^3$$

where: s — spacing of longitudinals, in m;

l — span of longitudinal, in m;

h — head taken in calculation, in m; vertical distance measured from the side longitudinal to deck at side, but not to be less than $0.01L + 0.7$ m, L being length of ship, in m;

C — coefficient, taken as:

$C = 9.0$, for rake-ended bow of pontoon barges;

$C = 8.0$, for others;

K — material factor.

11.4.3.3 The section modulus W of longitudinally framed web frames is not to be less than that obtained from the following formula:

$$W = CShl^2K \text{ cm}^3$$

where: S — spacing of web frames, in m;

l — span of web frame, in m;

h — head taken in calculation, in m; vertical distance measured from the midpoint of span of the web frame to deck at side, but not to be less than $0.01L + 0.7$ m, L being length of ship, in m;

C — coefficient, taken as:

$C = 9.5$, for rake-ended bow of pontoon barges;

$C = 8.5$, for others;

K — material factor.

11.4.3.4 Longitudinally framed web frames are to comply with the relevant requirements of 11.4.2.5 of this Section.

11.4.4 Deck framing of pontoons

11.4.4.1 The section modulus W of transversely framed deck beams is not to be less than that obtained from the following formula:

$$W = 4.5shl^2K \text{ cm}^3$$

where: s — spacing of deck beams, in m;

l — span of deck beam, in m;

h — head taken in calculation, in m; $h = 0.14p + 0.3$, but not to be less than $0.02L + 0.76$ m, L being length of ship, in m, p being design load, in kPa;

K — material factor.

11.4.4.2 The section modulus W of longitudinally framed deck longitudinals is not to be less than that obtained from the following formula:

$$W = 5shl^2K \text{ cm}^3$$

where: s — spacing of deck longitudinals, in m;

l — span of deck longitudinal, in m;

- h — head taken in calculation, in m, the same as in 12.4.4.1 of this Section;
 K — material factor.

11.4.4.3 The section modulus W of deck girders (including top chords of longitudinal trusses) is not to be less than that obtained from the following formula:

$$W = 5Shl^2K \text{ cm}^3$$

- where: S — average width of areas supported by girders, in m;
 l — span of girders, in m;
 h — head taken in calculation, in m, the same as in 12.4.4.1 of this Section;
 K — material factor.

11.4.4.4 The section modulus W of deck transverses (including top chords of transverse trusses) is not to be less than that obtained from the following formula:

$$W = 5Shl^2K \text{ cm}^3$$

- where: S — average width of areas supported by transverses, in m;
 l — span of transverses, in m;
 h — head taken in calculation, in m, the same as in 12.4.4.1 of this Section;
 K — material factor.

11.4.4.5 Primary structural members of deck (including deck girders and transverses) are to comply with the following requirements:

(1) The web depth h of primary members is not to be less than 2 times the depth of the slot for the passage of secondary members (deck beams and longitudinals), and not to be less than that obtained from the following formula:

$$h = 58.5l \text{ mm}$$

where: l — span of primary member, in m.

(2) The web thickness t of primary members is not to be less than that obtained from the following formula:

$$t = h/100 + 3 \text{ mm, not less than 7 mm}$$

where: h — web depth of primary members, in mm.

11.4.4.6 Where wheeled vehicles are stowed on the deck, the deck framing is also to comply with the relevant requirements in Section 21, Chapter 2 of this PART.

11.4.4.7 Where containers are carried on the deck, stacking devices are to be fitted on supporting members, and the strength of deck framing is to be checked by direct calculation. The static load of containers is to be taken as the load in calculation, and permissible stresses are as follows:

Permissible normal stress $[\sigma] = 0.5ReH$

Permissible shear stress $[\tau] = 0.292 ReH$

where: ReH — yield stress of material, in N/mm².

11.4.5 Truss structure of pontoon barges

11.4.5.1 Pontoon barges are to be fitted with trusses extending either fore and aft or athwartships for the support of hull structure.

11.4.5.2 A truss is comprised of top and bottom girders, pillars and diagonal bracings.

11.4.5.3 The top and bottom girders of longitudinal trusses are deck and bottom girders respectively.

11.4.5.4 The top and bottom girders of transverse trusses are deck transverses and bottom webs respectively.

11.4.5.5 Pillars are to comply with the relevant requirements of Section 10, Chapter 2 of this PART, and the load P acting on pillars is to be taken as the greater of the values obtained from the following formulae:

$$P_1 = p a_1 b_1 \quad \text{kN}$$

$$P_2 = 10D a_2 b_2 \quad \text{kN}$$

where: p — design cargo load, in kPa;

a_1 — average length of deck area supported by pillar, in m;

b_1 — average width of deck area supported by pillar, in m;

D — moulded depth, in m;

a_2 — average length of bottom area supported by pillar, in m;

b_2 — average width of bottom area supported by pillar, in m.

11.4.5.6 Diagonals are generally to have an angle of inclination with the horizontal of 45°, and a cross-sectional area of generally 50% of that of the adjacent pillar.

SECTION 5 - STRENGTHENING AT ENDS OF SHIP

11.5.1 General requirements

11.5.1.1 The ends of barges with general sea-going-ship-shaped bow forms are to be strengthened in accordance with Section 15, Chapter 2 of this PART.

11.5.1.2 The ends of fore rake end pontoon barges are to be strengthened in accordance with this Section. Figure 11.5.1.2 shows the shape and structural arrangement of a typical fore rake end.

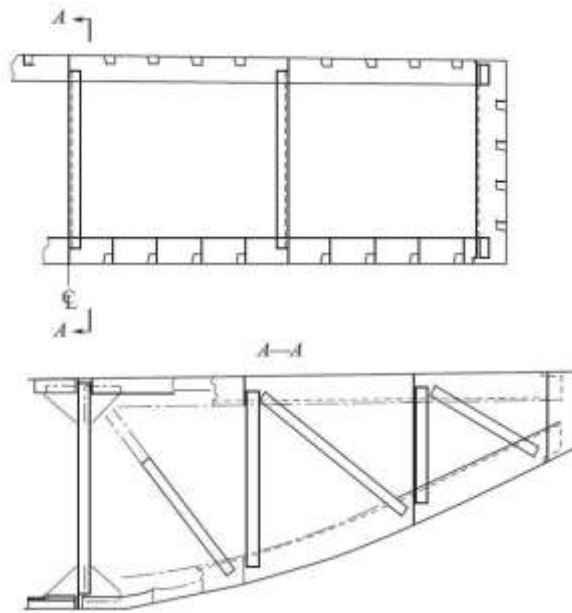


Figure 11.5.1.2

11.5.2 Structural requirements for fore rake end

11.5.2.1 The structural requirements for fore rake end apply to the bottom forward plating of the forward rake from the forward headlog to the lower turn of the rake. Where the collision bulkhead is located aft of the lower turn of the rake, these requirements apply to the bottom forward plating of the forward rake from the forward headlog to the collision bulkhead.

11.5.2.2 The span of bottom longitudinals is not to exceed 2.5 m. Bottom longitudinals may be supported by transverse bulkheads or bottom webs.

11.5.2.3 The span of bottom frames is not to exceed 2.5 m. Bottom frames may be supported by longitudinal bulkheads or bottom girders.

11.5.2.4 The scantlings of primary members are to comply with the relevant requirements for pontoons in Section 4 of this Chapter and in addition, the following requirements:

- (1) In general, the web depth of primary members is not to be less than 2.5 times the depth of the slot for the passage of secondary members.
- (2) The web depth h of primary members is not to be less than that obtained from the following

formula:

$$h = C/l \quad \text{mm}$$

where: l — span of primary members, in m;

C — coefficient, taken as follows:

83.5 for deck transverses;

125 for side transverses;

156 for bottom webs.

11.5.2.5 The bottom shell plating thickness is to be maintained up to the summer load waterline for the rake plating. Above this point the thickness may be tapered to that of the side shell requirements from a point not less than 1 m above the load waterline.

11.5.3 Strengthening of structures of bottom forward against slamming

11.5.3.1 The structures of bottom forward are to be strengthened against slamming in accordance with 2.15.3 of Section 15, Chapter 2 of this PART.

11.5.3.2 Where pontoon barges are towed or pushed at a speed of less than 10 kn and minimum fore draught equal to or greater than $0.01L$ (L being length of ship, in m), with trim being kept at zero, the requirements for strengthening of bottom forward in Section 15, Chapter 2 of this PART may be dispensed with.

APPENDIX 1

METHOD OF CHECKING TRANSVERSE STRENGTH OF PONTOON BARGES

1. General Requirements**1.1 Application**

1.1.1 This method is applicable only to the check of transverse strength of pontoon barges in accordance with 11.1.4.7 of this Chapter.

1.1.2 This method is not applicable to the strength assessment of local structures subjected to a concentrated load (e.g. large foundation, heavy cargo support and struts).

2. Loads**2.1 Load types**

2.1.1 Only the effects of maximum permissible deck load and external water pressure are taken into account for design conditions of transverse strength. The effects of hull girder bending moments (both vertical and horizontal ones) are not taken into account.

2.1.2 The load due to external water pressure consists of hydrostatic pressure and hydrodynamic wave pressure as follows:

at baseline: $P_B = 10d \pm 1.5C \text{ kN/m}^2$

at waterline: $P_W = \pm 3C \text{ kN/m}^2$

at side top: $P_s = 3P_0 \text{ kN/m}^2$

where: C – see 2.2.3.1 of Section 2, Chapter 2;

d – draught, in m;

P_0 – to be calculated as follows:

$P_0 = C - 0.67(D - d) \text{ kN/m}^2$;

D – moulded depth, in m.

In order to take account of the effects of beam sea acting along the ship's length in local areas, such effects are simulated by applying asymmetric external water pressure on both sides for design conditions. A superimposition of hydrostatic pressure and wave pressure may be assumed on one side and the effects of hydrostatic pressure and reverse hydrodynamic wave pressure on the other side (C being taken negative in the above formula), where any value below zero is to be taken as zero. The distribution of load effects is shown in Figure 2.1.2.

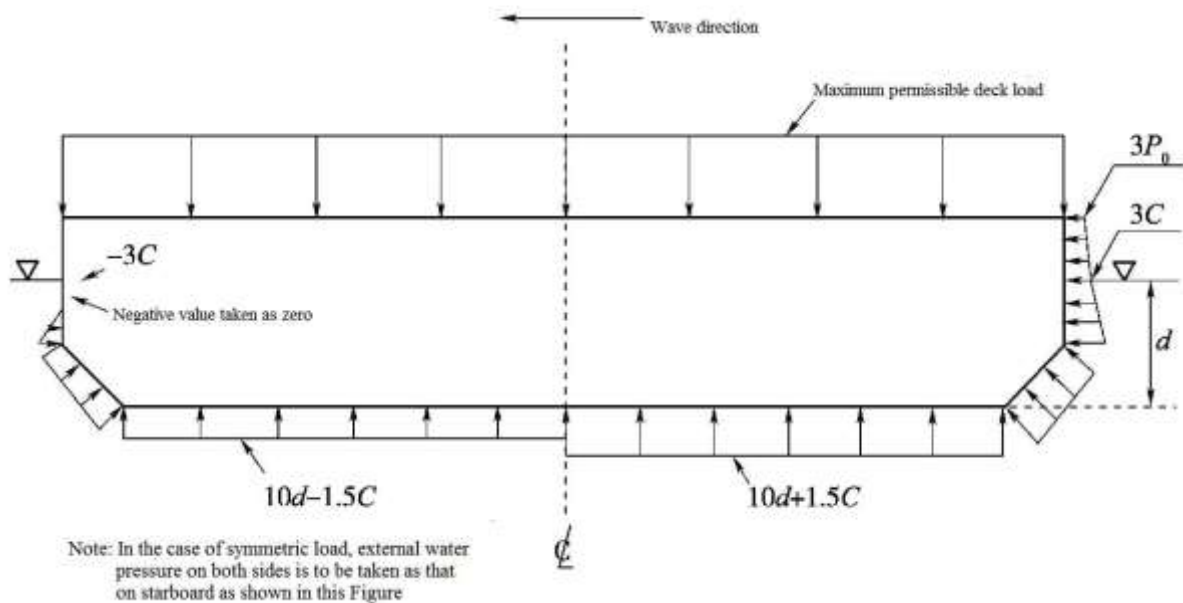


Figure 2.1.2

2.1.3 The following two conditions are taken into account for design conditions:

- (1) **Symmetric condition:** Maximum permissible deck load + external hydrostatic pressure + hydrodynamic wave pressure acting symmetrically inwards on both sides;
- (2) **Asymmetric condition:** Maximum permissible deck load + external hydrostatic pressure + antisymmetric hydrodynamic wave pressure acting inwards on one side and outwards on the other side.

3. Structural Models

3.1 Structural modelling

3.1.1 Model extent

- ① Longitudinal direction: In general, a typical midship hold/tank is to be taken for analysis, with fore and aft end faces (A and B) being at transverse bulkheads covered by the model;
- ② Transverse direction: Total breadth of the ship;
- ③ Vertical direction: Total moulded depth.

See Figure 3.1.1.

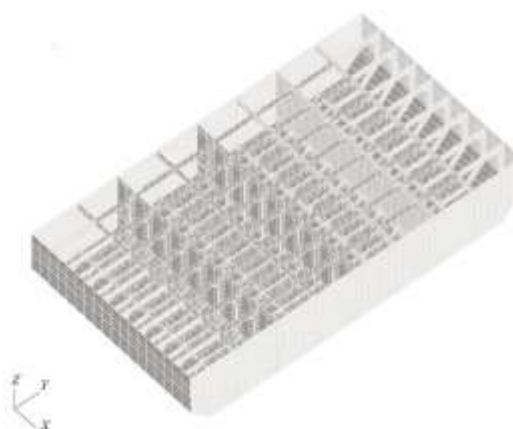


Figure 3.1.1 Model Extent (deck not shown)

3.1.2 Elements and meshing size of models

3.1.2.1 The elements and meshing size of models are to be in accordance with those specified for general finite element hold models, refer to 1.5.6, Chapter 1 of this PART.

3.1.2.2 The diagonals of transverse trusses are generally simulated by rod elements.

3.1.3 Boundary conditions

3.1.3.1 All nodes at edges of fore and aft end transverse bulkheads are to be restrained for 3 linear deflections, see Figure 3.1.3.1.

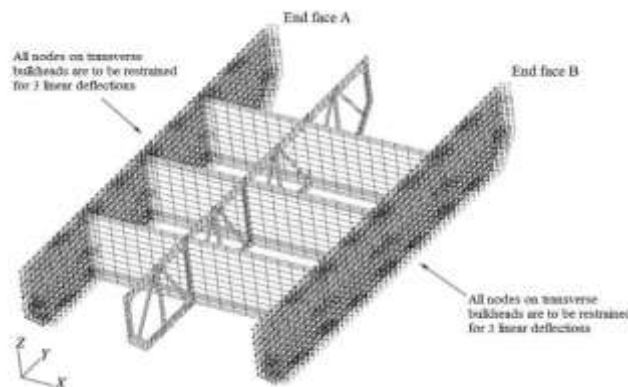


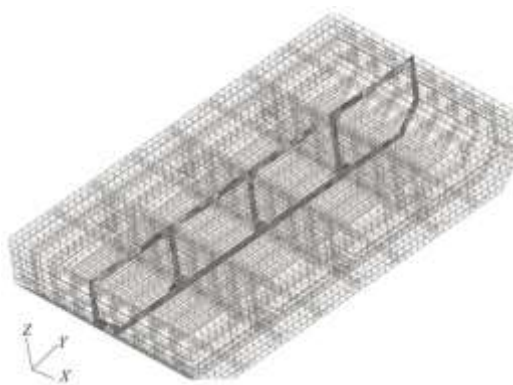
Figure 3.1.3.1 Boundaries Conditions of Model

4. Strength Assessment

4.1 General requirements

4.1.1 Assessment of results

4.1.1.1 The range of values for assessment of the results of finite element analysis is to be based on one of the web frames of the model, see Figures 4.1.1.1.



Figures 4.1.1.1

4.1.1.2 For floors and beam webs, the average shear stress based on the total height of webs may be taken as the shear stress in calculation.

4.2 Assessment of yield strength

4.2.1 Strength criteria

4.2.1.1 In all conditions, the calculated stress of individual structural members is not to be greater than the corresponding permissible values given in Tables 4.2.1.1(1) and (2).

Tables 4.2.1.1(1) - Plate Element

Structural Member	σ_e	$[\tau]$
Side transverse web, longitudinal bulkhead vertical girder web	170/K	–
Deck transverse web, bottom floor	170/K	90/K

Tables 4.2.1.1(2) - Beam and Rod Elements

Structural Member	$[\sigma_{rod}]$
Beam element simulating web faceplate of strength member of transverse web frame or beam fitted on transverse members	170 / K
Cross tie of transverse truss	141 / K

where: σ_e – equivalent stress of plate element (i.e. Von Mises stress), in N/mm²;

$$\sigma_e = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3\tau_{xy}^2}, \text{ based on membrane stress at centroid of the element}$$

σ_x – stress of element in direction X, in N/mm²;

σ_y – stress of element in direction Y, in N/mm²;

τ_{xy} – shear stress of element in plane XY, in N/mm²;

τ – average shear stress based on the total height of webs, in N/mm²;

σ_{rod} – axial stress of rod element or normal stress of beam element (excluding bending stress component), in N/mm²;

K – material factor.

CHAPTER 12 FLOATING CRANES

SECTION 1 GENERAL PROVISIONS

12.1.1 Application

12.1.1.1 This Chapter applies to single-deck crane barges with both deck and bottom being framed longitudinally.

12.1.1.2 Those not covered in this Chapter are to comply with the relevant requirements of Chapter 2 of this PART.

12.1.2 Class notation

12.1.2.1 Floating cranes complying with the requirements of this Chapter will be eligible to be assigned the class notation of Floating Crane.

12.1.3 Definitions

12.1.3.1 Fore end and aft end: The fore end and aft end of non-self-propelled floating cranes are to be determined according to their operation conditions. During transit, the floating cranes are to be treated as ordinary ships with the fore end of the hull in the forward direction being called the fore end and the opposite end the after end. In conditions other than transit, the end where the crane jib is fitted is called the fore end and the opposite end the aft end.

12.1.4 Arrangement and structures

12.1.4.1 The continuous longitudinal members of the hull are to be continuous from the fore end to the aft end as far as possible.

12.1.4.2 Two or more continuous longitudinal bulkheads (or longitudinal trusses) are to be fitted from the fore end to the aft end.

12.1.4.3 One transverse watertight bulkhead is to be fitted at a suitable position at each end of the barge. Between the end bulkheads, at least one intermediate transverse watertight bulkhead is to be fitted for barges not exceeding 50 m in length, and at least two intermediate transverse watertight bulkheads are to be fitted for barges exceeding 50 m in length. Such transverse bulkheads are to be arranged reasonably uniform.

12.1.4.4 Longitudinal or transverse supporting bulkheads or other effective structures with sufficient strength and rigidity are to be fitted underneath the cranes to provide adequate support. Such strengthened structures are to be so arranged as to effectively transmit stresses. The deck plating in way is to be increased in thickness or fitted with doublers. The thickness of doublers is not to be less than that of the deck plating. In addition, local strengthening is to be provided to the hull structure in way of other deck machinery or where heavy loads are imposed.

SECTION 2 - LONGITUDINAL STRENGTH

12.2.1 General requirements

12.2.1.1 The longitudinal strength is to comply with the relevant requirements in Section 2, Chapter 2 of this PART. Transit and lifting conditions are to be taken into account.

12.2.1.2 For fixed type floating crane, where the still water bending moment obtained from calculation is a sagging moment in lifting conditions, an additional bending moment (sagging moment) induced by the maximum horizontal component force which is imposed on the hull structure by the maximum load lifted is to be added.

12.2.1.3 For lifting conditions, the wave bending moment and wave shear force regarding the intended area of operation may be determined according to Section 2, Chapter 2 of PART TEN.

SECTION 3 - SHELL PLATING

12.3.1 Minimum thickness

12.3.1.1 The minimum thickness t of shell plating is not to be less than that obtained from the following formula:

$$t = 0.044L + 5.6 \text{ mm}$$

where: L — length of ship, in m.

12.3.2 Bottom shell

12.3.2.1 The thickness t of bottom shell plating within $0.5L$ amidships is not to be less than that obtained from the following formula:

$$t = 1.32s\sqrt{LK} + 2.5 \text{ mm}$$

where: s — spacing of longitudinals, in m;

L — length of ship, in m;

K — material factor.

12.3.3 Side shell plating

12.3.3.1 The thickness t of side shell plating within $0.5L$ amidships is not to be less than that obtained from the following formula:

$$t = 1.27s\sqrt{LK} + 2.5 \text{ mm}$$

where: s — spacing of frames, in m;

L — length of ship, in m;

K — material factor.

SECTION 4 – DECKS

12.4.1 Thickness of deck plating

12.4.1.1 The thickness t of strength deck plating within $0.5L$ amidships is not to be less than that obtained from the following formula:

$$t = 8.75s\sqrt{K} + 2.5 \quad \text{mm}$$

where: s — spacing of longitudinals, in m;

K — material factor.

12.4.1.2 The thickness t of strength deck plating outside $0.5L$ amidships is not to be less than that obtained from the following formula:

$$t = 7.13s\sqrt{K} + 2.5 \quad \text{mm}$$

where: s — spacing of longitudinals, in m;

K — material factor.

12.4.1.3 The thickness of deck plating in the cargo area is, in addition, not to be less than that obtained from the following formula:

$$t = 4.5s\sqrt{hK} \quad \text{mm, but not less than 6 mm}$$

where: s — spacing of beams or longitudinals, in m;

h — design head, in m, to be taken as $0.14p + 0.3$, p being the design load, in kPa;

K — material factor.

SECTION 5 - SINGLE BOTTOMS

12.5.1 Centre keelson

12.5.1.1 Floating cranes are to be provided with a centre keelson, with side keelsons being fitted on each side of the centre keelson, spaced not more than 2.5 m apart.

12.5.1.2 The web thickness t and the sectional area A of the face plate of the centre keelson are not to be less than:

$$t = 0.065L + 5 \quad \text{mm}$$

$$A = 0.60L + 9 \quad \text{cm}^2$$

where: L — length of ship, in m.

12.5.2 Side keelsons

12.5.2.1 The web thickness t and the sectional area A of the face plate of side keelsons are not to be less than:

$$t = 0.065L + 5 \quad \text{mm}$$

$$A = 0.24L + 10 \quad \text{cm}^2$$

where: L — length of ship, in m.

12.5.3 Plate floors

12.5.3.1 The spacing of plate floors is not to exceed 2.5 m.

12.5.3.2 The section modulus W of plate floors is not to be less than that obtained from the following formula:

$$W = 4Shl^2K \text{ cm}^3$$

where: S — spacing of floors, in m;

K — material factor;

h — design head, in m, to be taken as d or $0.66D$, whichever is the greater (d and D being draught and moulded depth respectively, in m);

l — span of floor, in m.

12.5.3.3 The web depth h of floors is not to be less than that obtained from the following formula and in addition, this depth is to be greater than 2.5 times the depth of the slot for the passage of longitudinals:

$$h = 60/l_1 \text{ mm}$$

where: l_1 — horizontal distance between longitudinal bulkheads or between the longitudinal bulkhead and side shell, in m.

12.5.4 Bottom longitudinals

12.5.4.1 The section modulus W of bottom longitudinals is not to be less than that obtained from the following formula:

$$W = 11.90shl^2K \text{ cm}^3$$

where: s — spacing of longitudinals, in m;

K — material factor;

h — design pressure head, in m, to be taken as d or $0.66D$, whichever is the greater (d and D being draught and moulded depth respectively, in m);

l — span of longitudinal, in m.

SECTION 6 - DOUBLE BOTTOMS**12.6.1 General requirements**

12.6.1.1 Where double bottoms are provided, the height h of the double bottom is to be determined by the following formula, but not to be less than 700 mm:

$$h = b/18 \text{ mm}$$

where: b — horizontal distance between longitudinal bulkheads (or longitudinal trusses), in mm.

12.6.1.2 The thickness of the centre girders, side girders, plate floors and inner bottom plating within the machinery space is to be increased by 2 mm above that obtained from the respective formulae given below in this Section.

12.6.2 Centre girders

12.6.2.1 The thickness t of centre girders is not to be less than that obtained from the following formula:

$$t = 0.05L + 4 \text{ mm}$$

where: L — length of ship, in m.

12.6.3 Side girders

12.6.3.1 The thickness t of side girders is not to be less than that obtained from the following formula:

$$t = 0.60\sqrt{L} + 2 \text{ mm}$$

where: L — length of ship, in m.

12.6.4 Plate floors

12.6.4.1 The thickness t of plate floors is not to be less than that obtained from the following formula:

$$t = 0.60\sqrt{L} + 2 \text{ mm}$$

where: L — length of ship, in m.

12.6.5 Inner bottom plating

12.6.5.1 The thickness t of inner bottom plating is not to be less than that obtained from the following formula:

$$t = 0.67s\sqrt{LK} + 2.5 \text{ mm}$$

where: s — spacing of the inner bottom longitudinals, in m;

K — material factor;

L — length of ship, in m.

12.6.6 Longitudinals

12.6.6.1 The section modulus of bottom longitudinals is to be determined in accordance with 12.5.4.1 of this Chapter.

12.6.6.2 The section modulus of inner bottom longitudinals is to be 85% of that of the bottom longitudinals.

SECTION 7 - SIDE FRAMING

12.7.1 Side transverses

12.7.1.1 Side transverses are to be fitted in line with plate floors and their section modulus W is not to be less than that obtained from the following formula:

$$W = 9.5Shl^2K \text{ cm}^3$$

where: S — spacing of side transverses, in m;

K — material factor;

h — vertical distance, in m, measured from the mid-point of span of the side transverse to upper deck at side;

l — span of side transverse, in m.

12.7.1.2 The web depth h of side transverses is not to be less than that obtained from the following formula and in addition, this depth is to be greater than twice the depth of the slot for the passage of longitudinals:

$$h = 100l \text{ mm}$$

where: l — span of side transverse, in m.

SECTION 8 - STRENGTH DECK FRAMING

12.8.1 Strength deck loading

12.8.1.1 The design head h of the strength deck is to be selected from Table 12.8.1.1.

Table 12.8.1.1 - Design Head h

Item	Deck Longitudinals	Deck Girders and Deck Transverses	Pillars
Design head, h (m)	$0.02 L + 0.76$	$0.085 L - 1.04 (D - d)$	$0.098 L - 1.10 (D - d)$

Note: L is length of ship, D moulded depth and d draught, in m.

12.8.1.2 Where the deck is subject to load, the design head is to be taken as $0.14p$ (p being the design load, in kPa), in m, but not to be less than the corresponding design head h given in Table 12.8.1.1.

12.8.2 Deck girders

12.8.2.1 The section modulus W of deck girders is not to be less than that obtained from the following formula:

$$W = 3.5bh^2K \text{ cm}^3$$

where: b — mean width, in m, of deck area supported by the girder;

K — material factor;

l — span of deck girder, in m;

h — design head of deck, in m, see 13.8.1 of this Section.

12.8.3 Deck transverses

12.8.3.1 Deck transverses are to be fitted in line with side transverses and their section modulus W is not to be less than that obtained from the following formula:

$$W = 3.9Shl^2K \text{ cm}^3$$

where: S — spacing of deck transverses, in m;

K — material factor;

l — span of deck transverse, in m;

h — design head of deck, in m, see 13.8.1 of this Section.

12.8.3.2 The web depth of deck transverses is not to be less than twice the depth of the slot for the passage of longitudinals.

12.8.4 Deck longitudinals

12.8.4.1 The section modulus W of deck longitudinals is not to be less than that obtained from the following formula:

$$W = 8.5shl^2K \text{ cm}^3$$

where: s — spacing of longitudinals, in m;

K — material factor;

h — design head of deck, in m, see 13.8.1 of this Section;

l — span of longitudinal, in m.

SECTION 9 - PILLARS AND TRUSSES

12.9.1 Pillars

12.9.1.1 Pillars are to comply with the relevant requirements of Section 10 of Chapter 2 of this PART, but the design head h of pillars underneath the strength deck is to be determined according to 12.8.1 of this Chapter.

12.9.2 Longitudinal trusses

12.9.2.1 Longitudinal trusses are to be composed of deck girders, keelsons, pillars and diagonals.

12.9.2.2 The sectional area of pillars of the longitudinal trusses is to comply with the requirements of Section 10 of Chapter 2 of this PART.

12.9.2.3 Diagonals of trusses

(1) The angle of inclination of diagonals of trusses is to be about 45°.

(2) The sectional area of diagonals of trusses is not to be less than 0.5 times that of the pillars calculated according to Section 10 of Chapter 2 of this PART and the ratio of the length of the diagonal to its minimum sectional radius of inertia is not to exceed 120.

CHAPTER 13 ORE CARRIERS

SECTION 1 - GENERAL PROVISIONS

13.1.1 Application

13.1.1.1 This Chapter applies to the determination of structural arrangements and scantlings within the cargo region of self-propelled single deck ore carriers with machinery aft, having two longitudinal bulkheads in the cargo region and a double bottom throughout the centre hold, intended for the carriage of ore cargoes in the centre hold. A typical cross section of such ore carriers is shown in Figure 13.1.1.1. Ore carriers of 250 m and over in length and engaged in unrestricted service are to satisfy the requirements of ISC Rules for Structures of Ore Carriers.

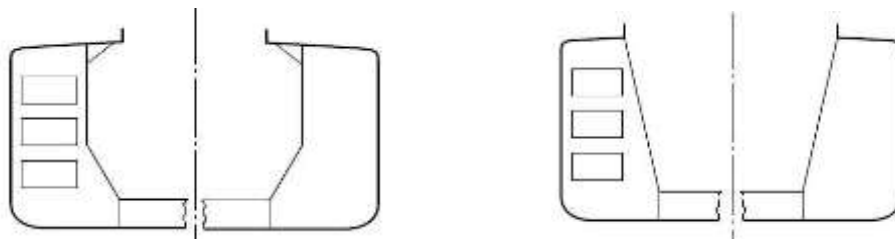


Figure 13.1.1.1

13.1.1.2 The fitting of a fore-castle, the loading manual and loading instrument, cargo hold hatch covers and the flooding condition (where applicable) are to comply with the relevant requirements of Chapter 8 of this PART.

13.1.1.3 The strengthening for grabs is to comply with the relevant requirements of Section 23, Chapter 2 of this PART.

13.1.1.4 The requirements of Sections 3 and 4 of this Chapter are only applicable to the cargo hold area. Those not covered in this Chapter are to comply with the relevant requirements of Chapter 2 of this PART.

13.1.1.5 Ore carriers of 150 m and over in load line length and carrying solid bulk cargoes having a density of 1.0t/m^3 and above, as defined in SOLAS regulation XII/1, are to comply with the relevant requirements of Section 15, Chapter 7 of this PART.

13.1.2 Class notation

13.1.2.1 Ore carriers complying with the requirements of this Chapter are eligible to be assigned the class notation of Ore Carrier.

13.1.2.2 When requirements for loading and unloading in multiple ports have not been raised in the design of ore carriers in accordance with ISC Guidelines for Direct Strength Analysis of Hull Structure of Ore Carriers, No MP notation is to be assigned to indicate the limitation.

13.1.2.3 Ore carriers complying with the requirements of Section 5 of this Chapter are eligible to be assigned the class notation of **EL100**.

13.1.3 Arrangements and structural configuration

13.1.3.1 The bottom, and the strength deck outside the line of cargo hatchway openings, are to be framed longitudinally within the cargo region. Inside the line of openings, the strength deck is to be framed transversely.

13.1.3.2 The transverse watertight bulkheads in centre holds within the cargo region are to be located in the same plane with those in wing tanks as far as practicable, otherwise means are to be provided to ensure the continuity of transverse strength. However, the form of construction used for transverse watertight bulkheads in centre holds may be different from that used in wing tanks.

13.1.3.3 Strength frame rings, transverse watertight bulkheads and wash bulkheads, which may be fitted in wing tanks within the cargo region, are to be in the same plane with bottom floors of center holds.

13.1.3.4 Where necessary, the bottom between strength frame rings may be fitted with intermediate floors.

13.1.4 Direct strength calculation and fatigue strength assessment for hull structure

13.1.4.1 For ore carriers of 150 m and over in length, direct strength calculation in respect to primary members of the hull is to be carried out in accordance with the requirements of ISC Guidelines for Direct Strength Analysis of Hull Structure of Ore Carriers.

13.1.4.2 For ore carriers of 150 m and over in length, fatigue strength assessment in respect to the following locations within the cargo region is to be carried out in accordance with the requirements of ISC Guidelines for Fatigue Strength of Ship Structure:

- (1) connections of longitudinals (bottom, side, deck and longitudinal bulkhead) to transverse web frames;
- (2) connections of longitudinals (bottom, side, deck and longitudinal bulkhead) to transverse bulkheads;
- (3) connections of longitudinal bulkheads to inner bottom plates;
- (4) connections of inner bottom plates to lower tools;
- (5) longitudinal bulkhead knuckles (if any).

13.1.4.3 For ore carriers of 250 m and over in length, special consideration is to be given to the effects of springing and whipping on hull structure fatigue strength. For detailed methods, see ISC Guidelines for Direct Calculation Assessment of Hull Structure Including Springing and Whipping.

SECTION 2 - LONGITUDINAL STRENGTH

13.2.1 General requirements

13.2.1.1 The longitudinal strength is to comply with the requirements of Section 2, Chapter 2 of this PART.

13.2.1.2 Where the hold deck opening is large, the longitudinal strength in respect to a combination of bending moment and torque is to be checked in accordance with the requirements of Section 10, Chapter 6 of this PART, with the torque of cargo being taken as zero in general.

13.2.2 Ultimate strength of hull girder

13.2.2.1 The ultimate bending capacity of any transverse section of hull girder during navigation is to comply with the following requirements.

(1) The vertical ultimate bending capacity of hull girder is to comply with the following

$$\gamma_s \overline{M}_s + \gamma_w M_w \leq \frac{M_U}{\gamma_R}$$

where: $\overline{M}_s$ — permissible still water bending moment, in kN·m;
 M_w — wave bending moment, in kN·m;
 M_U — vertical ultimate bending capacity of hull girder, in kN·m;
 $\gamma_s, \gamma_w, \gamma_R$ — partial safety factors, to be taken as:

$\gamma_s = 1.0$;

$\gamma_w = 1.2$;

$\gamma_R = \gamma_M \gamma_{DB}$;

where:

γ_M — partial safety factor, covering material, geometric and strength prediction uncertainties, to be taken as: $\gamma_M = 1.05$;

γ_{DB} — partial safety factor, covering the effect of double bottom bending, to be taken as:

$\gamma_{DB} = 1.10$ for hogging condition;

$\gamma_{DB} = 1.0$ for sagging condition.

(2) Curve M - χ

The ultimate bending capacities of a hull girder transverse section M_U , in hogging and sagging conditions, are defined as the maximum values of the curve of bending moment capacity M versus the curvature χ of the transverse section considered.

The curvature χ is positive for hogging condition and negative for sagging condition.

The curve M - χ is to be obtained by means of an incremental-iterative approach in accordance with Appendix 5, Chapter 6 of this PART.

(3) The hull girder transverse sections are constituted by the elements contributing to the hull girder longitudinal strength, and the standard diminution thickness given in Table 13.2.2.1 is to be deducted in calculation.

Table 13.2.2.1 - Standard thickness deduction

Position	Condition	Standard Thickness Deduction (mm)
Within 1.5 m below weather deck	One side connected to ballast water	1
	Two sides connected to ballast water	2
Elsewhere	—	1

13.2.2.2 For ore carriers of 250 m and over in length, special consideration is to be given to the effects of whipping on hull girder ultimate strength. For detailed methods, see ISC Guidelines for Direct Calculation Assessment of Hull Structure Including Springing and Whipping.

SECTION 3 - HULL FRAMING

13.3.1 Double bottom

13.3.1.1 Unless provided otherwise in this Section, the structural arrangement and scantlings of double bottom are to comply with the relevant requirements of Section 6, Chapter 2 and Section 2, Chapter 7 of this PART. For ore carriers of 230 m and over in length, however, plate floors may be spaced not more than 2.8m apart.

13.3.1.2 The width and depth of the double bottom in way of centre holds are to comply with the strength requirements of this Chapter and in addition, the requirements for stability in loaded conditions.

13.3.1.3 Where the proposed depth of the double bottom exceeds 1.5 times the minimum depth required in Section 6 of Chapter 2 of this PART, the scantlings of the stiffeners on floors and girders are to be increased and the buckling of stiffeners, floors and girders is to be checked.

13.3.1.4 The scantlings of the stiffeners of watertight floors and girders in double bottom are to comply with the requirements for the stiffeners on bulkheads in deep tanks, and the stiffeners are to be bracketed at both ends.

13.3.1.5 Where single bottom is fitted in way of wing tanks, attention is to be given to a smooth transition of the inner bottom plating of the double bottom in way of center holds into single bottom wind tanks. The inner bottom plating is to be extended into the wing tank with a sufficient width and bracketed to the bulkhead or strength frame ring. The thickness t (mm) of bracket is not to be less than $5+0.025L$, where the L is the length of ship (to be taken not greater than 300m for calculation), and the thickness of bracket is to be given a smooth transition of inner bottom plating.

13.3.1.6 Where single bottom is fitted in way of wing tanks and if intermediate floors are fitted only in way of centre hold bottom between strength frame rings, attention is to be given to a smooth transition of the floors into wind tanks, and vertical brackets are to be fitted in corresponding positions within wing tanks. Such brackets are, in general, to extend transversely over a sufficient width and vertically to a sufficient height above the extension of inner bottom plating in wing tanks. The thickness of the brackets may be the same as that of plate floors. The thickness of brackets may be directly calculated for ore carriers with the length of 150m and above, but not less than the minimum thickness of solid floors required in 13.3.1.8.

13.3.1.7 Where the double bottom is interconnected with wing tanks or centre holds are used as storm ballast tanks, the scantlings of which are also to comply with the requirements in Section 13, Chapter 2 of this PART for deep tanks.

13.3.1.8 The minimum thickness of solid floors is not to be less than the value calculated by the following formula:

$$t_{\min} = \max(0.6 L + 2.5, 12) \text{ mm}$$

where: L – length of ship, in m, to be taken not greater than 300 m for calculation.

13.3.2 Single bottom

13.3.2.1 The section modulus W of bottom longitudinals is not to be less than that obtained by the following formula:

$$W = 11.5 s d l^2 K \text{ cm}^3$$

where: s — spacing of longitudinals, in m;

d — draught, in m;

l — span of longitudinal, in m;

K — material factor.

13.3.2.2 The scantlings of bilge longitudinals are to be graduated between those required for the bottom and lowest side longitudinals.

13.3.2.3 Floors are to be spaced not more than 3.6 m apart. The section modulus W and the net floor area A of floors at the span point are not to be less than those obtained as follows, but not greater than those of corresponding centre hold floors:

$$W = 4.59 S D l^2 K \text{ cm}^3$$

$$A = 0.56 S D l K \text{ cm}^2$$

where: S — spacing of floors, in m;

D — moulded depth, in m;

l — span of floor, in m;

K — material factor.

13.3.2.4 The spacing and scantlings of bottom girders are to be determined by direct calculation.

13.3.3 Deck framing

13.3.3.1 The deck framing is to comply with the relevant requirements of Section 8, Chapter 2 of this PART.

13.3.3.2 The buckling of deck structure between hatchways is to be checked.

13.3.4 Side framing

13.3.4.1 The ship's sides are normally longitudinally framed, and the side longitudinals within $0.1D$ from bottom and deck are to continuously pass through transverse bulkheads. The section modulus W of side longitudinals is, in addition to satisfying relevant requirements of 2.7.5, Chapter 2 of this PART, not to be less than that obtained by the following formula:

$$W = 7.2s(h+1.2)^2K \quad \text{cm}^3$$

where: s — spacing of longitudinals, in m;

h — vertical distance measured from the longitudinal under consideration to deck line at side amidships, in m, but not less than 2.5 m;

l — span of longitudinal, in m;

K — material factor.

13.3.4.2 Web frames are to be fitted in the plane of plate floors of longitudinally framed bottom.

13.3.4.3 The section modulus W of web frames is not to be less than that obtained by the following formula:

$$W = CS(h + 1.2)^2K \quad \text{cm}^3$$

where: S — spacing of web frames, in m;

h — vertical distance measured from the mid-span of web frame to deck line at side, in m;

l — span of web frame, in m;

C — coefficient: $C = 11$, without horizontal strut; $C = 3.2$, with 1 horizontal strut; $C = 3$, with 2 horizontal struts;

K — material factor.

13.3.4.4 The net web area A of web frames is not to be less than that obtained by the following formula:

$$A = C_1S(h + 1.2)lK \quad \text{cm}^2$$

where: S — spacing of web frames, in m;

h — vertical distance measured from the mid-span of web frame to deck line at side, in m;

l — span of web frame, in m;

C_1 — coefficient: $C_1 = 0.5$ at section of span points and 0.25 at other sections, with 1 horizontal strut; $C_1 = 0.66$ at section of span points and 0.33 at other sections, with 2 horizontal struts;

K — material factor.

13.3.4.5 The dimensions of web frames may be directly calculated for ore carriers with the length of 150 m and above.

13.3.5 Strength frame rings in wing tanks

13.3.5.1 The strength frame ring in wing tanks is composed of web beams, web frames, plate floors, vertical girders on the longitudinal bulkhead and cross ties.

13.3.5.2 The spacing S of strength frame rings is not to be more than that obtained by the following formula:

$$S = 0.006L + 3.2 \text{ m, but not greater than 5.6 m}$$

where: L — length of ship, in m.

13.3.5.3 Cross ties are to comply with the relevant requirements of Section 8, Chapter 4 of this PART.

The dimensions of cross ties may be directly calculated for ore carriers with the length of 150m and above.

13.3.5.4 The cross ties are to be subject to integral buckling check as beams.

13.3.5.5 The minimum thickness of webs of strength frame rings in wing tanks is not to be less than the value calculated by the following formula:

$$t_{\min} = \max(0.6\sqrt{L} + 2.5, 12) \text{ mm}$$

where: L — length of ship, in m, to be taken not greater than 300m for calculation.

13.3.6 Cargo hold boundary

13.3.6.1 Cargo hold boundary means longitudinal bulkhead, corrugated transverse bulkhead as well as upper and lower stool (if any), plane transverse bulkhead, upper deck and hatch coaming in the cargo hold (except for inner bottom) which are in contact with cargo.

13.3.6.2 Thickness t of cargo hold boundary plate is not to be less than the value obtained from the following formula:

$$t = 4.65 C_1 s \sqrt{\frac{K_c H K}{\gamma}} \text{ mm}$$

where:

s — length of shorter side of plate panel, in m;

γ — loading rate, in m³/t, not to be more than 0.833;

H — vertical distance measured from lower edge of panel to deck in way of midship side, in m;

$C_1 = 1.2 - \frac{s}{2l}$, where l is length of longer side of plate panel, C_1 is to be taken as 1 for $C_1 > 1$;

K_c — cargo pressure coefficient, to be taken as:

$K_c = \cos^2 \alpha + (1 - \sin \psi) \sin^2 \alpha$ for transverse bulkhead and longitudinal bulkhead, lower stool, vertical upper stool and hatch coaming;

$K_c = 0$ for upper deck and inclined upper stool;

where: α — included angle between considered plate and horizontal plane, in degree;

ψ — angle of repose assumed for cargo in bulk, in degree, to be taken as 35° for carriage of ore;

K — material factor.

13.3.6.3 Section modulus W of cargo hold boundary stiffener is not to be less than the value obtained from the following formula:

$$W = \frac{8.5}{\gamma} K_c H s l^2 K \quad \text{cm}^3$$

where: γ and K_c — the same as those in 16.3.6.2;

l — span of stiffener, in m;

s — spacing of stiffeners, in m;

H — vertical distance measured from the midpoint of span of stiffener to deck in way of midship side, in m;

K — material factor.

13.3.7 Web stiffeners of non-watertight primary members within cargo hold area

13.3.7.1 Where the dimensions of web stiffeners of non-watertight primary members within cargo hold area are calculated, the thickness deduction listed in 13.3.7.1 is to be reduced.

Table 13.3.7.1 - Thickness Deduction

Location	Thickness deduction (mm)
Both sides within ballast tanks	2.0
Elsewhere	1.0

13.3.7.2 Net thickness of web stiffeners is to satisfy the following criteria:

(1) Minimum net thickness of stiffener web plate

The net thickness of stiffener web plate is not to be less than $3.0+0.015L$, where L is ship length (L need not be taken greater than 300 m during calculation).

(2) Stiffener web plate

$$t_w \geq \frac{h_w}{C_w} \sqrt{\frac{R_{eH}}{235}}$$

(3) Flange

$$t_f \geq \frac{b_{f-out}}{C_f} \sqrt{\frac{R_{eH}}{235}}$$

where: C_w C_f — slenderness coefficient given in Table 13.3.7.2;

b_{f-out} — maximum distance, in mm, from mid thickness of the web to the flange-edge, as shown in Figure 13.3.7.2;

h_w — depth of stiffener web, in mm, as shown in Figure 13.3.7.2;

t_f — net flange thickness, in mm;

t_w — net thickness of plate, in mm;

R_{eH} — Specified minimum yield stress of the plate material, in N/mm².

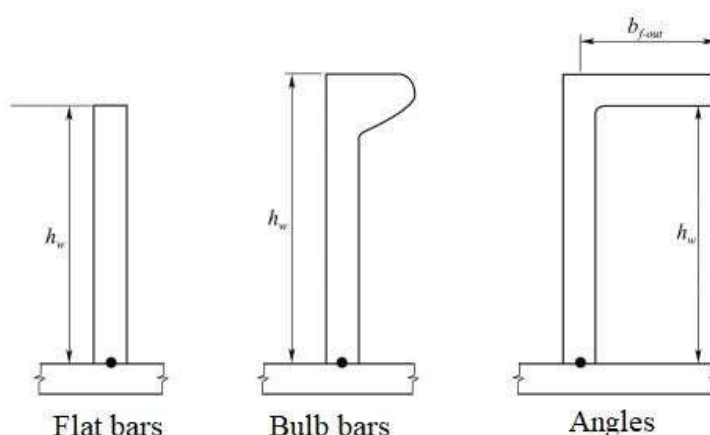


Figure 13.3.7.2 Stiffener Scantling Parameters

Table 13.3.7.2 - Slenderness Coefficients

Type of stiffener	Cw	Cf
Angle bars	75	12
Bulb bars	45	–
Flat bars	22	–

13.3.7.3 The total flange breadth bf , in mm, for angle and T-bars is to satisfy the following criterion:

$$bf \geq 0.25h_w$$

where: h_w — as defined in 13.3.7.2;

13.3.7.4 Bending stiffness of web stiffeners

The net moment of inertia, in cm^4 , of web stiffener, I_{st} , fitted on non-watertight primary members within cargo hold area onboard ore carriers, with effective attached plate, $seff$, is not to be less than the minimum moment of inertia defined in Table 16.3.7.4, the breadth of effective attached plate $seff$, is to be calculated by the following formula:

$$seff = 0.8s \quad \text{mm}$$

where: s — breadth of web plate panel, in mm, to be taken as the spacing of web stiffeners.

Table 13.3.7.4 - Stiffness Criteria for Web Stiffeners

Stiffener Arrangement	Minimum Moment of Inertia of Web Stiffeners, cm^4
A. Web stiffeners fitted along the primary member span 	$I_{st} \geq Cl^2 A_{eff} \frac{R_{eH}}{235}$
B. Web stiffeners fitted normal to the primary member span 	$I_{st} \geq 1.14ls^2 t_w \left(2.5 \frac{1000l}{s} - 2 \frac{s}{1000l} \right) \frac{R_{eH}}{235} \cdot 10^{-5}$
where:	

C — slenderness coefficient to be taken as:

$C = 1.43$ for longitudinal stiffeners including sniped stiffeners;

$C = 0.72$ for other stiffeners.

l — length of web stiffener, in m.

(1) For web stiffeners welded to local supporting members, the length is to be measured between the flanges of the local supporting members.

(2) For sniped web stiffeners, the length is to be measured between the lateral supports, e.g. the total distance between the flanges of the primary member as shown for stiffener arrangement B.

A_{eff} — net section area of web stiffeners, including attached plate with effective width assumed to be 80% of stiffener spacing s , in cm^2 .

t_w — net web thickness of the primary member, in mm.

ReH — specified minimum yield stress of the material of the web plate of the primary member, in N/mm^2 .

SECTION 4 – BULKHEADS

13.4.1 Transverse watertight bulkheads

13.4.1.1 Transverse watertight bulkheads are to be fitted with plate floors at bottom.

13.4.1.2 The scantlings of upper and lower stools of transverse watertight bulkheads are, if fitted, to comply with the requirements of this Section and in addition, the relevant requirements of Section 12, Chapter 2 of this PART.

13.4.1.3 The transverse bulkheads forming the boundary of ballast holds are to comply with the requirements of Section 13, Chapter 2 of this PART for deep tank bulkheads.

13.4.1.4 The thickness of the lowest strake of transverse watertight bulkheads is to be not less than that of inner bottom plating defined in 2.22.3.4 and 2.23.3.1 of Chapter 2 in this PART and is to be gradually tapered upwards.

13.4.2 Longitudinal watertight bulkheads

13.4.2.1 Longitudinal watertight bulkheads are to be plane, and framed longitudinally in general.

13.4.2.2 The longitudinal bulkheads are to be fitted with continuous bottom girders.

13.4.2.3 The scantlings of the longitudinal bulkheads are to comply with the requirements of this Section and in addition, the relevant requirements of Section 12, Chapter 2 of this PART.

13.4.2.4 The thickness of the longitudinal bulkhead plating in way of the knuckle is to be appropriately increased and the knuckle may be strengthened by horizontal girders to improve resistance to transverse compressive buckling stresses. The scantlings of the horizontal girders are to be determined by direct calculation.

13.4.2.5 Primary members are to be fitted at any vertical knuckle of longitudinal bulkhead. Distance between knuckle and primary members is not to be greater than 70 mm. Where the

knuckle is not vertical, it is to be strengthened appropriately with normal stiffeners in the same line with the knuckle or other equivalent measures are to be taken.

13.4.2.6 Bulkhead plating

- (1) The thickness t of bulkhead plating is not to be less than that obtained by the following formula:

$$t = 4s\sqrt{hK} + 2.5 \text{ mm}$$

where: s — spacing of stiffeners, in m;

h — vertical distance, in m, measured from lower edge of strake to tank top on the centreline, but not less than $0.4D$;

K — material factor.

- (2) The thickness t of bulkhead plating within $0.1D$ from deck is not to be less than that obtained by the following formula:

$$t = 4.2s\sqrt{DK} + 2.5 \text{ mm}$$

where: s — spacing of stiffeners, in m;

D — moulded depth, in m;

K — material factor.

- (3) The thickness t of bulkhead plating is to additionally comply with the following:

$$t \geq as/27D \text{ mm}$$

where: s — spacing of stiffeners, in m;

a — vertical distance, in m, measured from $D/2$ to the centre of panel;

D — moulded depth, in m.

- (4) The thickness of the lowest strake of the longitudinal bulkheads is not to be less than that of adjacent inner bottom plating defined in 2.22.3.4 and 2.23.3.1 of Chapter 2 in this PART and is to be gradually tapered to the thickness of longitudinal bulkhead plating.
- (5) The thickness of longitudinal bulkhead plating within $0.1D$ from deck need not exceed the sheer strake thickness with the same spacing of frames.

13.4.2.7 Vertical webs

- (1) The vertical webs on longitudinal bulkheads are to be fitted within wing tanks, and the dimensions of the vertical webs are to be calculated according to 13.3.4.3 of this Chapter, and direct strength calculation may be carried out for ore carriers with the length of 150m and above.
- (2) The brackets at both ends of the vertical web are to comply with the relevant requirements of 1.2.7 of Chapter 1 of this PART.
- (3) Buckling-restrained stiffeners are generally to be fitted on the vertical web plating.

13.4.2.8 Horizontal stiffeners

- (1) The section modulus W of horizontal stiffeners is not to be less than that obtained by the following formula:

$$W = 7.2s(h+1.2) / ^2K \quad \text{cm}^3$$

where: s — spacing of horizontal stiffeners, in m;

h — vertical distance, in m, measured from horizontal stiffener to tank top on the centreline, but not less than 2.5 m;

l — span of horizontal stiffener, in m;

K — material factor.

(2) Horizontal stiffeners are to continuously pass through transverse bulkheads within $0.1D$ from deck and inner bottom.

13.4.3 Wash bulkheads

13.4.3.1 Where necessary, plane perforated wash bulkheads are to be fitted in wing tanks.

13.4.3.2 Wash bulkheads are to comply with the relevant requirements of Section 11, Chapter 4 of this PART.

SECTION 5 - EASY LOADING REQUIREMENTS

13.5.1 General requirements

13.5.1.1 This Section applies to ore carriers having a single hold being capable of loading 100% (easy loading) capacity in one step for all cargo holds.

13.5.1.2 Average loading rate during easy loading is not to be more than the provisions in Table 13.5.1.2. Higher average loading rate is to be specially considered.

Table 13.5.1.2 - Average loading rate

Deadweight Tonnage (t)	Average Loading Rate (t/h)
220,000 – 250,000	14,000
> 250,000	16,000

13.5.2 Class notation

13.5.2.1 Ore carriers complying with the provisions of this Section are to be assigned class notation EL100.

13.5.3 Hull structure strength

13.5.3.1 In the whole process of easy loading, actual still water bending moment and still water shearing force of hull girder are not to exceed permissible still water bending moment and permissible still water shearing force in harbor condition.

13.5.3.2 In the whole process of easy loading, it is to be ensured that double bottom and transverse bulkhead have sufficient local strength, and direct calculation of structural strength is to be carried out in accordance with ISC Guidelines for Direct Strength Analysis of Hull Structure of

Ore Carriers.

13.5.4 Equipment provision and requirements

13.5.4.1 If ballast adjustment is required to control that actual still water bending moment and still water shearing force of hull girder do not exceed permissible still water bending moment and still water shearing force in harbor condition, requirements of 13.5.4.2 and 13.5.4.3 are to be complied with.

13.5.4.2 The ballast system is to be able to match the requirements of mean loading rate in 13.5.1.2, including ballast tank arrangement, capacity of ballast pump and arrangement of ballast piping system.

13.5.4.3 The ship is to be provided with tank (e.g. ballast tank, fuel oil tank, etc.) remote control sounder and ship draught reading system, which are synchronous with loading instrument on board. It is not necessary to consider fuel oil tanks without level change during loading.

13.5.5 Requirements of easy loading manual

13.5.5.1 Easy loading manual which is approved by ISC is to be provided on board or may be included in other approved loading manual.

13.5.5.2 Easy loading sequence is to include operation sequence of each step of loading from the beginning to the end as well as synchronous ballast adjustment, so as to ensure that the requirements of 13.5.3.1 are complied with during loading (including each cargo hold from empty load to full load).

13.5.5.3 Easy loading manual is at least to include following:

- (1) loading capacity in each hold for each step;
- (2) ballast water adjustment in each ballast tank for each step;
- (3) maximum still water bending moment and shearing force at the end of each step;
- (4) ship's draught and trim at the end of each step.



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