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**GUIDELINES FOR HULL
STRUCTURES OF
PUBLIC AFFAIR SHIPS AT SEA**

2021

Effective from 1 July 2021

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CHAPTER 1 GENERAL PROVISIONS

1.1 General requirements

1.1.1 The Guidelines apply to public affair ships at sea whose hull structures are of FRP, steel or aluminium alloy material.

1.1.2 For high speed public affair ships of 20 m and over in length^①, hull structures are to comply with relevant provisions of ISC Rules for Construction and Classification of Sea-going High Speed Craft. But when the design vertical acceleration a_{cg} at the center of gravity of a ship is determined by the owner or designer, its value may not be restricted by the upper limit of a_{cg} given in the rules above.

1.1.3 For non-high speed public affair ships of 20 m and over in length:

(1) patrol ships of less than 90 m in length in restricted service are to be in accordance with relevant provisions of the Guidelines;

(2) public affair ships other than those in (1) above are to be in accordance with relevant provisions of Chapters 1 and 2, PART TWO of ISC Rules for Classification of Sea-going Steel Ships. For block coefficient $C_B < 0.6$, wave loads may be calculated in accordance with the requirements of 2.2.3, Chapter 2, PART TWO of ISC Rules for Classification of Sea-going Steel Ships.

1.1.4 For public affair ships of less than 20 m in length, hull structures are to comply with relevant provisions of ISC Rules for Classification of Sea-going Boats.

1.1.5 Patrol ships specified in 1.1.3(1) of this Chapter are characterized by:

(1) $L/B > 5$;

(2) $B/D < 2.5$;

(3) $C_B \geq 0.40$.

L, B, D, C_B are defined in 1.3 of this Chapter. Special consideration will be given to patrol ships with other ship type characteristics.

1.1.6 Collision-resistance requirements for hull structures may be in accordance with Chapter 9 of the Guidelines if necessary.

1.2 Plans and documents

1.2.1 Plans and documents are to comply with the requirements of Section 1, Chapter 2, PART TWO of ISC Rules for Classification of Sea-going Steel Ships.

① “Length” in 1.1.2, 1.1.3 and 1.1.4 is as defined in ISC Rules for Classification of Sea-going Steel Ships.

1.3 Definitions and symbols

1.3.1 Unless expressly provided otherwise, definitions and symbols used in the Guidelines are as follows:

- (1) *Public affair ships* are ships used for administrative purposes of the Government.
- (2) *Patrol ships* are public affair ships mainly engaged in patrols, on-site supervision, escort, evidence collection, search and rescue command, etc., in accordance with relevant laws, such as maritime patrol ships, supervision ships, fishery administration supervision and law enforcement ships, etc.
- (3) *High speed* means a maximum speed V greater than or equal to $7.19\nabla^{0.1667}$ kn.
- (4) *Maximum speed* V , in kn, is the speed achieved at the maximum continuous propulsion power at the ship's full-load displacement and in smooth water.
- (5) *Lightship displacement*, in tonnes, is the displacement of a ship, the construction of which is completed and which is fully equipped, without personnel and their effects, food, fresh water, liquid loads, supplies, fuel oil, lubricating oil, feedwater, jet fuel, special loads etc.
- (6) *Full displacement* Δ , in tonnes, is the lightship displacement plus weights of rated personnel and their effects, food, fresh water, liquid loads, supplies, jet fuel, special loads etc., plus 100% of the fuel oil, lubricating oil, feedwater required for the endurance.
- (7) *Full-load displacement* ∇ , in m^3 , is the displacement corresponding to the full-load displacement of the ship.
- (8) *Full-load draught* T , in m, is the mean draught at the full-load displacement.
- (9) *Full-load waterline* is a waterline corresponding to the full-load draught and parallel to the baseline.
- (10) *Length* L , in m, is the length of the full-load waterline, excluding appendages, at or below the full-load waterline.
- (11) *Breadth* B , in m, is the breadth of the broadest part of the moulded watertight envelope of the rigid hull, excluding appendages, at or below the full-load waterline.
- (12) *Waterline beam* B_{WL} , in m, is the maximum moulded breadth at the full-load waterplane.
- (13) *Moulded depth* D , in m, is the vertical distance measured at the midship cross section from the baseline to the top of uppermost complete deck at side.
- (14) *Block coefficient* C_B is a ship form coefficient calculated according to the following:

$$C_B = \frac{\Delta}{1.025LB_{WL}T}$$

(15) *Within the reference coordinate system OXYZ*, the origin is taken as the intersection of a perpendicular at the end of the full-load waterline with the baseline in way of longitudinal centerline, and *x*, *y* and *z* are considered positive respectively in the forward, left and up directions.

(16) *Amidship* is at the middle of the length *L*.

(17) *Main deck* is the uppermost deck extending throughout the length of the ship.

(18) *Strength deck* is the uppermost continuous deck or long superstructure deck included in the hull girder strength.

(19) *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*.

(20) *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.

(21) *Deckhouse* is an enclosed structure on the uppermost continuous deck or any other exposed deck, with the side plating being inboard of the shell plating more than 4% of the breadth *B*.

(22) *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.

(23) *Long forecastle* is the first tier long superstructure that extends from the stem, past amidship but not reaching the stern.

(24) *Bulkhead deck* is the uppermost continuous deck to which all transverse watertight bulkheads extend.

(25) *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.

(26) *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.

(27) *Restricted service* is a generic term of the service categories 1, 2 and 3 as shown in Table 1.3.1(27) below:

Table 1.3.1(27)

Category	Limitation for navigation	
	Distance to land (n mile)	
Service category 1	200 (summer/tropical*)	100 (winter*)
Service category 2	20 (summer/tropical*)	10 (winter*)
Service category 3	Sheltered waters**	

Notes:

* Seasonal areas as specified in Annex II to the International Convention on Load Lines, 1966.

** Sheltered waters include the sea areas between an island and the shore and between islands with a distance of less than 10 n miles in between, which forms a comparatively good sheltered or similar condition with a little wave.

(28) *The material factor K* of hull structural steel is given in Table 1.3.1(28).

Material Factor K**Table 1.3.1(28)**

Yield strength R_{eH} (N/mm ²)	Material factor K
235	1.0
315	0.78
355	0.72
390	0.68

(29) R_{eH} is yield strength of steel, in N/mm², see relevant provisions of ISC Rules for Materials and Welding.

CHAPTER 2 STRUCTURAL ARRANGEMENT

2.1 Arrangement of watertight transverse bulkheads

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

- (1) one collision bulkhead;
- (2) one after peak bulkhead;
- (3) for engine room located amidships, two bulkheads are fitted to form the boundary of machinery space; for engine room located at stern, one bulkhead is fitted before the machinery space; for ships provided with electric propulsion plant, generator room and propulsion motor room are to be enclosed by watertight bulkheads.

2.1.2 In addition to complying with the requirements of 2.1.1, the number and distribution along ship length of watertight bulkheads are to comply with relevant requirements for damage stability.

2.1.3 Where the watertight bulkhead is not suitable to be arranged in a plane, a stepped bulkhead may be provided. In this case, the part of the deck forming the step is to be watertight and have the strength equivalent to that of the bulkhead.

2.2 Collision bulkheads

2.2.1 The collision bulkhead is to be located at a distance from the forward perpendicular of not less than 5% of the length of the ship and not more than 3 m+ 5% of the length of the ship.

2.2.2 A collision bulkhead is to be fitted which is to be watertight up to the bulkhead deck. Where a long forward superstructure is fitted, the collision bulkhead is to be extended weathertight to the deck next above the bulkhead deck.

2.2.3 The collision bulkhead may have steps or recesses provided they are within the limits prescribed in 2.2.1.

2.3 Arrangement of cofferdams

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

2.3.2 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.

2.3.3 Spaces intended for carrying flammable liquids are to be separated from accommodation and service spaces by cofferdams.

2.3.4 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, cofferdams need not be provided between them.

2.4 Arrangement of double bottoms

2.4.1 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.

2.5 Compartments located forward of the collision bulkhead

2.5.1 Fuel oil and other flammable oils are not to be carried in forepeak tanks and other compartments located forward of the collision bulkhead.

2.6 Fuel oil tanks

2.6.1 Ballast water is not to be carried in fuel oil tanks except for emergencies.

2.7 Arrangement of means of access and openings

2.7.1 The number and size of small hatchways and openings in means of access leading to tanks or other enclosed spaces are to be kept to a minimum while ensuring proper working of the ship.

2.7.2 The inner bottom manhole is not to be smaller than 400mm × 400mm or 500mm × 380mm. The number (generally at least 2) and the arrangement are to give easy access to any part of the double bottom.

2.7.3 Double bottom floors and girders are to comply with the following requirements:

(1) Manholes are to be provided in floors and girders (excluding continuous centre girders), so as to give easy access to any part of the double bottom.

(2) The size of manholes and lightening holes in floors and girders is in general to be less than 50% of the height of double bottom in way.

(3) Manholes are in general not to be cut in the continuous centre girders within 0.75*L* amidships, but if such holes are essential in exceptional cases, suitable compensation is to be provided. Manholes are not permitted in floors and girders under the pillar.

2.7.4 Tanks, ballast tanks and cofferdams are at least to be provided with 1 access hatchway and ladder.

2.7.5 When the access hatch is open, light plates are to be placed on it to prevent personnel from falling.

2.7.6 The ladder structure is to comply with the following requirements:

(1) vertical ladders or inclined ladders with an inclination angle generally not greater than 65°;

(2) ladders and railings are to have appropriate strength and rigidity, and be securely connected to the compartment structure by supports. The cross section of the side girder of the ladder is to be flat steel not less than 60mm × 6mm;

(3) the width between the side girders of the ladder is not to be less than 400mm;

(4) steps of the inclined ladder are to be arranged at equal intervals with a vertical distance of less than 300 mm. The step is to be composed of two square steels with a cross-section of not less than 16 mm × 16 mm to form a horizontal step, with the corner edges of the square steel facing upwards, or an equivalent structure. The step is to be welded to the side girder;

(5) all inclined ladders are to be provided with handrails of sound construction at suitable heights on both sides of the step.

CHAPTER 3 STRUCTURAL DESIGN PRINCIPLES

3.1 General requirements

3.1.1 This Chapter specifies principled requirements for arrangement and size of main structures of the hull.

3.1.2 The spacing of longitudinals is not to be less than the value given in the table below:

Spacing of longitudinals		Table 3.1.2
Ship length L , in m	$L < 80$	$L \geq 80$
Minimum permissible spacing of longitudinals, in mm	200	300

3.1.3 Frames are to be spaced apart not less than 500 mm; it may be the original frame spacing plus intermediate frame in local areas.

3.1.4 The span of secondary and primary members is defined as follows:

(1) Where there is no end bracket for secondary members, the span point is taken at the end of the member where the end is not bracketed. Where there is an end bracket for secondary members, the span point may be taken at the mid-length of the bracket.

(2) Primary members are generally fitted with end brackets, and the span point is to be taken at a point distant, K_e , from the end of the primary member, as shown in Figure 3.1.4. K_e is to be calculated as follows:

$$K_e = K_b \left(1 - \frac{d_w}{d_b}\right)$$

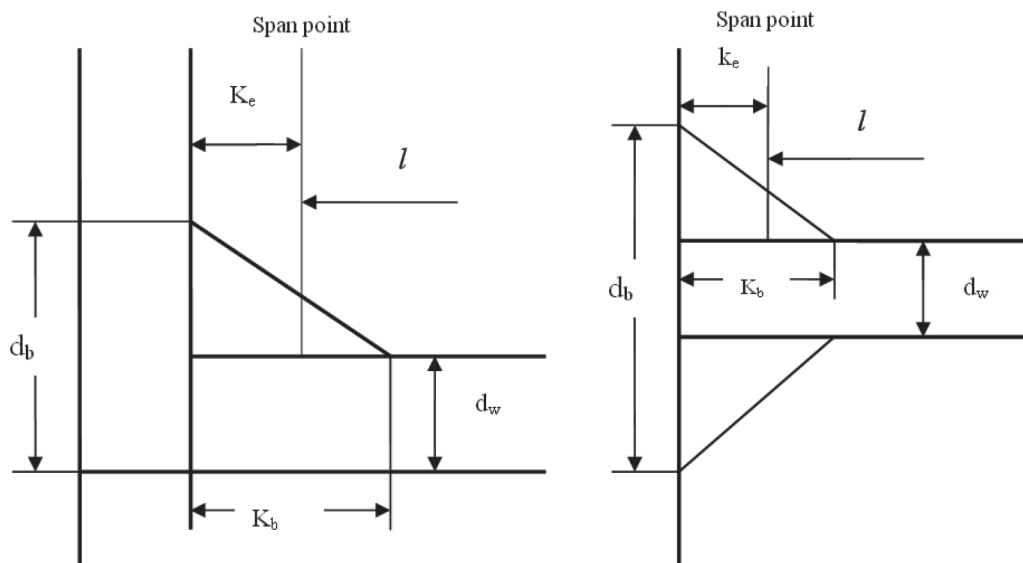


Figure 3.1.4

Where a primary member is supported by a pillar, the supporting point may be taken as the span point of the member.

3.1.5 The average value of stiffener spacing is taken as the effective width of the attached plate of secondary member.

3.1.6 The effective width b_e of the attached plate of primary member is calculated in accordance with the following formula:

$$b_e = 0.3S_g \left(\frac{l_g}{S_g} \right)^{2/3} \text{ but not greater than } l_g/5$$

where: l_g — span of primary members, in m, to be taken in accordance with 3.1.4;
 S_g — spacing of primary members, in m.

3.1.7 The direct calculation method may be used by the designer to check hull member size, but the plate thickness is to comply with the requirements for minimum thickness and necessary calculation information is to be submitted for review.

3.1.8 The continuity of primary longitudinal members is to be ensured in the design of ship structures. Longitudinal members are to extend in fore and aft directions, as far as is practicable. The end of longitudinal interrupted members is not to be terminated abruptly, and their sectional area is to be reduced gradually to achieve a gradual transition.

3.1.9 The first tier superstructure extending to both sides is not to be terminated within 0.25 L amidships (0.125 L fore and aft from midship). The transition from its ends to both topside plates is to be smooth and adjacent structures are to be reinforced as necessary.

3.1.10 Decks and inner bottom plates near upper and lower edges of equivalent girders in vertical direction are to be connected along the ship's length as far as is practicable. Where such decks and inner bottom plates are arranged at different levels, an inclined intermediate transition is to be fitted to ensure their continuity. Where such decks and inner bottom plates must be interrupted along the ship's length, side stringers, brackets or other stiffening members are to be fitted to achieve a certain transition for such intercostal structures, thereby ensuring a uniform change of hull sections.

3.1.11 Primary longitudinal bulkheads near upper and lower edges of equivalent girders in vertical direction are also required to be continuous. Where there is any change in the transverse distance between a primary longitudinal bulkhead and the centerline plane along the ship's length, the knuckle is to be on the primary transverse bulkhead or the secondary bulkhead.

3.1.12 Where there is any abrupt change in the vertical scantlings of sections forming the framing, the modified portion is generally at a rigid component and connected by a transitional bracket or connected in radiused transition. Where the height of a section must be changed between two rigid components, this change is to be transitional within a length not less than 4 times the difference in its heights.

3.1.13 The distance from the longitudinal framing of various hull structures to the centerline plane is to be uniform as far as practicable, i.e. the longitudinal framing of decks and bottom as well as vertical stiffeners of transverse bulkheads and transoms are to be in an appropriate longitudinal vertical plane. The transverse framing of various hull portions is in general to form enclosed ring framing.

3.1.14 Any hull structural framing is to be effectively connected to the adjacent framing as far as practicable. Brackets or other equivalent members are to be fitted at framing breaks or between stiffeners. The form and size of brackets are to be uniform as far as practicable. No free end is allowed for stiffeners in tanks.

3.1.15 Stiffeners in hull structures are in general to pass through tight or nontight members to maintain their continuity, as follows:

(1) where a stiffener intersects with deck or bulkhead or where a longitudinal intersects with a T-shaped girder, a cut-out is to be made preferably in deck, bulkhead or T-shaped girder web for the passage of the stiffener, and provision is to be made for transmitting the shear force acting on the stiffener to the above members;

(2) where any structural member passes through a tight structure, tightness of the connection is to be ensured;

(3) where a bulb flat passes through a nontight structural member and if the strength is required to be compensated, a nontight collar may be used for compensation; in areas where vibration is strong, nontight collars may also be used for compensation;

(4) bottom frames (floors) and beams (including web beams) are generally interrupted at keelsons and deck girders.

3.1.16 Interruption of structural members is to be avoided for shell openings as far as practicable. Where any structural member is interrupted at an opening, the opening is to be suitably reinforced; corners of openings (holes) must be rounded to a radius not less than 0.1 times the opening width; manholes and other openings are to be avoided in areas of load concentration and high stress.

3.1.17 No opening of any form is to be fitted in sheer strakes above strength deck.

3.1.18 The shell plating, which is subject to significant forces (e.g. near hawsepipes opening), is to be reinforced by insert plates or doubler plates, to such an extent that anchor flukes will not touch the shell plating outside the reinforced area.

3.1.19 The rudder stock outlet is to be reinforced by a flange, doubler plate or insert plate, and the diameter of the reinforced area is not to be less than 2 times the opening diameter. The thickness of the insert is generally not to be less than 1.5 times the thickness of the shell plating; the thickness of the doubler plate is not to be less than the thickness of the shell plating.

3.2 Bottom structures

3.2.1 The bottom structure includes bottom shell, bottom framing and double bottom and does not include fore and aft end structures. Bottom girder is a generic term for centre and side keelsons. The bottom is to be fitted with centre keelsons and in addition, with 1 ~ 4 side keelsons at both sides.

3.2.2 The height of side girders within double bottom is in general not to be less than 700 mm. The height of side girders may be 650 mm in local areas. For ships having a length of less than 60 m, the minimum height of side girders within double bottom may be suitably reduced, provided that such space is accessible for welding.

3.2.3 Bottom girders are to be continuous in their length, that is, they are to pass through watertight bulkheads, and all floors which intersect bottom girders are to be interrupted at the intersection.

3.2.4 Where more than two side keelsons are fitted at both sides of bottom, only one pair of symmetrically arranged side keelsons are allowed to be terminated at the same transverse strength members. The end of side keelsons is to be terminated at the primary transverse bulkhead or other transverse strength members supporting side keelsons, and the primary transverse bulkhead or transverse strength member is to be fitted with brackets connected to side keelsons.

3.2.5 In general, no manhole is to be made in the centre keelson or centre girder web and no opening is allowed in the face plate of keelson. Where any hole is necessary for the passage of pipes, it is to be made at mid-height of the web, the diameter of the opening is not to be greater than 0.25 times the web height and the edge of the opening is to be appropriately strengthened.

3.2.6 The manhole (round or elliptical) in the side keelson or side girder web and the hole for the passage of pipes are generally to be arranged at the mid-height of the web, the height of the hole is not to exceed 0.5 times the web height; otherwise, the edge of the hole is to be strengthened by flat steel having a thickness not less than the thickness t of the side keelson or side girder web and a width not less than $12t$ (taken as 60 mm if $12t$ is greater than 60 mm).

3.2.7 The hole in floors is in generally to be arranged at the mid-height of the floor web, and the diameter of the hole is not to exceed 0.5 times the web height; otherwise, it is to be strengthened in accordance with 3.2.6 above. Where the edge of the manhole in a floor is more than 400 mm distant from the bottom girder, the floor on the side of the manhole close to the girder is to be vertically stiffened, and the upper and lower ends of the stiffener are in generally to be connected to longitudinals of inner bottom and shell.

3.2.8 Floors may not be reinforced for the following two types of holes:

- (1) the hole is at the mid-height of the floor and the diameter of the hole is not greater than 25% of floor height;
- (2) the hole is near the floor edge, but the diameter of the hole is not greater than 10% of floor height.

Round holes arranged in a line are to be considered as one hole where the edge-to-edge distance is not greater than the diameter of the largest hole.

3.2.9 The inner bottom is to extend in fore and aft directions and to both sides, as far as is practicable, generally continuously through all transverse bulkheads. The inner bottom plating near fore and aft ends is to gradually become the face plate of centre keelson and side keelson within a distance of no less than 3 frame spaces, and free edges of the inner bottom in such transitional areas are to be strengthened by flat steel. In general, manholes are to be provided at both ends of each bottom tank within the double bottom area.

3.3 Side structures

3.3.1 The thickness of the side shell plating which is subject to impact or wear, e.g. that around hawser holes, is in general to be increased by approximately 50% of the thickness of the adjacent shell plating, or doubler plates are to be used for reinforcement.

3.3.2 Where the side framing is fitted with side stringers, their sectional size is generally to be the same as that of web frames. The end of side stringers is to be terminated on the primary transverse bulkhead or other transverse strength framing. Side stringers should be preferably interrupted at their intersection with web frames so as to maintain the continuity of web frames; frames may be interrupted at side stringers, and the continuity of side stringers is to be maintained at their intersection with frames.

3.3.3 Side stringers and non-continuous lower decks are to be within the same plane, and the end of side stringers is to be connected by a bracket which is preferably to be round as shown in Figure 3.3.3.

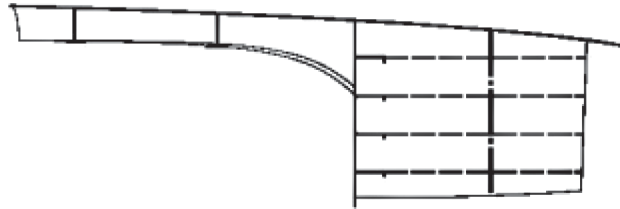


Figure 3.3.3

3.4 Fore and aft end structures

3.4.1 The fore end structures refer to bottom and side structures aft of $0.35L$ from the fore perpendicular, including shell plating, keel, longitudinals, floors and bulkheads. The aft end structures refer to hull structures forward of $0.25L$ from the aft perpendicular, including the lowest deck, platforms or side stringers (or structures below the full-load waterline where there are no such components).

3.4.2 Raised floors are to be fitted at every frame of the forepeak, and the height of the floors is to be such that frames and floors are effectively connected. The forepeak flat extending toward the midship is to be fitted with side stringers or an extension flat; the end of such side stringers is to be connected to the horizontal girder of transverse bulkheads to form a horizontal ring system; the extension flat at its centerline plane is to be fitted with girders, and the end of such girders is to be connected to the vertical girder of transverse bulkheads to form a ring system consisting of flat girders, bulkhead vertical girders and centre keelsons.

3.4.3 Bottom girders and other longitudinal strength members at the fore end are to extend in forward direction so far as practicable, and attention is to be given to maintaining the structural continuity; where centre keelsons can not be connected to the stem due to structural reasons, they are to be terminated after passing through the transverse bulkhead and extending appropriately.

3.4.4 Bow spaces not accessible for maintenance are to be structurally sealed or sprayed with bituminous paint.

3.4.5 The thickness of the shell plating connected to the propeller shaft bracket and rudder bearing is to be increased by 50% of the required thickness of the adjacent shell plating and is not to be less than that of the shell plating amidships. The joints of individual sections are not to pass through such plating of increased thickness.

3.4.6 Floor webs within the area of specially strengthened structures forward of $0.125L$ from the aft end are to be additionally fitted with flat steels at longitudinals, and their size is to comply with 6.3.7.

3.4.7 Stern bottom girders and longitudinals are to extend to the aft end to form a vertical ring system consisting of bottom girders (longitudinals), stern transom plates and bulkhead vertical girders (vertical stiffeners) deck girders (longitudinals).

3.4.8 The bottom structure near stern tube, propeller shaft bracket and rudder bearing is to be reinforced appropriately.

3.5 Deck structures

3.5.1 The beam of longitudinally framed decks is generally interrupted at deck girders. The beam of transversely framed decks passes deck girders through an opening and is welded to them. Deck beams and side frames are to be connected by brackets or may have a radiused connection.

3.5.2 Strength deck girders are not to be completely terminated in the same cross section, and only one pair of symmetrical deck girders may be terminated in the same cross section. The end of strength deck girders is to be terminated on the primary transverse bulkhead or other transverse strength members.

3.5.3 The strength deck longitudinals 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.

3.5.4 Strength deck girders and longitudinals are to be continuous, also where passing through primary transverse bulkheads.

3.5.5 The thickness of deck stringers within $0.5L$ amidships is to be increased by 20% ~ 30% of that of adjacent deck plating, and the width of deck stringers is preferably to be taken as 750 ~ 1500 mm.

3.5.6 Where a tier of deck is terminated and there are no side stringers at this deck level, transition brackets are to be fitted to connect longitudinals within the deck plane. The length l of brackets is in general not to be less than $0.15D$, and their width is in general not to be less than 0.5 times the bracket length, as shown in Figure 3.5.6.

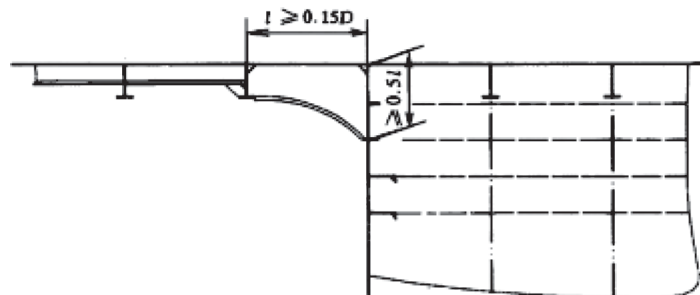


Figure 3.5.6

3.5.7 Where cut-outs are made in each tier of decks below the strength deck for the continuous passage of side frames, they are to be reinforced by fitting collars. Where the tier of deck they pass through is required to be watertight, tight collars are to be fitted.

3.5.8 For large openings (e.g. engine room openings) in the strength deck, where the corners openings are parabolic or elliptical, insert plates are not required, but the requirements as shown by Figure 3.5.8 are to be complied with.

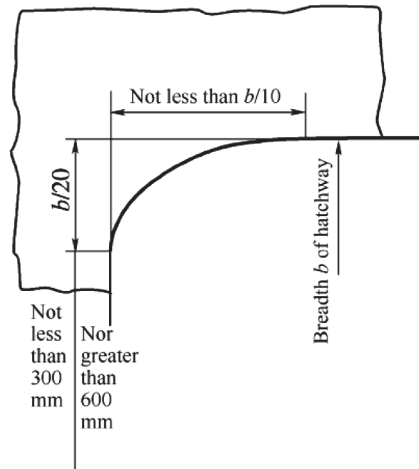


Figure 3.5.8

3.5.9 For large openings (e.g. engine room openings) in the strength deck, where the corners of openings 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. The size of insert plates are to comply with Figure 3.5.9. The thickness of the insert plate is not to be less than 1.5 times the thickness of strength deck framing, and the increased thickness need not be greater than 4 mm. For the lower tier deck below the strength deck, the thickness of inserts is to be 2 mm greater than the deck thickness.

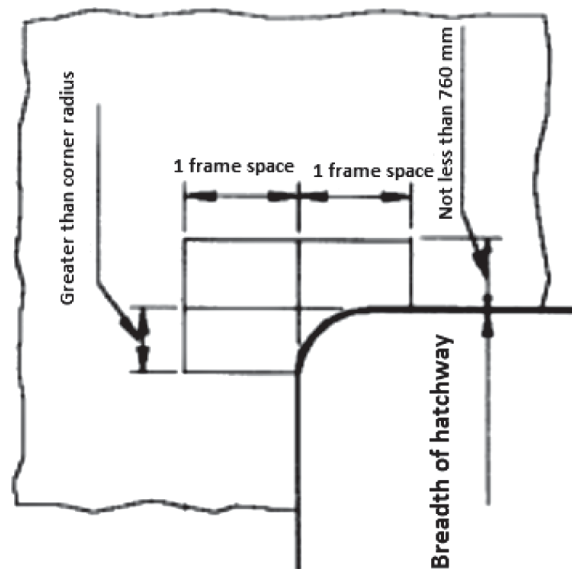


Figure 3.5.9

3.5.10 Where the distance from the web of deck girders and web beams to the support is within $1/8$ of the span of girders or web beams, it is not suitable to cut openings. Under special circumstances, opening with a diameter not greater than $1/8h_w$ according to Figure 3.5.10 is allowed. For this type of opening, where the distance between openings is less than 1.5 times the sum of the diameter of the two openings, or the center of the opening is not at $1/3h_w$ from the beam attached plate, strengthening is to be carried out.

3.5.11 Where cables or pipes need to pass through the web of deck girders or web beams, the opening is to be located with $3/4$ of the span of girders or web beams, and the edge of opening is to be smooth and well-rounded. Where the size and position of the opening satisfy the following requirements, the edge of opening may not be reinforced:

- (1) the height of opening is not greater than $1/3 h_w$, and length of opening is not greater than $2/3 h_w$;
- (2) the distance from the center of opening to the attached plate is $1/3 h_w$;
- (3) although the distance from the center of opening to the attached plate is not $1/3 h_w$, the opening edge is within the range of opening edge in accordance with (1) and (2);
- (4) the distance between opening edges is not less than the sum of the height of two openings.

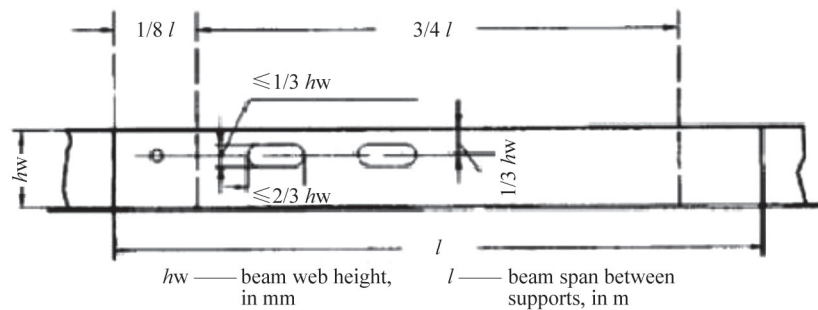


Figure 3.5.11

3.5.12 Where the opening does not satisfy any requirement in 3.5.11, strengthening is to be carried out. 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 no 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.

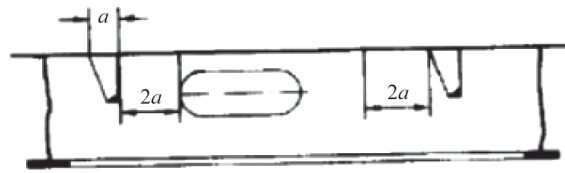
3.5.13 Where dense small openings are cut in the web and the spacing does not satisfy the requirements of 3.5.11 (4), the maximum outer contour line of all openings is to be used as the calculated height and length of openings.

3.5.14 When girders or web beams are subject to large concentrated loads, special consideration is to be given to openings in the web.

3.5.15 For web beams or girders connected to pillars or masts, openings are to be avoided as far as possible within $1/8$ of the span near pillars or masts. When openings must be cut, they are to comply with 3.5.11, and to be strengthened according to 3.5.12.

3.5.16 Openings are generally to be avoided in the strength deck web beams under the end walls of the superstructure. Where openings must be cut, they are to be strengthened according to 3.5.12.

3.5.17 Where longitudinals pass through the beam web, openings are not permitted within the range of 2 times the width of the opening on the left and right side of the opening, as shown in Figure 3.5.17.



a — Width of opening where longitudinals pass through

Figure 3.5.17

3.6 Bulkhead structures

3.6.1 Each primary transverse bulkhead is in general to extend upward to the main deck.

3.6.2 Primary bulkheads are preferably to be fitted with vertical girders below deck girders. Bulkheads below pillars and areas of stress concentration along bulkheads are preferably to be fitted with vertical girders, and such vertical girders are to be capable of withstanding forces transmitted from girders and pillars.

3.6.3 Vertical girders and vertical stiffeners of primary transverse bulkheads are in general to be arranged with the corresponding longitudinal deck framing in the same plane, and so far as practicable aligned with the bottom framing.

3.6.4 Stiffeners of primary longitudinal bulkheads are in general horizontally arranged and where they are designed as corrugated bulkheads, corrugations are generally horizontal so as to effectively contribute to the longitudinal strength. Horizontal stiffeners of primary longitudinal bulkheads are to be spaced apart approximately consistent with longitudinal stiffeners in other areas of the ship, e.g. at deck, side and bottom.

3.6.5 Primary longitudinal bulkheads below pillars and areas of stress concentration along bulkheads are preferably to be fitted with vertical girders. Vertical girders of primary longitudinal bulkheads and corresponding transverse members are to be fitted in the same plane and their ends are to be securely connected to the transverse members, without any form of free ends.

3.6.6 Beams and floors passing through primary longitudinal bulkheads are to be strengthened by collars and watertightness is to be ensured.

3.6.7 The primary longitudinal bulkhead is in general to pass through transverse bulkheads to maintain its longitudinal continuity, and its knuckles are to be fitted at the primary transverse bulkhead.

3.6.8 Where the height of deck or flat is different along the ship's length, primary longitudinal bulkheads are to be fitted with an inclined intermediate transition section to ensure their continuity.

3.6.9 Primary longitudinal bulkheads contributing to the longitudinal strength are in general to extend fore and aft, and are to be terminated on primary transverse bulkheads. In addition, a gradual transition to the hull's longitudinal framing is to be achieved by vertical girders on the back of primary transverse bulkheads. See Figure 3.6.9.

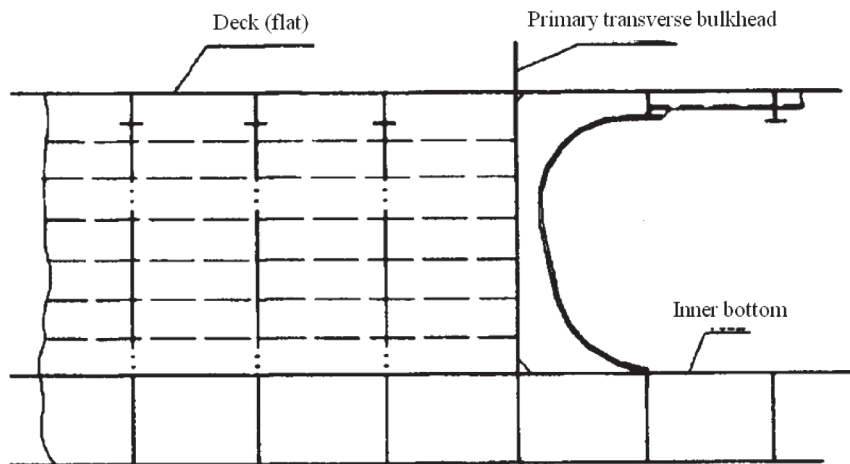


Figure 3.6.9

3.7 Superstructures and deckhouses

3.7.1 Each tier of superstructures and the corresponding hull framing are to be arranged within the same plane so far as is practicable to form a transverse system. The arrangement may be adapted to door and window openings as appropriate, and strengthening is to be carried out.

3.7.2 The front and back walls of each tier of superstructures should be framed vertically. End wall frames are to be spaced depending on the opening width of doors and windows, and aligned so far as practicable with deck longitudinals.

3.7.3 In the case of multi-tier superstructures, the transverse wall of the upper superstructure is to coincide with that of the lower superstructure insofar as practicable. Where side walls of the upper superstructure do not coincide with side walls or longitudinal walls of the lower superstructure, their transverse walls must coincide. Where this requirement is impracticable, effective reinforcing beams are to be fitted below the transverse wall of the upper superstructure and if necessary, additional pillars are to be fitted. Attention must be given to eliminate hard points at the intersection of upper and lower longitudinal and transverse walls.

3.7.4 The ends of vertical stiffeners of deckhouses are to be aligned with the framing above and below them.

3.7.5 The deck plating of increased thickness is in general to be integral. Doubler plates of increased thickness may also be allowed in special cases.

3.7.6 The end walls of the first tier of superstructures are to coincide with transverse hull members in the same plane, as far as practicable. The lower ends of its side wall stiffeners and end wall stiffeners are to be aligned so far as practicable with strength deck components and bracketed to the strength deck.

3.7.7 Superstructures, which have a length exceeding 0.15 times the ship's length L and not less than 6 times their height, are to be designed as strength superstructures.

Long deckhouses, which meet the above condition and which are supported by not less than 3 transverse rigid hull members (transverse bulkheads and pillar-supported reinforced beams), are to be preferably designed as strength superstructures.

3.7.8 The ends of side walls of superstructures or deckhouses are to have a smooth transition in the form and scantlings shown in Figure 3.7.8. Free edges of side wall plating in the transition are to be provided with bulb flats and if necessary, longitudinals are to be fitted for reinforcement.

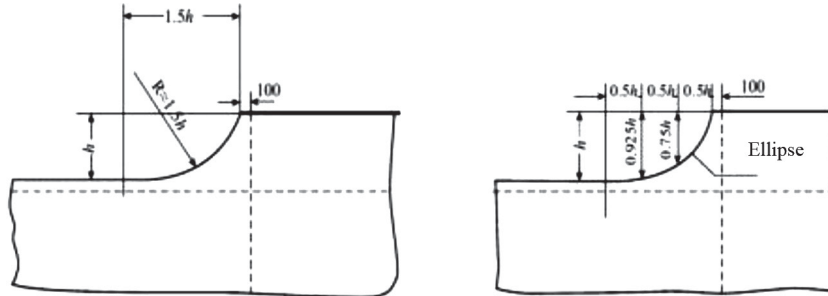


Figure 3.7.8

3.7.9 The thickness of sheer strakes and deck stringers in the superstructure and deckhouse end area is to be increased, i.e. increased by 40% for sheer strakes and 20% for deck stringers. The scope of increased thickness is to be as required by Figure 3.7.9. The thickness of sheer strakes and deck stringers at the end of forecastles and poops having a length less than $0.2L$ need not be increased.

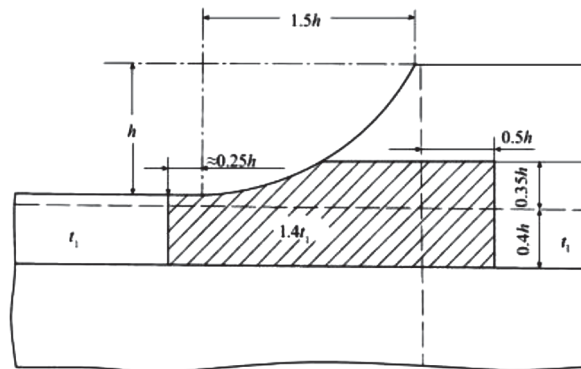


Figure 3.7.9

3.7.10 Long deckhouses, which have a length exceeding $0.15L$ and 6 times their height, may be separated by telescopic joints into several short deckhouses (having a length less than $0.15L$ and 6 times their height) capable of being relatively moved, and each of them is preferably to be connected to only two transverse rigid hull members.

3.7.11 The deck and side walls of short superstructures should be transversely framed.

3.7.12 Telescopic joints are to be such that the ends of two adjacent portions of the deckhouse are capable of free movement in opposite directions. Telescopic joints are preferably to be fitted in a passage. The telescopic joint is generally to be distant from the corner of large strength deck openings not less than the height of the deckhouse. Telescopic joints are to be spaced apart not more than $0.15L$ and 6 times the height of the deckhouse, and not less than 3 times the height of the deckhouse. The telescopic joints of walls at both sides and deck plating are to be in the same plane without shifting.

3.7.13 Superstructures of the second tier and above are in general to be designed as short superstructures. The lower ends of stiffeners of side walls of these superstructures may be sniped, the lower ends of stiffeners of the front walls of the second-tier deckhouses is preferably to be fixed, and the lower ends of stiffeners of other end walls may be sniped.

CHAPTER 4 DESIGN LOADS

4.1 General requirements

4.1.1 This Chapter specifies hull girder loads acting on the entire hull structure, as well as design loads acting on local hull structures for the check of local structural strength.

4.1.2 Design loads given in this Chapter are based on the full-load displacement condition.

4.2 Symbols and definitions

4.2.1 Symbols and definitions are as follows:

(1) Wave coefficient C_w :

$$C_w = (118 - 0.36L) \frac{L}{1000}$$

C_w may be reduced by 5% for ships of service category 1;
 C_w may be reduced by 10% for ships of service category 2;
 C_w may be reduced by 15% for ships of service category 3.

(2) Common acceleration factor a_0 :

$$a_0 = \frac{3C_w}{L} + \frac{C_v V}{\sqrt{L}}$$

where: $C_v = \frac{\sqrt{L}}{50}$, but not greater than 0.2;

$\frac{V}{\sqrt{L}}$ is not to be less than 0.8, where V is design speed, in knots.

4.3 Hull motions

4.3.1 Hull motions are assumed as periodic. The motion amplitude defined in formulas in this Chapter is half of that from peak to valley.

4.3.2 As an alternative to formulas in this Chapter, the hull motion amplitude with a probability level of 10^{-8} , as obtained from seaworthiness calculations or model tests, may be used. Seaworthiness calculations or model test results are to be submitted for approval.

4.3.3 The single amplitude θ of the rolling angle is to be obtained from the following formula:

$$\theta = \frac{50(1.25 - 0.025T_R)K_b}{B + 75} \quad \text{rad}$$

where: T_R — period of roll, in s, calculated according to 4.3.4;

K_b — coefficient, taken as:

$K_b = 1.0$ for ships with bilge keel;

$K_b = 1.2$ for ships without bilge keel;

$K_b = 0.8$ for ships with anti-rolling fin.

4.3.4 The period of roll T_R is to be obtained from the following formula:

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

where: K_r — roll radius at full-load displacement, in m; if K_r is unknown, taken as $K_r = 0.39B$;

GM — metacentric height at full-load displacement, in m; if GM is unknown, taken as $GM = 0.07B$.

4.3.5 The single amplitude ϕ of the pitching angle is to be obtained as follows, but not to be taken as greater than 0.14:

$$\phi = \frac{a_0}{4C_B} \quad \text{rad}$$

4.3.6 The vertical acceleration a_v combined from heave acceleration and vertical components of pitching and rolling acceleration may be approximately taken as follows:

$$a_v = \frac{K_v a_0 g}{C_B} \quad \text{m/s}^2$$

where: K_v — distribution factor of vertical acceleration, see Figure 4.3.6:

$K_v = 1.3$ for $x \leq 0$;

$K_v = 0.7$ for $0.3L \leq x \leq 0.6L$;

$K_v = 1.5$ for $x \geq L$.

Values of K_v are to be obtained by linear interpolation between the above areas.

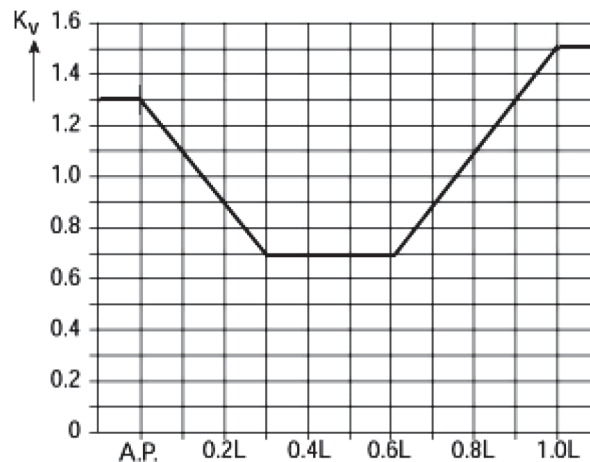


Figure 4.3.6 Distribution Factors of Vertical Acceleration

4.4 Hull girder loads

4.4.1 The symbol convention of vertical bending moments and shear forces at any hull transverse section is as shown in Figure 4.4.1:

The vertical still water bending moment M_{SW} or the vertical wave bending moment M_{WV} is positive when it induces tensile stresses in the strength deck (hogging bending moment), and it is negative when it induces compressive stresses (sagging bending moment).

The vertical shear force Q is positive in the case of downward resulting forces preceding the hull transverse section under consideration or upward resulting forces following the section; it is negative in the opposite case.

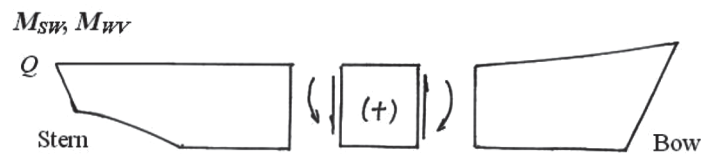


Figure 4.4.1 Symbol Convention of Bending Moments M_{SW} , M_{WV} and Shear Force Q

4.4.2 The maximum vertical still water bending moment M_{SW} and the shear force Q_{SW} are to be determined according to loading conditions of the ship.

4.4.3 The vertical wave bending moment M_{WV} at any hull transverse section is to be determined by the following formulas:

$$\text{Hogging conditions: } M_{WVH} = 150 F_M C_W L^2 B C_B (1 + C_A) \times 10^{-3} \quad \text{kN}\cdot\text{m}$$

$$\text{Sagging conditions: } M_{WVS} = -85 F_M C_W L^2 B (C_B + 0.7) (1 + C_A) \times 10^{-3} \quad \text{kN}\cdot\text{m}$$

where: F_M — distribution factor defined in Table 4.4.3 (see Figure 4.4.3);

C_W — determined for service categories according to 4.2.1(1);

C_A — coefficient, calculated as follows:

$$C_A = \frac{7.1 H_A (1 + 1.26 F_{CH})^2}{L}$$

where: $H_A = \frac{C_W L}{200}$, not to be taken greater than $0.8 C_W$;

F_{CH} — characteristic Froude number;

$$F_{CH} = 0.164 \frac{V_{CH}}{\sqrt{L}};$$

where: characteristic speed V_{CH} , in knots, taken as the greater of $0.75 V$ and cruising speed.

Distribution Factor F_M

Table 4.4.3

Location of hull transverse section	Distribution factor F_M
$0 \leq x < 0.4 L$	$2.5 \frac{x}{L}$
$0.4 L \leq x < 0.65 L$	1.0
$0.65 L \leq x \leq L$	$2.86 (1 - \frac{x}{L})$

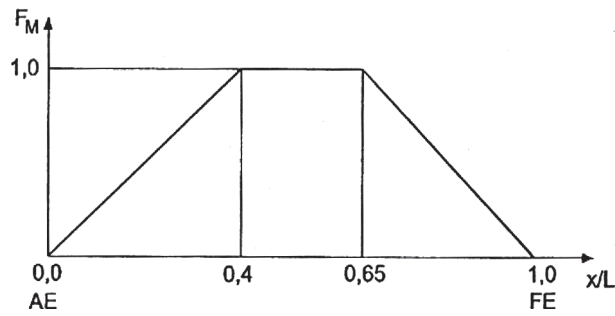


Figure 4.4.3 Distribution Factor F_M

4.4.4 The addition of the vertical wave bending moment induced by forebody flare is to be calculated as follows:

(1) The addition of the sagging wave bending moment induced by forebody flare is to be considered where forebody flare characteristics exist and the following two conditions occur:

a) Speed V is not less than 17.5 kn;

b) $\frac{100F_r A_s}{LB} > 1$

where: F_r — Froude number, $F_r = 0.164 \frac{V}{\sqrt{L}}$;

A_s — horizontal projected area of forebody flare, in m^2 ; see Figure 4.4.4(1), from the following formula:

$$A_s = ba_0 + 0.1L(a_0 + 2a_1 + a_2)$$

where: a_0, a_1, a_2 — taken as the values shown in Figure 4.4.4(1), in m.

The “deck having the maximum flare” in Figure 4.4.4(1) is to be taken up to the forecastle deck, if any.

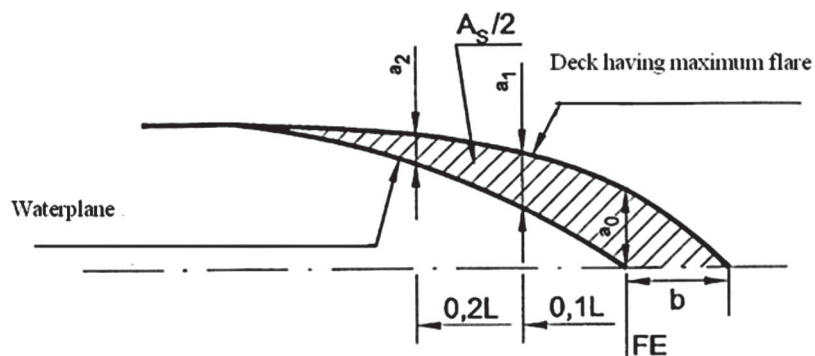


Figure 4.4.4(1) Horizontal Projected Area A_s of Forebody Flare

(2) Where the addition of the wave bending moment induced by the flare is considered, the sagging wave bending moment $M_{WV.sj}$ is to be obtained from the following formula:

$$M_{WV.sj} = F_D M_{WVS} \quad \text{kN}\cdot\text{m}$$

where: F_D — distribution factor of the addition of the sagging wave bending moment induced by the flare, as given in Table 4.4.4 (2), but not to be taken as less than 1.0.

Distribution Factor F_D of Addition of Bending Moment

Table 4.4.4 (2)

Location of hull transverse section	Distribution factor F_D of addition
$0 \leq x < 0.4L$	1
$0.4L \leq x < 0.5L$	$1 + 10(C_D - 1)\left(\frac{x}{L} - 0.4\right)$
$0.5L \leq x \leq L$	C_D

C_D in Table 4.4.4 (2) is to be calculated as follows, but not greater than 1.2:

$$C_D = 262.5 \frac{A_s}{C_w LB(C_B + 0.7)} - 0.6$$

where: A_s is horizontal projected area of flare, in m^2 ; see Figure 4.4.4(1).

4.4.5 The vertical shear force Q_{wv} at any hull transverse section is to be determined by the following formula:

$$Q_{wv} = 30F_Q C_w LB(C_B + 0.7) \times 10^{-2} \quad \text{kN}$$

where: F_Q — distribution factor defined in Table 4.4.5 for positive and negative shear forces, where

$$A = \frac{190C_B}{110(C_B + 0.7)}, \quad x \text{ is the ordinate of the transverse section.}$$

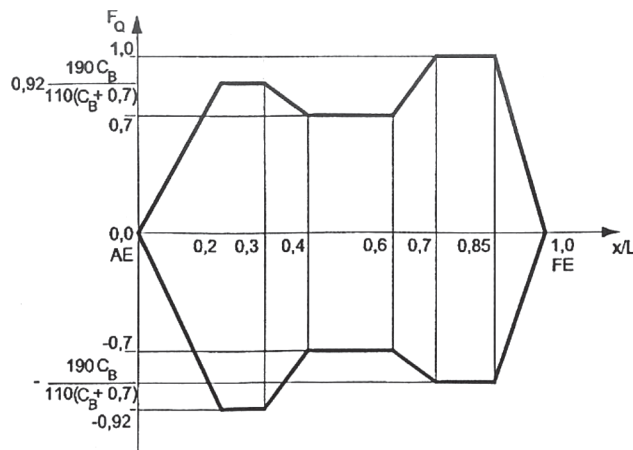


Figure 4.4.5 Distribution Factor F_Q of Shear Force

Distribution Factor of Positive and Negative Shear Forces **Table 4.4.5**

Location of hull transverse section x	Distribution Factor F_Q	
	Positive wave shear force	Negative wave shear force
$0 \leq x < 0.2L$	$4.6A \frac{x}{L}$	$-4.6 \frac{x}{L}$
$0.2L \leq x \leq 0.3L$	$0.92A$	-0.92
$0.3L < x < 0.4L$	$(9.2A - 7)(0.4 - \frac{x}{L}) + 0.7$	$-2.2(0.4 - \frac{x}{L}) - 0.7$
$0.4L \leq x \leq 0.6L$	0.7	-0.7
$0.6L < x < 0.7L$	$3(\frac{x}{L} - 0.6) + 0.7$	$-(10A - 7)(\frac{x}{L} - 0.6) - 0.7$
$0.7L \leq x \leq 0.85L$	1	$-A$
$0.85L < x \leq L$	$6.67(1 - \frac{x}{L})$	$-6.67A(1 - \frac{x}{L})$

4.4.6 The vertical bending moment M_V and the vertical shear force Q_V in hogging and sagging conditions are to be calculated by the following formulas respectively:

- ① The vertical bending moment M_{VH} at any hull girder transverse section in the hogging condition:

$$M_{VH} = M_{SW} + M_{WVH} \quad \text{kN}\cdot\text{m}$$

- ② The vertical bending moment M_{VS} at any hull girder transverse section in the sagging condition:

$$M_{VS} = M_{SW} + M_{WV \cdot sf} \quad \text{kN}\cdot\text{m}$$

- ③ The vertical shear force Q_V at any hull girder transverse section is to be determined by the following formula, regardless of hogging or sagging condition:

$$Q_V = Q_{SW} + Q_{WV} \quad \text{kN}$$

4.5 Local design loads

4.5.1 The pressure on bottom and side is to be calculated in the following cases respectively as follows:

- (1) The seawater pressure P_1 on bottom and side below the full-load waterline is to be obtained from the following formula:

$$P_1 = 9.81h_0 + P_W \quad \text{kN/m}^2$$

where: h_0 — vertical distance, in m, from the considered load point to the full-load waterline;

P_W — additional hydrodynamic wave pressure at the considered load point obtained from the following formula:

$$P_W = P_l + \frac{135y}{B + 75} - 25C_w \frac{h_0}{L} \quad \text{kN/m}^2$$

where: $P_l = (K_s C_w + f)(0.8 + 0.1 \frac{V}{\sqrt{L}})$ kN/m²

K_s — coefficient, determined according to the ordinate x of the considered load point as follows:

$$K_s = 2 + \frac{3.1}{\sqrt{C_B}} \quad \text{for } x \leq 0$$

$$K_s = 2.5 \quad \text{for } 0.2L \leq x \leq 0.7L$$

$$K_s = 10 \quad \text{for } x \geq 1.0L$$

K_s is to be obtained by linear interpolation where x is between the above areas.

f — vertical distance, in m, from the full-load waterline to the top of the ship's side (forecastle included) at the transverse section for considered load points; but not greater than C_w ;

C_w — determined according to 4.2.1(1) of this Chapter;

y — horizontal distance, in m, from the centre line to the considered load point, but not less than $B/4$.

(2) The seawater pressure P_1' on bottom with $x = 0.65L \sim 1.0L$ (the bottom being the area from the baseline up to $0.2T$) is to be obtained from the following formula:

$$P_1' = 162C_1 K_s \sqrt{L} \quad \text{KN/m}^2$$

where: C_1 — coefficient:

$$C_1 = 3.6 - 6.5 \left(\frac{T}{L}\right)^{0.2}, \text{ not greater than } 1.0;$$

K_s — coefficient, determined according to the ordinate x of the considered load point as follows:

$$K_s = 0.65 \text{ for } x = 0.65L;$$

$$K_s = 1.0 \text{ for } x = (0.75 \sim 0.85)L;$$

$$K_s = 0.35 \text{ for } x = 1.0L;$$

K_s is to be obtained by linear interpolation where x is between the above areas.

(3) The seawater pressure P_2 on the ship's side above the full-load waterline is to be obtained from the following formula:

$$P_2 = (K_s C_w + f)(0.8 + 0.1 \frac{V}{\sqrt{L}}) + \frac{135y}{B + 75} - 4h_0 \quad \text{kN/m}^2$$

where: h_0, f and y — the same as in 4.5.1(1);

K_s — coefficient, determined according to the ordinate x of the considered load point as follows:

$$K_s = 4 \text{ for } x \leq 0;$$

$$K_s = 2.5 \text{ for } 0.2L \leq x \leq 0.7L;$$

$$K_s = 6 \text{ for } x = 0.9L;$$

$$K_s = 5 \text{ for } x \geq 1.0L;$$

K_S is to be obtained by linear interpolation where x is between the above areas.

P_2 is to be taken not less than $(6.25 + 0.025L)$ kN/m² at the ship's side.

(4) The slamming pressure P_{sl} induced by forebody side flare is to be considered for forebody side areas (such area includes side area more than $0.2T$ above the baseline and includes forecastle (if any)) with $x = 0.65L \sim 1.0L$ and calculated as follows:

$$P_{sl} = KP \quad \text{kN/m}^2$$

where: P — seawater pressure P_2 in kN/m², determined according to 4.5.1(3) for considered load points above the full-load waterline;

seawater pressure P_1 in kN/m², determined according to 4.5.1(1) for considered load points below the full-load waterline;

K — coefficient, calculated as follows:

$$K = \frac{C_{FL} (0.2V + 0.6\sqrt{L})^2}{42C_w (C_B + 0.7) \left[1 + \frac{20}{C_B} \left(\frac{x}{L} - 0.7\right)^2\right]} (10 + z - T)$$

where: x, z — coordinates x and z , in m, of considered load points;

C_w — see 4.2.1(1) of this Chapter;

C_{FL} — coefficient, to be taken as:

$$C_{FL} = 0.8 \quad \text{Normal circumstances}$$

$$C_{FL} = \frac{0.4}{1.2 - 1.09 \sin \alpha} \quad \text{When flare angle } \alpha \text{ is greater than } 40^\circ.$$

(5) P_1, P_1', P_2 and P_{sl} obtained according to 4.5.1 may be reduced respectively for service categories of ships as follows:

- a) C_w may be reduced by 5% for ships of service category 1;
- b) C_w may be reduced by 10% for ships of service category 2;
- c) C_w may be reduced by 15% for ships of service category 3.

4.5.2 The pressure P_3 acting on exposed deck and superstructure/deckhouse weather decks, and on the lower edge of side and back walls of deckhouses on such weather decks is to be calculated as follows, but not less than 5 kN/m²:

$$P_3 = 0.3 \frac{L}{\sqrt{h_0}} [4(x/L)^2 - 3(x/L) + 1] \quad \text{kN/m}^2$$

where: x — ordinate of considered load points, in m;

h_0 — vertical distance, in m, from the considered load point to the full-load waterline.

4.5.3 The pressure P_3 acting on the lower edge of front walls of superstructures/deckhouses on weather decks, as obtained according to 4.5.2, is to be increased by 50%.

4.5.4 Where the weather deck or the superstructure deck is designed to carry heavy units, the influence of inertial forces induced by motions of the ship is to be considered in addition to the weight of the heavy units.

4.5.5 The considered pressure P of non-exposed deck is to be obtained from the following formula:

$$P = P_1 + 4.9 \quad \text{kN/m}^2$$

where: P_1 — loads due to equipment and articles, including static and dynamic loads.

4.5.6 The load P considered for watertight bulkheads is to be calculated as follows, but not less than 0:

$$P = 9.81(T - z + h_B) \quad \text{kN/m}^2$$

where: T — draught, in m, at the full-load displacement;

z — height, in m, of the considered structural member above the baseline;

h_B — height, in m, of additional head of water, see Figures 4.5.6(1) and 4.5.6(2), determined according to the superstructure type and the ordinate x of watertight bulkheads:

$$h_B = \frac{7}{6}F_A \quad \text{for } X = 0;$$

$$h_B = \frac{1}{2}F \quad \text{for } X = 0.375L - 0.625L;$$

$$h_B = \frac{7}{6}F_F \quad \text{for } X = L$$

h_B is to be obtained by linear interpolation where X is between the above areas.

where: F — height, in m, of the main deck amidships above the full-load waterline;

F_A — $F_A = F$ for ships without a long forecastle or bridge;

F_A is the height, in m, of the long forecastle deck/bridge deck amidships above the full-load waterline for ships with a long forecastle or bridge;

F_F — F_F is the height of the main deck at $x = L$ above the full-load waterline for ships without a long forecastle or bridge;

F_F is the height of the long forecastle deck at $x = L$ above the full-load waterline for ships with a long forecastle;

F_F is the height, in m, of the bridge deck amidships above the full-load waterline for ships with a bridge.

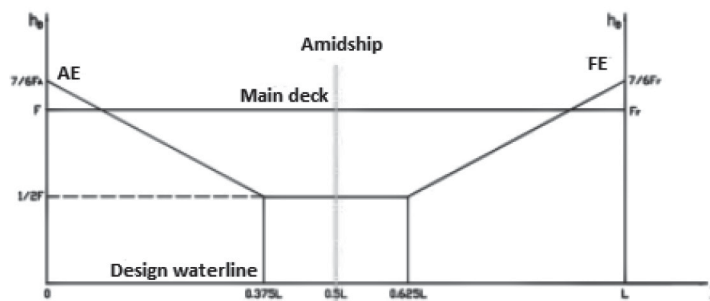


Figure 4.5.6(1) Additional head of water without long forecastle

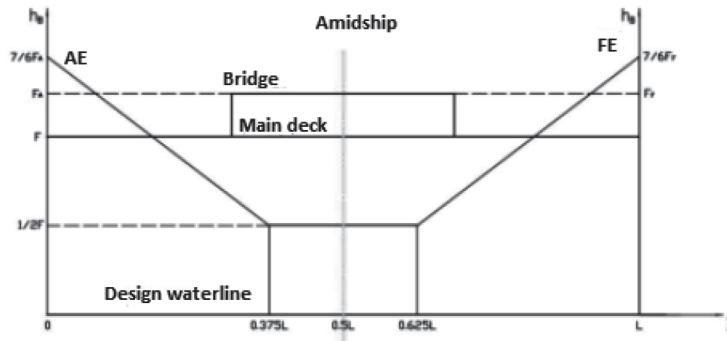


Figure 4.5.6(2) Additional head of water with bridge

4.5.7 The pressure P of the collision bulkhead is to be calculated as follows:

$$P = 9.81 (T - z + h_B) + 13.24 \quad \text{kN/m}^2$$

where: T , z , h_B , see 4.5.6.

4.5.8 The considered pressure P of liquid tank boundary is to be taken as the greater of the following:

$$P = (9.81 + 0.5a_v)h \quad \text{kN/m}^2$$

$$P = 9.81(h + h_p) \quad \text{kN/m}^2$$

where: a_v — vertical acceleration of the ship in way, in m/s^2 , calculated according to 4.3.6;

h — vertical distance, in m, from the considered pressure point to the top of the tank;

h_p — vertical distance, in m, from the top of tank to air pipe.

4.5.9 The pressure P of inner bottom is to be calculated for the considered pressure P of watertight bulkheads of the compartment in way, see 4.5.6. Where the inner bottom is part of the tank boundary, the calculation pressure specified in 4.5.8 is also to be considered.

CHAPTER 5 HULL GIRDER STRENGTH

5.1 General requirements

5.1.1 Hull girder strength is to be checked if either of the following conditions applies:

- (1) the length of the ship L is greater than 50 m;
- (2) there is a large opening in the strength deck within $0.4L$ amidships, the breadth of which is greater than half of the breadth of the strength deck.

5.1.2 The longitudinal strength of the ship is to be checked in various loading conditions.

5.1.3 The sections for check are to be taken at $0.4L$ amidships, in way of maximum shear forces, at large openings in deck and at side, at any locations where there are significant changes in hull cross-section, and at abrupt structural changes.

5.1.4 The hull girder transverse section is considered to be composed of members that contribute to the longitudinal strength of the hull girder. Any longitudinal member whose length on both sides of the section is greater than D can be included in the hull girder section. Main engine foundations and bilge keels are not to be included.

5.1.5 Superstructures or deck houses in the range of $0.25L$ to $0.75L$ from stern, with a length greater than $0.15L$ and 6 times greater than its own height, and supporting at least 3 transverse bulkheads and without elastic joints, are to be considered fully contributing to the longitudinal strength and can be included in the hull girder section.

5.1.6 Superstructures or deck houses not complying with any one of the conditions mentioned in 5.1.5 above are not to be considered as effectively contributing to the hull girder strength and are therefore to be excluded in the hull girder sectional area. If they are considered partially contributing to the hull girder strength, their contribution is to be determined by direct calculation.

5.1.7 In the calculation of characteristics of the hull girder transverse sections, elliptical openings exceeding 2.5 m in length or 1.2 m in breadth, and circular openings exceeding 0.9 m in diameter, are to be deducted from the sectional areas included in the hull girder transverse sections.

5.2 Section modulus and first moment of hull girders

5.2.1 The section modulus Z_A at any point of a hull transverse section is to be obtained from the following formula:

$$Z_A = \frac{I_Y}{|z - N|} \quad \text{m}^3$$

where: I_Y — the moment of inertia, in m^4 , of the considered section about its horizontal neutral axis;
 z — coordinate Z in the reference coordinate system, in m;
 N — height, in m, of the horizontal neutral axis of the considered transverse section above the baseline.

5.2.2 For the first moment S (m^3) at a level Z above the baseline where the considered point is above the horizontal neutral axis, S is the amount of the first moments, calculated with respect to the horizontal neutral axis of all structural members above the horizontal line passing the point. Where the considered point is below the horizontal neutral axis, S is the amount of the first moments, calculated with respect to the horizontal neutral axis of all structural members below the horizontal line passing the point.

5.3 Hull girder stress

5.3.1 The normal stress σ_1 induced by vertical bending moments at any point of the considered transverse section is to be obtained from the following formula:

$$\sigma_1 = \frac{M_V}{Z_A} \times 10^{-3} \quad \text{N/mm}^2$$

where: M_V — vertical bending moment of hull girders, in $kN \cdot m$, to be determined in accordance with 4.4.6;

Z_A — section modulus, in m^3 , at any point of the considered transverse section, calculated according to 5.2.1.

5.3.2 For the two transverse sections before and after midship respectively, the shear strength acting on shell plating at both sides and longitudinal bulkheads is to be checked. The following formula is to be used for calculation of the shear force τ_1 at the calculation point z (z being height above the baseline). Several points are to be taken for calculation of τ_1 in vertical direction and the greatest shear stress so obtained is to be checked:

$$\tau_1 = \frac{Q_V S}{I_y t} \quad \text{N/mm}^2$$

where: t — gross thickness, in mm , of both side shell plating and longitudinal bulkheads at the calculation point z (z being height above the baseline);

S — first moment, in m^3 , at a level z above the baseline according to 5.2.2;

Q_V — vertical shear force of hull girders, in kN , to be determined in accordance with 4.4.6;

I_y — the moment of inertia, in m^4 , of the considered section about its horizontal neutral axis.

5.4 Criteria for check of hull girder yield strength

5.4.1 The hull girder yield strength is to be checked for selected hull transverse sections in accordance with 5.1.2. The normal stress σ_1 obtained under vertical bending moments according to 5.3.1, regardless of in a hogging or sagging condition, is to comply with the following formula:

$$\sigma_1 \leq [\sigma_1] \quad \text{N/mm}^2$$

where: $[\sigma_1]$ — permissible normal stress:

$$\text{for } 0.4L \text{ amidships, } [\sigma_1] = \frac{175}{k} \quad \text{N/mm}^2$$

$$\text{for } 0.1L \text{ from ship ends, } [\sigma_1] = \frac{125}{k} \quad \text{N/mm}^2$$

k — material factor.

The normal stress in other regions is obtained by linear interpolation.

5.4.2 The hull girder shear strength is to be checked for selected hull transverse sections in accordance with 5.1.2. The absolute value of the shear stress τ_1 obtained according to 5.3.2, regardless of positive or negative shear forces, is to comply with the following formula:

$$|\tau_1| \leq [\tau_1] \quad \text{N/mm}^2$$

where: $[\tau_1]$ — permissible shear stress:

$$[\tau_1] = \frac{110}{k} \quad \text{N/mm}^2$$

k — material factor.

5.5 Check of hull girder rigidity

5.5.1 Where the hull is of higher strength steel of which the yield strength R_{eH} is greater than 235 N/mm², the hull girder rigidity is to be checked. This check may be omitted for small ships having a length L less than 70 m.

5.5.2 The hull rigidity is to be checked for hull deflection curves obtained under the vertical bending moment M_V at the normal displacement of the ship. The maximum deflection of steel ships is not to be greater than $L/500$. The vertical deflection of the hull girder transverse section can be calculated as follows:

$$\nu = \frac{10^{-6}}{E} \int_0^x \int_0^x \frac{M(x)}{I_y(x)} dx \cdot dx - \frac{10^{-6} x}{EL} \int_0^L \int_0^x \frac{M(x)}{I_y(x)} dx \cdot dx \quad \text{m}$$

where: $M(x)$ — vertical bending moment of the hull girder varying along the ship length, in kN·m;

$I_y(x)$ — moment of inertia, in m⁴, of the hull transverse section about its horizontal neutral axis varying along the ship length;

x — x-coordinate of the transverse section, in m;

E — modulus of elasticity of hull material, to be assumed $E = 2.06 \times 10^5$ N/mm² for steel.

When calculating the vertical deflection ν of the hull girder transverse section according to the above formula, the hull girder is to be divided into 10 equal sections within the entire length L , and 9 transverse sections are to be taken for calculation except the sections at two ends.

5.6 Buckling strength

5.6.1 Check of hull girder buckling strength is to be carried out for ships the length of which is 60 m or over.

5.6.2 For structural members contributing to the longitudinal strength and subject to the hull girder compressive stress, the buckling strength is to be checked, and provision is to be made for keeping their stability.

5.6.3 For the side shell plating and longitudinal bulkhead contributing to the longitudinal strength and subject to the hull girder shear stress, the shear buckling strength is to be checked to ensure that its stability will not be lost under vertical shear forces.

5.6.4 When calculating Euler stresses according to 5.6.6(2) and (3), the thickness considered for members is to be the design thickness minus the sum of deducted thicknesses of two surfaces. The thickness deduction of each surface is to be taken from the following Table:

Surface Thickness Deduction of Structural Members **Table 5.6.4**

Ambient environment of member surface		Thickness deduction, in mm
Ballast tank		1.0
Fuel oil tank	Plate surface sloped at an angle not greater than 25° to the horizontal line	0.75
	Plate surface sloped at an angle greater than 25° to the horizontal line	0.5
	Secondary and primary supporting members	0.75
Machinery spaces, storerooms		0.25
External seawater		0.5
External atmosphere		0.25
Working and accommodation spaces		0

Note: The surface thickness deduction of aluminum alloy members is 0.

5.6.5 Criteria for check of buckling strength are as follows:

(1) Compressed members are to meet the following criterion:

$$\frac{\sigma_c}{\sigma_1} \geq 1.0$$

where: σ_1 — negative normal stress, in N/mm^2 , obtained according to 5.3.1 being compressive stress;
 σ_c — critical buckling stress, in N/mm^2 , of compressed members, see 5.6.6.

(2) Side plating and longitudinal bulkhead subjected to shear forces is to meet the following criterion:

$$\frac{\tau_c}{\tau_1} \geq 1.0$$

where: τ_1 — shear force, in N/mm^2 , obtained according to 5.3.2;
 τ_c — critical shear buckling stress, in N/mm^2 , of members subjected to shear forces, see 5.6.7.

5.6.6 The critical buckling stress of compressed members is to be determined as follows:

(1) The critical buckling stress σ_c of compression plate panels and attached plate longitudinals may be obtained from the following formulas, using the Euler stress σ_E obtained according to (2) and (3) of this paragraph:

$$\sigma_c = \sigma_E \quad \text{N/mm}^2 \quad \text{for} \quad \sigma_E \leq \frac{R_{eH}}{2}$$

$$\sigma_c = R_{eH} \left(1 - \frac{R_{eH}}{4\sigma_E} \right) \quad \text{N/mm}^2 \quad \text{for} \quad \sigma_E > \frac{R_{eH}}{2}$$

Where compressed members are of manganese steel ($R_{eH}=390 \text{ N/mm}^2$), their critical buckling stress σ_c (N/mm^2) may be taken from Table 5.6.6.

Critical Buckling Stress σ_C of Members

Table 5.6.6

σ_E (N/mm ²)	σ_C (N/mm ²)	σ_E (N/mm ²)	σ_C (N/mm ²)
20	20	400	310
40	40	420	320
60	58	440	330
80	76	460	338
100	94	480	344
120	112	500	352
140	130	520	358
160	146	540	364
180	163	560	372
200	180	580	378
220	194	600	382
240	210	650	394
260	224	700	404
280	238	750	414
300	250	800	424
320	264	850	438
340	276	900	442
360	290	950	450
380	300	1000	458

(2) The Euler stress σ_E of the compressed panel may be calculated as follows:

$$\sigma_E = 0.9K_c E \left(\frac{t}{1000s} \right)^2 \quad \text{N/mm}^2$$

where: t — considered thickness of plate, in mm, deducted according to Table 5.6.4;

E — elastic modulus of materials, in N/mm²; $E = 2.06 \times 10^5$, in N/mm² for ordinary marine steel;

s — length, in m, of the shorter plate panel side.

K_c — coefficient, calculated according to the following:

$$K_c = \frac{8.4}{\psi + 1.1} \quad \text{for plating with longitudinal stiffeners (parallel to compressive stress);}$$

$$K_c = C \left[1 + \left(\frac{s}{l} \right)^2 \right]^2 \frac{2.1}{\psi + 1.1} \quad \text{for plating with transverse stiffeners (perpendicular to compressive stress)}$$

where: l — length, in m, of the longer plate panel side;

$C = 1.3$ 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, $0 \leq \psi \leq 1$.

(3) The Euler stress σ_E of the attached plate of longitudinals may be calculated as follows:

$$\sigma_E = \frac{\pi^2 EI}{Al^2} \times 10^{-4} \quad \text{N/mm}^2$$

where: I — section moment of inertia, in cm^4 of the attached plate of longitudinals; thickness of members deducted according to Table 5.6.4, width of attached plates taken according to 3.1.5;
 A — sectional area of the attached plate of longitudinals, in cm^2 ; thickness of members deducted according to Table 5.6.4, width of attached plates taken according to 3.1.5;
 E — elastic modulus of materials, in N/mm^2 ; $E = 2.06 \times 10^5$, in N/mm^2 for ordinary marine steel;
 l — span of longitudinals, in m.

(4) The critical buckling stress σ_C of the face plate of primary longitudinal supporting members under compression, e.g. deck girders, bottom girders and side girders and other T-shaped built-up sections, may be taken from Table 5.6.6. The Euler stress σ_E of the face plate is to be calculated as follows:

$$\sigma_E = 8.33 \left(\frac{100t}{b} \right)^2 \quad \text{N/mm}^2$$

where: t — thickness of face plate, in mm; deducted according to Table 5.6.4;
 b — half of width of face plate, in mm.

5.6.7 The critical shear buckling stress of structural member under shear force is to be determined as follows:

(1) The critical shear buckling stress τ_C is to be calculated as follows:

$$\tau_C = \tau_E \quad \text{N/mm}^2 \quad \text{for } \tau_E \leq \frac{\tau_S}{z}$$

$$\tau_C = \tau_S \left(1 - \frac{\tau_S}{4\tau_E} \right) \quad \text{N/mm}^2 \quad \text{for } \tau_E > \frac{\tau_S}{z}$$

where: $\tau_S = \frac{R_{eH}}{\sqrt{3}}$

τ_E — Euler shear stress, in N/mm^2 , of structural member under shear force, calculated according to 5.6.7(2).

(2) The Euler shear stress τ_E of structural member under shear force is to be calculated as follows:

$$\tau_E = \frac{K\pi^2 E}{12(1-\mu^2)} \left(\frac{t_b}{1000s} \right)^2 \quad \text{N/mm}^2$$

where: t_b — plate thickness after deducting values given in Table 5.6.4, in mm;
 s — length of the shorter plate panel side, in m;
 E — elastic modulus, in N/mm^2 , to be taken as 2.06×10^5 for ordinary steel;
 μ — Poisson ratio, to be taken as 0.3 for steel;

K — coefficient, $K = 5.34 + 4 \left(\frac{s}{l} \right)^2$;

l — length of the longer plate panel side, in m.

CHAPTER 6 HULL LOCAL SCANTLING

6.1 Plating

6.1.1 The requirements of this paragraph apply to the bending strength check of plating subjected to lateral pressure. Plates subjected to hull girder compressive stresses are to comply with the buckling strength requirements in Chapter 5 of the Guidelines.

6.1.2 The elementary plate panel is the smallest unstiffened part of plating between secondary members.

6.1.3 The load points of plates for calculation are to be taken at the lower edge of plate panels.

6.1.4 For plates with thickness equal to or greater than 4 mm, where the decimal part of the calculated plate thickness is 0.25 mm or less, it may be neglected; where it is greater than 0.25 mm but less than 0.75 mm, it is to be taken as 0.5 mm; where it is 0.75 mm or more, a round number of 1.0 mm is to be taken. For plates with thickness less than 4 mm, where the decimal part is 0.15 mm or less, it may be neglected; where it is greater than 0.15 mm but less than 0.65 mm, it is to be taken as 0.5 mm; where it is 0.65 mm or more, a round number of 1.0 mm is to be taken.

6.1.5 The symbols regarding plates are defined as follows:

s : length, in m, of short side of plate panel;

ℓ : length, in m, of long side of plate panel;

C_1 : reduction factor for curved plates, $C_1 = 1 - 0.5s/r$, where r is radius of curvature, in m;

C_2 : correction factor for aspect ratio of panel:

$$C_2 = \ell/s * (1 - 0.25\ell/s) \quad \text{when } \ell/s < 2$$
$$C_2 = 1.0 \quad \text{when } \ell/s \geq 2$$

P : lateral pressure on plate panel, in kN/m^2 , taken according to Chapter 4;

R_{eff} : yield strength of steel, in N/mm^2 , see the relevant requirements of ISC Rules for Materials and Welding;

$R_{\text{p0.2W}}$: proof strength, in N/mm^2 , of aluminium alloy plate in annealed condition, see relevant requirements of ISC Rules for Materials and Welding.

6.1.6 Minimum plate thickness

(1) The actual plate thickness is not to be less than that given in Table 6.1.6(1).

Minimum Plate Thickness (Steel)

Table 6.1.6(1)

Location		Ship length L (mm)	Minimum plate thickness t_{min} (mm)	
Bottom	Bottom shell	—	$\frac{L}{30} + 2$, not less than 4	
	Inner bottom	$L < 80$ $L \geq 80$	4 5	
Side	Side shell	—	$\frac{L}{30} + 2$, not less than 4	
Decks, platform	Strength deck	$L < 60$ $60 \leq L < 80$ $L \geq 80$	3 4 5	
	Other decks, platform	—	3	
Watertight bulkheads	Primary longitudinal/ transverse bulkhead		Lower part of bulkhead	Middle and upper parts of bulkhead
		$L < 80$ $L \geq 80$	4 5	3 3
	Liquid tank bulkhead	—	4	
Superstructures and short deckhouses	Top plating and external walls		Top plating	External wall
		$L < 60$ $L \geq 60$	3 3	2.5 ^① 3

Note: ① The minimum thickness is 3 mm for aluminium deckhouses.

(2) The thickness of plate keels is to be increased by 1 ~ 3 mm over that of the adjacent bottom shell plating. The width of plate keels is to be 1000 ~ 1800 mm.

(3) The thickness of shear strakes is not to be less than that of strength deck stringers. The width of shear strakes is to be 1000 ~ 1500 mm for ships having a length L equal to or greater than 80 m.

(4) The thickness of strength deck stringers within $0.25L \sim 0.75L$ from the aft end is to be increased by 20 ~ 30% over that of the adjacent deck plating. The width of these deck stringers is to be 750 ~ 1500 mm.

(5) The minimum plate thickness t_{min} of the strength deck within $0.25L \sim 0.75L$ from the aft end is also to comply with the following formula:

$$t \geq \frac{s}{1.252} \sqrt{\sigma_c} \quad \text{mm}$$

where: s — length, in m, of the shorter side of strength deck plate panel;

σ_c — critical buckling stress, in N/mm^2 , of strength deck, see 5.6.6.

(6) The thickness of the bottom shell plating over the propeller, within one time the diameter of the propeller respectively before and after the propeller, is not to be less than that of the plate keel in way.

6.1.7 The plate thickness required for the local strength is to be calculated as follows:

(1) For steel hull, the thickness t of bottom and side plate panels subjected to wave impacts or combination of wave impacts and seawater pressure is not to be less than the value obtained from the following formula:

$$t = 23.5C_1C_2s\sqrt{\frac{P}{R_{eH}}} \quad \text{mm}$$

(2) For steel hull, the thickness t of plate panels subjected to other pressure is not to be less than the value obtained from the following formula:

$$t = 25C_1C_2s\sqrt{\frac{P}{R_{eH}}} \quad \text{mm}$$

(3) The thickness t of panels of deckhouses constructed of aluminium alloy is not to be less than the value obtained from the following formula:

$$t = 23.5C_1C_2s\sqrt{\frac{P}{R_{p0.2W}}} \quad \text{mm}$$

6.2 Stiffeners

6.2.1 The requirements of this paragraph apply to check of the bending strength of stiffeners subjected to lateral pressure and their end shear strength. Stiffeners subjected to hull girder compressive stresses are to comply with the buckling strength requirements in Chapter 5 of the Guidelines.

6.2.2 The load points of stiffeners for calculation are to be determined as follows:

- (1) The mid-span l of the stiffener is to be the calculation point for stiffeners subjected to an evenly distributed load.
- (2) The point at which the mean value of loads on lower and upper ends of the stiffener occurs is to be taken for stiffeners subjected to an unevenly distributed linear load.

6.2.3 The symbols regarding stiffeners are defined as follows:

l : span of stiffeners, in m;

s : spacing, in m, of stiffeners, measured at mid-span along the chord;

W : section modulus, in cm^3 , of the stiffener, with an attached plate having an effective width $b_e, b_e = s$;

A_e : effective shear area, in cm^2 , at the end of the stiffener;

P : lateral pressure on the stiffener, in kN/m^2 ; taken according to Chapter 4;

R_{eH} : yield strength of steel, in N/mm^2 ; see the relevant requirements of ISC Rules for Materials and Welding;

$R_{p0.2W}$: proof strength, in N/mm^2 , of aluminium alloy sections in an annealed condition, see the relevant requirements of ISC Rules for Materials and Welding.

6.2.4 The required scantlings of steel stiffeners are to be determined as follows:

(1) Section modulus required for bending strength

- ① The section modulus W of stiffeners of bottom or side areas subjected to wave impacts or combination of wave impacts and seawater pressure is not to be less than the value obtained from the following formula:

$$W = 94 \frac{Psl^2}{R_{eH}} \quad \text{cm}^3$$

- ② The section modulus W of stiffeners of bottom, side and deck areas subjected to other pressure (including top plating of non-exposed decks/superstructures/deckhouses) is not to be less than the value obtained from the following formula:

$$W = 106 \frac{Psl^2}{R_{eH}} \quad \text{cm}^3$$

- ③ The section modulus W of stiffeners of watertight bulkheads, liquid tank bulkheads and deckhouse external walls is not to be less than the value obtained from the following formula:

$$W = 125 \frac{Psl^2}{R_{eH}} \quad \text{cm}^3$$

- (2) Effective shear area at end of stiffeners required for shear strength

- ① The effective shear area A_e at the end of stiffeners is to be calculated as follows:

$$A_e = 0.01ht \quad \text{cm}^2$$

where: h — web depth of stiffeners, in mm;
 t — web thickness of stiffeners, in mm;

- ② The effective shear area A_e at the end of stiffeners of bottom and side areas subjected to wave impacts or combination of wave impacts and seawater pressure is not to be less than the value obtained from the following formula:

$$A_{e\min} = 9.8 \frac{Psl}{R_{eH}} \quad \text{cm}^2$$

- ③ The effective shear area A_e at the end of stiffeners of hull areas, including bottom, side and deck (including top plating of non-exposed decks/superstructures/deckhouse), which are subjected to other pressure, is not to be less than the value obtained from the following formula:

$$A_{e\min} = 10.87 \frac{Psl}{R_{eH}} \quad \text{cm}^2$$

- ④ The effective shear area A_e at the end of stiffeners of bulkheads (including watertight bulkheads, collision bulkheads and liquid tank bulkheads) and superstructure/deckhouse external walls is not to be less than the value obtained from the following formula:

$$A_{e\min} = 13.0 \frac{Psl}{R_{eH}} \quad \text{cm}^2$$

6.2.5 The required scantlings of stiffeners of deckhouses constructed of aluminium alloy are to be determined as follows:

- (1) The section modulus W of stiffeners of the top plating of deckhouses is not to be less than the value obtained from the following formula:

$$W = 85 \frac{Psl^2}{R_{P0.2W}} \quad \text{cm}^3$$

(2) The section modulus W of stiffeners of external walls of deckhouses is not to be less than the value obtained from the following formula:

$$W = 100 \frac{Psl^2}{R_{P0.2W}} \quad \text{cm}^3$$

(3) The effective shear area A_e of stiffeners of the top plating of deckhouses is not to be less than the value obtained from the following formula:

$$A_{e \min} = 8.6 \frac{Psl}{R_{P0.2W}} \quad \text{cm}^2$$

(4) The effective shear area A_e of stiffeners of external walls of deckhouses is not to be less than the value obtained from the following formula:

$$A_{e \min} = 10.3 \frac{Psl}{R_{P0.2W}} \quad \text{cm}^2$$

6.3 Primary supporting members

6.3.1 The requirements of this paragraph apply to check of the bending strength and shear strength of primary supporting members subjected to lateral pressure. Primary members subjected to hull girder compressive stresses are to comply with the buckling strength requirements in Chapter 5 of the Guidelines.

6.3.2 The requirements of paragraph apply also to deck pillars subjected to axial compressive loads.

6.3.3 The symbols regarding primary supporting members are defined as follows:

b : average width of the area supported by primary members, in m;

l_g : span, in m, of the primary member;

W : section modulus, in cm^3 , of primary supporting members;

A_e : effective shear area, in cm^2 , at ends of the primary member, to be calculated as follows:

$$A_e = 0.01h_w t_w \quad \text{cm}^2 \quad \text{without end brackets}$$

$$A_e = 0.01h_w t_w + \Delta A_e \quad \text{cm}^2 \quad \text{with end brackets}$$

where: h_w — actual height of web plate deducting openings at the section under consideration, in mm;

t_w — thickness of web plate, in mm;

ΔA_e — additional shear area with end brackets, in cm^2 , to be taken according to the horizontal inclination angle of the face plate of the bracket, see Figure 6.3.3.

When $\theta = 45^\circ$, $\Delta A_e = 0.9f_1$; when $\theta = 0^\circ$, $\Delta A_e = 0$, when θ is an intermediate value, ΔA_e can be obtained by interpolation;

f_1 is the cross-sectional area of the face plate of the bracket at the section under consideration, in cm^2 .

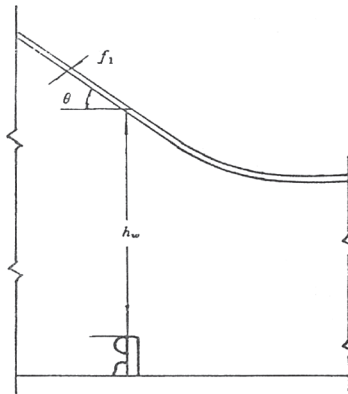


Figure 6.3.3

P : lateral pressure, in kN/m^2 , on the primary supporting member; taken according to Chapter 4;
 R_{eH} : yield strength of steel, in N/mm^2 ; see the relevant requirements of ISC Rules for Materials and Welding.

6.3.4 The required minimum thickness of the web and face plate of primary members is as follows:

(1) The minimum web thickness is required respectively as follows:

① The minimum web thickness t_{\min} is not to be less than the value obtained from the following formula:

$$t_{\min} = \frac{S_w}{K_1} \text{ mm} \quad \text{under bending and shear loads;}$$

$$t_{\min} = \frac{S_w}{K_2} \text{ mm} \quad \text{under compressive load}$$

where: S_w — width of plate panel, in mm, to be taken as the spacing of web stiffeners;

K_1, K_2 — coefficient, taken according to the following table:

Table 6.3.4(1) ①

Yield strength of primary supporting members, $R_{eH} \text{ N/mm}^2$	K_1	K_2
235	60	47
315	55	42
355	52	39
390	47	37

Stiffener thickness generally is not to be less than web thickness of primary members, breadth is generally not to be less than eight times its thickness, but it need not be greater than 0.5 times the width of face plate of primary members (when primary member is of flanged profiles, it need not be greater than the width of face plate), or other members with equivalent moment of inertia of neutral axis (neutral axis is perpendicular to web height direction) are used.

② The minimum web thickness t_{\min} of primary members at bottom is also to comply with the requirements of Table 6.3.4(1) ② .

Minimum Web Thickness t_{\min} (mm) of Primary Members at Bottom

6.3.4(1) ②

Ship length L (m)	Centre keelson or girder	Side keelson or girder	Floor
$L < 80$	5	4	4
$L \geq 80$	6	5	5

- ③ The minimum web thickness t_{\min} of primary members at side is also to comply with the requirements of Table 6.3.4(1) ③ .

Minimum Web Thickness t_{\min} (mm) of Primary Members at Side

6.3.4(1) ③

Ship length L (m)	Web frame, side girder	Floor
$L < 80$	4	3
$L \geq 80$	5	4

- (2) The minimum face plate thickness t_{\min} is not to be less than the value obtained from the following formula:

$$t_{\min} = \frac{b}{18\sqrt{k}} \quad \text{mm}$$

where: b — width of face plate, in mm;
 k — material factor of face plate.

6.3.5 Primary members subjected to lateral pressure are to comply with the following requirements:

- (1) The section modulus W is not to be less than the value calculated by the following formula:

$$W = K_1 \frac{bl_g^2 P}{R_{eH}} \quad \text{cm}^3$$

where: K_1 — coefficient, to be taken as 109 for watertight bulkhead girders and 150 for other primary members.

- (2) Effective shear area A_e at ends of the primary member is not to be less than the value calculated by the following formula:

$$A_e = 13.5 \frac{bl_g P}{R_{eH}} \quad \text{cm}^2$$

- (3) For primary members in grillage structure, the scantlings of members are determined by calculating according to the requirements of Chapter 7 of the Guidelines.

6.3.6 Deck pillars subjected to axial compressive load are to comply with the following buckling strength requirements:

- (1) The compressive stress σ_P of deck pillars subjected to axial compressive load is not to exceed the critical buckling stress σ_C calculated according to (2) of this paragraph. The compressive stress σ_P of deck pillars is to be calculated as follows:

$$\sigma_P = \frac{Pab + P_0}{A} \times 10 \quad \text{N/mm}^2$$

where: P — average vertical load, in kN/m², of the deck supported by the pillar; determined according to Chapter 4;

P_0 — vertical load, in kN, on the pillar above the considered pillar along the same perpendicular;

a — length, in m, of the area of the deck supported by the pillar;

b — width, in m, of the area of the deck supported by the pillar;

A — transverse sectional area, in cm², of the pillar.

(2) The critical buckling stress σ_C of deck pillars is to be calculated as follows:

$$\sigma_C = \sigma_E \quad \text{N/mm}^2 \quad \text{for } \sigma_E \leq \frac{R_{eH}}{2}$$

$$\sigma_C = R_{eH} \left(1 - \frac{\sigma_{eH}}{4\sigma_E} \right) \quad \text{N/mm}^2 \quad \text{for } \sigma_E > \frac{R_{eH}}{2}$$

where: σ_E — Euler stress, in N/mm², of compressed pillar; calculated as follow:

$$\sigma_E = \frac{\pi^2 EI}{Al^2} \times 10^{-4}$$

where: E — elastic modulus of pillar, in N/mm²;

$E = 2.06 \times 10^5$ — steel;

$E = 0.69 \times 10^5$ — aluminium alloy;

A — transverse sectional area, in cm², of the pillar;

l — length of the pillar, in m;

I — minimum moment of inertia, in cm⁴, of the transverse section of the pillar about the neutral axis.

6.3.7 For web stiffeners fitted on primary members, the section moment of inertia I is to comply with the following requirements respectively:

(1) The section moment of inertia I of vertical stiffeners is not to be less than that obtained from the following formula:

$$I = 11.4 l s^2 t \left(2.5 \frac{l}{s} - 2 \frac{s}{l} \right) \quad \text{cm}^4$$

where: t — web thickness of primary members, in mm;

l — length of web stiffeners, in m;

s — spacing of stiffeners, in m.

(2) The section moment of inertia I of horizontal stiffeners is not to be less than that obtained from the following formula:

For deck, side and bottom girders:

$$I = 1.43 l^2 A \quad \text{cm}^4$$

where: l — length of web stiffeners, in m;

A — section area of stiffeners together with attached plating (the thickness of the attached plating may be excluded in the increased thickness required for direct strength analysis), in cm².

For other primary members:

$$I = 0.72l^2A \quad \text{cm}^4$$

where: l — length of web stiffeners, in m;

A — section area of stiffeners together with attached plating (the thickness of the attached plating may be excluded in the increased thickness required for direct strength analysis), in cm^2 .

CHAPTER 7 DIRECT STRENGTH ANALYSIS

7.1 Local structural strength analysis

7.1.1 This paragraph specifies the method for direct calculation of local structural strength of hull.

7.1.2 The extent of the model is to include the area to be analyzed and extend sufficiently to eliminate the effects of boundary conditions.

7.1.3 Inner and external shell plates, deep webs of transverse rings, girders, floors, plane bulkhead web stiffeners, frames and other members are to be simulated by shell elements. In high stress areas and areas of significant stress gradient, such as lightening holes, manholes, positions adjacent to knuckles or structural discontinuities, triangular elements are to be avoided as practicable as possible.

7.1.4 Stiffeners of plates, which are subject to lateral 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.

7.1.5 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 shell elements are to be arranged in vertical direction for bottom girders and floors.

(3) Normally, the aspect ratio of plate elements is not to exceed 3. 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.

7.1.6 The fore and aft ends of the model are to be symmetrical; transverse and vertical linear displacements at the intersection of the transverse bulkhead and the ship's side are to be taken as zero.

7.1.7 Loads are to include deck loads (including weather decks and non-weather decks), side seawater pressure, tank pressure, bottom load, bulkhead pressure, etc. as specified in Chapter 4 of the Guidelines, which are to be applied to structural models after reasonable combination.

7.1.8 Permissible stresses are to be taken as:

$$\begin{aligned} \text{permissible equivalent stress: } [\sigma] &= 180/k \text{ N/mm}^2 \\ \text{permissible shear stress: } [\tau] &= 94/k \text{ N/mm}^2 \end{aligned}$$

where: k — material factor.

$$\text{equivalent stress: } \sigma = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3\tau_{xy}^2}$$

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 .

7.2 Check of ice resistance of hull structures

7.2.1 For ships which are required to operate in broken ice, as specified in the specification of ship, the required ice resistance of hull structures (shell plates, frames, longitudinals) is to be checked.

7.2.2 The load q considered for ice load of side frames is to be determined according to Figure 7.2.2. The direction in which the load acts is to be taken perpendicular to shell plating.

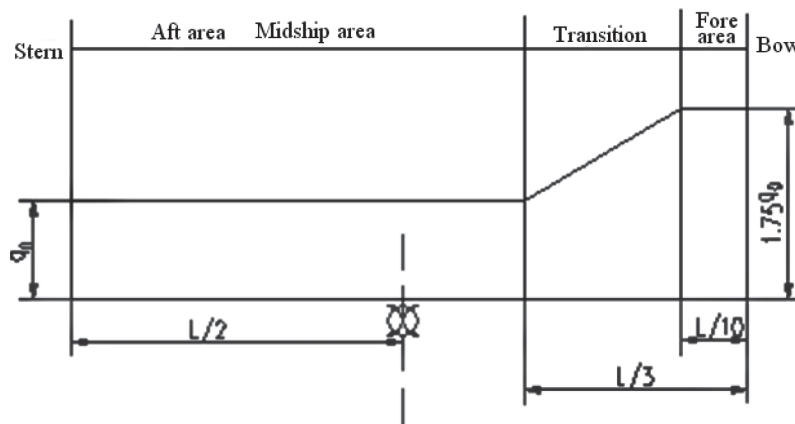


Figure 7.2.2

where q_0 is to be determined as follows:

$$q_0 = 9.81 K \sqrt[4]{B \cdot \Delta}$$

where: q_0 — ice load, in kN/m , on every metre of waterline in midship and aft areas;

B — ship breadth, in m ;

Δ — full-load displacement of the ship, in tonnes;

K — coefficient, taken as 0.8 for the full-load displacement less than 2,000 t, 1.0 for the full-load displacement greater than 10,000 t, and 0.9 for in between.

7.2.3 The uniform pressure p of side shell plating and longitudinals is to be determined as follows:

$$p = 0.002 q$$

where: p — uniform pressure, in MPa ;

q — ice load, in kN/m , determined according to Figure 7.2.2.

7.2.4 The areas where the considered ice loads, as determined according to Figure 7.2.2 and by the formulas in 7.2.2 and 7.2.3, may act along the height at side, are to be determined according to Table 7.2.4. For ships the breadth of which is not shown in the Table, the possible action areas of ice load are to be determined by linear interpolation.

Table 7.2.4

Maximum breadth of ship (m)	Possible action area of ice load (m)	
	Above full-load waterline	Below full-load waterline
5	0.25	0.50
10	0.40	0.80
15	0.50	1.00
20	0.55	1.10

7.2.5 In the calculation of ice resistance of side frames according to the considered load, as determined in 7.2.2, the action of this load is to be taken at the most unfavorable position of the frame.

7.2.6 When checking the ice resistance of hull, the permissible stress of side framing and shell plating is to meet the following requirement:

$$\text{at base: } [\sigma] = R_{eH}$$

$$\text{at span: } [\sigma] = 0.80R_{eH}$$

$$[\tau] = 0.57[\sigma]$$

Chapter 8 OTHER STRUCTURES

8.1 Stem

8.1.1 The cross-sectional area A of the cast (forged) stem up to 0.5 m above the full-load waterline is to comply with the following formula:

$$A \geq 1.1L$$

where: A — cross-sectional area of the stem, in cm^2 ;
 L — length of ship, in m.

8.1.2 Where the stem is a combination of cast (forged) steel and steel plate, the cast (forged) steel portion is to be carried to the deck or flat above the full-load waterline; and the upper portion is to be of steel plate. The thickness of the steel plate connected to the cast (forged) portion is in general to be increased by 25% ~ 50% over that of the adjacent shell plating.

8.1.3 The cast steel stem is to be provided with horizontal stiffeners.

8.1.4 Exposed corners and edges of the stem are to be fully rounded.

8.1.5 Stem brackets are to be fitted along the height of the stem, spaced not more than 0.5 m apart. Stem brackets are to be extended backwards beyond the joint line of the stem and shell plating, and effectively connected to longitudinals. The scantlings of stem brackets are not to be less than that as specified in Table 8.1.5.

Table 8.1.5

Ship length L (m)	Minimum permissible scantlings of stem bracket (mm)	
	Thickness	Flange
$L < 80$	4	30
$L \geq 80$	5	40

8.1.6 Plate stems are to comply with the following requirements:

(1) The thickness t of plate stems up to 0.5 m above the full-load waterline is not to be less than that obtained from the following formula:

$$t = 0.1L + 3 \quad \text{mm}$$

However, t is not to be less than the maximum thickness of the shell plating amidships and is to maintain at least one deck (or platform) upward.

(2) The thickness of the remainder of the stem may be gradually tapered upwards. The thickness of plate stems is to increase at least 25% over that required for the adjacent shell plating.

(3) The welding seams of plate stems are to be 400~600 mm away from the fore end.

8.2 Propeller shaft bracket

8.2.1 In general, one propeller shaft of a ship is fitted with two brackets. The aft bracket should generally be supported by two arms and the fore bracket by a single arm. The single-arm bracket may be used in small naval ships. In the case of a two-arm bracket, the difference of the two arms in length is to be kept to a minimum, and the angle between them is in general not to be less than 50°.

8.2.2 The propeller shaft bracket is to be fitted at frames, reinforced structure or bulkhead. The shell plate thickness in way of the fixing of the bracket arm is to be increased by 50% over that of the adjacent shell plating and not less than that of the shell plating amidships. No joint of block sections is to pass through such plate of increased thickness. The bottom structure near the bracket is to be reinforced accordingly. The portion of the supporting arm that is integrated into the hull is to have a length of 0.2 ~ 0.25 times the arm length. The supporting arm is to have radiused transition at connection to hull.

8.2.3 The strength of the propeller shaft bracket is to be checked as follows:

(1) a space combination structure consisting of propeller, propeller shaft and propeller shaft bracket is to be adopted to check the strength of propeller shaft bracket by finite element direct calculation;

(2) the design load when checking the strength of the propeller shaft bracket is based on the assumption that the propeller shaft rotates at the maximum speed and the centrifugal force and eccentric thrust generated on the propeller shaft when the following blade breaking occurs:

- ① The centrifugal force C and eccentric thrust P generated when one blade of the three-blade propeller shaft is broken can be calculated according to the following formula:

$$C = (2\pi n)^2 R_1 q_1 \times 10^{-3} \quad \text{kN}$$

$$P = 2P_1 \quad \text{kN}$$

where: n — maximum speed of the propeller shaft, in r/s;

R_1 — distance from the center of gravity of each blade to the axis of the propeller shaft, in m;

q_1 — mass of each blade, in kg;

P_1 — thrust of each blade, in kN; $P_1 = Q/3$;

Q — maximum thrust of the propeller shaft, in kN.

- ② The centrifugal force C and eccentric thrust P generated when two adjacent blades of the four-blade propeller shaft is broken can be calculated according to the following formula:

$$C = \sqrt{2}(2\pi n)^2 R_1 q_1 \times 10^{-3} \quad \text{kN}$$

$$P = 2P_1 \quad \text{kN}$$

where: n , R_1 , q_1 , Q are same as those in 8.2.3(2) ①

P_1 — thrust of each blade, in kN; $P_1 = Q/4$.

- ③ The centrifugal force C and eccentric thrust P generated when two adjacent blades of the five-blade propeller shaft is broken can be calculated according to the following formula:

$$C = 1.62(2\pi n)^2 R_1 q_1 \times 10^{-3} \quad \text{kN}$$

$$P = 3P_1 \quad \text{kN}$$

where: n , R_1 , q_1 , Q are same as those in 8.2.3(2) ①

P_1 — thrust of each blade, in kN; $P_1 = Q/5$.

(3) The permissible stress of the propeller shaft bracket is to be determined as follows:

permissible normal stress $[\sigma] = 0.8R_{eH}$ N/mm²;

permissible shear stress $[\tau] = 0.46R_{eH}$ N/mm².

8.3 Main engine foundations

8.3.1 Where diesel engines are used as main engines, the minimum thickness of webs and face plates of their seating girders is to be determined according to the engine power, and not less than as specified in Table 8.3.1.

Table 8.3.1

Diesel engine power, in kw	Thickness t of seating girder web, in mm	Thickness t of seating girder face plate, in mm
370	4	12
750	5	14
1500	6	16
3000	8	18
4500	10	20
6000	12	20
7500	14	22
9000	16	24

8.3.2 Girders of the engine seating are to coincide with bottom girders as far as practicable. Otherwise, partial girders having a thickness equal to that of bottom girders are to be fitted below the seating girders. Where there is inner bottom, such partial girders may be T-shaped sections (inner bottom girders) hanged on the inner bottom upside down. If transverse brackets are not to coincide with bottom floors and if it is not possible or necessary to provide transverse stiffeners, transverse brackets must be extended transversely to the nearest bottom girders or suitably situated hull longitudinals.

8.3.3 The engine seating is to be securely fixed on primary hull members (floors, bottom girders). In the case of a seating on which unbalanced forces act, both ends of the seating should be carried to primary transverse bulkheads and so far as practicable, securely connected to them. In general, transition brackets are to be fitted at the back side of the primary transverse bulkhead.

8.3.4 The face plate of girders of the engine seating is generally to be reinforced by brackets. The brackets are generally to be evenly arranged between transverse brackets of the seating. The face plate bracket of girders of the engine seating is generally to have a height equal to that of the web of girders of the engine seating. The height of the bracket is allowed to be not equal to that of the web only where the width of the web exceeds 2 times that of the face plate, provided that the height of the bracket is not less than 2 times its width.

8.3.5 Girders of the engine seating are not to be terminated abruptly, and their cross section is to have a gradual transition. In general, no hole is to be made in the girder web. If any hole is necessary, the requirement of 3.2 is to be complied with.

8.3.6 The web thickness of transverse brackets and diaphragms of the engine seating may be 1 ~ 2 mm less than that of girders of the engine seating, provided that the web thickness of transverse brackets and diaphragms is not less than 3 mm.

8.3.7 The web thickness of girders of the thrust bearing seating is generally to be the same as that of girders of the engine seating.

8.3.8 If necessary, the finite element method is to be used to calculate the natural frequency of the engine seating to avoid the excitation frequency of the engine and prevent resonance.

8.4 Bulwarks

8.4.1 Where bulwarks the length of which is not less than $0.15L$ are provided within $0.5L$ amidships, effective measures are to be taken so as to ensure their freedom from the longitudinal bending of the hull.

8.4.2 The strength of bulwarks is to be capable of withstanding the sea water pressure or the loads of some equipment.

8.4.3 The top edge of bulwarks is to be stiffened by a flat bar or bulb steel.

8.4.4 Bulwarks are to be provided with vertical stiffeners at the position of deck beam. The lower end of stiffeners is connected to the deck by brackets. Strengthened stiffeners are provided every 2 to 3 frames.

8.4.5 Bulwarks are to be provided with discharges. Bulwarks are not to be cut for other openings near the breaks of superstructures.

8.5 Support structure for podded propulsion units

8.5.1 Members of the hull support structure for a podded propulsion unit comprise a pedestal girder and its face plate (if fitted) that support the strut, and an orthotropic grillage of webs and floors that are connected to or surround the pedestal girder, as shown in Figure 8.5.1. This grillage may be of single or double bottom construction, but normally of double bottom in way of the podded propulsion unit.

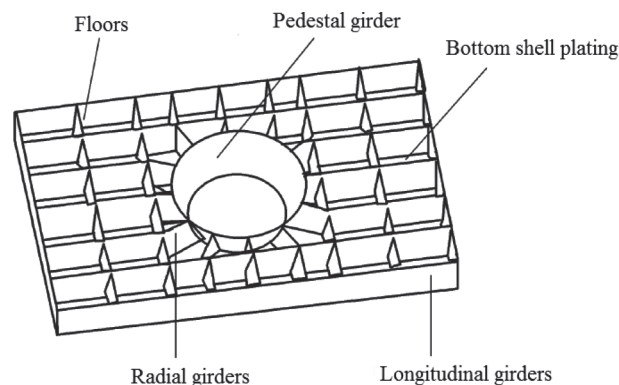


Figure 8.5.1

8.5.2 The outer ends of radial girders are generally to be connected to bottom longitudinal girders and floors and aligned with them both longitudinally and transversely, transferring the supported load to the hull structure. If the spacing of radial girders is too great, consideration is to be given to arranging supporting brackets between the slewing bearing outer races and pedestal girder to increase the rigidity of outer races. The thickness of the pedestal girder and its surrounding girders is not to be less than the minimum thickness of solid floors or girders at the same positions required by the Guidelines. Where abutting plates are of dissimilar thickness, tapering is to be carried out according to the relevant applicable requirements.

8.5.3 In general, full penetration welding is to be applied in way of connections of the pedestal girder to the bottom shell plating and to the inner bottom plating or top outer races, and in way of the end connections between the radial girders and the pedestal girder. Radial girder webs are to be welded to the underside of the outer races at the top of the pedestal girder and its face plate, if fitted, is to be welded to the outer side of such outer races. Elsewhere, for primary members, double continuous fillet welding is to be applied using a minimum weld factor of 0.34.

8.5.4 The hull support structure is to be able to withstand the maximum loads transferred from the strut of podded propulsion unit and is to be sufficiently stiff that any deformation as a consequence of the maximum loads will not exceed the limits required for slewing bearing operation. The limits are to be based on the operational requirements for the pod.

8.5.5 The arrangement of the hull support structure and scantlings of its primary members are subject to direct strength analysis according to the following requirements:

- (1) The support structure is to be modelled (e.g. elements and mesh size, etc.) by regular means of hull structure direct calculation, and the boundary conditions are to be obtained on the principle that response consequences of the members for assessment are not affected.
- (2) Loads are to be provided by the pod manufacturer/designer, generally taking into consideration normal and ultimate conditions of the podded propulsion unit (see Note ① of Table 8.5.5).
- (3) The calculated stress of the structural member is not to be greater than the permissible value. The permissible stress value is obtained by the material yield strength divided by the corresponding safety factor given in Table 8.5.5.

		Safety Factor	
		Table 8.5.5	
Stress type	Condition	Normal condition	Ultimate condition
Normal stress		1.67	1.50
Shear stress		2.50	2.25
Equivalent Von Mises stress of plate elements		1.43	1.33

- Notes: ① Normal condition means the normal operation condition, in which the structure does not fail while the ship is in normal service; ultimate condition means the most critical condition, in which the structure is subject to the maximum load expected due to accident.
- ② For check of the equivalent Von Mises stress of plate elements, only the equivalent stresses at the mid plane (membrane) at the element centroid are to be considered. However, high stress due to poor-shape elements may not be considered.
- ③ The safety factor for a plate element directly connected to the pedestal and located at the corner of a three-dimensional intersection may be appropriately reduced, but not to be less than 1.1. Where refined mesh analysis is applied here, the stress value of the element may be deducted by 5%.

8.5.6 In addition, scantlings of primary members are not to be less than those required for the stern structure in the Guidelines, as applicable.

8.6 Helicopter decks

8.6.1 The structure of helicopter decks is to comply with the relevant requirements in Section 18, Chapter 2, PART TWO of ISC Rules for Classification of Sea-going Steel Ships.

CHAPTER 9 COLLISION-RESISTANCE REQUIREMENTS FOR HULL STRUCTURE

9.1 General requirements

9.1.1 Upon the voluntary application of the Owner, the structure may be reinforced for collision resistance according to 9.2, 9.3 and 9.4 of this Chapter.

9.1.2 As an alternative, upon the request of the Owner, the finite element simulation calculation may also be adopted for capacity assessment of collision resistance .

9.2 Main deck stringers and sheer strakes

9.2.1 The thickness of main deck stringers and sheer strakes from the stem to $0.33L$ backward is to be 1.15 times the Rule value.

9.3 Secondary members and primary members

9.3.1 The section modulus of the secondary members and primary members on the main deck and ship sides from the stem to $0.33L$ backward is to be 1.25 times the Rule value.

9.4 Stems

9.4.1 The cross-sectional area of the stem structure is to be 1.1 times the Rule value.

9.5 Fenders

9.5.1 Where necessary, fender structure may be provided according to the collision-resistance demand for public affair ships.