RULES
FOR THE CLASSIFICATION AND CONSTRUCTION OF SMALL SEA-GOING SHIPS

PART II
HULL

July
2023

GDAŃSK

RULES FOR THE CLASSIFICATION AND CONSTRUCTION OF SMALL SEA-GOING SHIPS developed and edited by Polski Rejestr Statków S.A., hereinafter referred to as PRS, consist of the following Parts:

Part I – Classification Regulations
Part II – Hull
Part III – Hull Equipment
Part IV – Stability and Freeboard
Part V – Fire Protection
Part VI – Machinery and Piping Systems
Part VII – Electrical Installations and Control Systems,

whereas the materials and welding shall fulfil the requirements specified in *Part IX – Materials and Welding*, of the *Rules for the Classification and Construction of Sea-going Ships*.

Part II – Hull – July 2023 was approved by PRS Executive Board on 29 June 2023 and enters into force on 1 July 2023.

Upon the entry into force of this *Part II*, its requirements apply to new ships in the full scope.

The requirements of this *Part II* apply to the existing ships to an extent resulting from the provisions of *Part I – Classification Regulations*.

The requirements of *Part II – Hull* are extended by the following Publications:

Publication 21/P – Testing of the Hull Structures
Publication 40/P – Non-metallic Materials
Publication 76/P – Stability, Subdivision and Freeboard of Passenger Ships Engaged on Domestic Voyages
Publication 2/I – Prevention of Vibration in Ships
Publication 16/I – Shipbuilding and Repair Quality Standard
Publication 100/P – Safety requirements for sea-going passenger ships and high-speed passenger craft engaged on domestic voyages

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1.1 Application

1.1.1 *Part II – Hull* applies to the construction of small sea-going ships (single side-skin ships of length *L* less than 24 m) mentioned in paragraph 1.1.1 of *Part I – Classification Regulations,* intended for restricted service.

The requirements specified in *Part II – Hull* are not applicable to open craft (e.g. undecked boats).

Chapters from 2 to 21 apply to ships with metallic hull. Chapter 22 applies to ships with hull made of glass reinforced plastic, and Chapter 23 – fishing vessels with wooden hull.

The requirements specified in Chapter 1 apply to all ships irrespective of the hull material.

1.1.2 In this part of the *Rules for the Classification and Construction of Small Sea-going Ships* (hereinafter referred to as the *Rules*), it is assumed that the ratios between the main dimensions of the ship are within the following intervals (except that as provided in 1.1.3 and 1.1.4):

.1 length to moulded depth ratio, *L*:*H*:
- in fishing vessels, irrespective of their operating area – not more than 17;
- in restricted service ships assigned the following marks in the symbol of class (see *Part I – Classification Regulations*, paragraph 3.4.2):
  I – not more than 18,
  II – not more than 19,
  III – not more than 20;

.2 breadth to moulded depth ratio, *B*:*H*:
- in fishing vessels, irrespective of their operating area – not more than 2.5,
- in restricted service ships assigned the following marks in the symbol of class:
  I – not more than 2.5,
  II – not more than 3,
  III – not more than 4.

1.1.3 In ships with glass reinforced plastic hull, the ratios between the main dimensions of the ship shall be within the following intervals:
$6 \le L{:}H \le 10$,
$3 \le L{:}B \le 5$,
$2 \le B{:}H \le 2.5$.

1.1.4 In fishing vessels with wooden hull, the ratios between the main dimensions *L*:*H* and *B*:*H* shall not exceed the values specified in sub-chapter 23.1.

1.1.5 For ships with ratios between the main dimensions other than those specified in 1.1.2, 1.1.3 or 1.1.4 as well as ships which are atypical for other reasons, the construction and scantlings of members ensuring the required hull strength are subject to PRS consideration in each particular case.

1.2 Definitions and Symbols

1.2.1 General

Definitions of general terminology used in the *Rules* are contained in *Part I – Classification Regulations*. In this part of the *Rules*, the following definitions and symbols regarding the ship hull are introduced in addition to those specified in *Part I*.

1.2.2 General Symbols

a_0 – regulatory spacing of structural members, [m] (see 12.2.2).

AP – after perpendicular – the perpendicular at the centre plane, at distance L_0 from *FP* aftwards.

B – breadth of ship, [m] – the greatest breadth of the ship measured amidships between the outer edges of frames – in a ship with metal shell plating or between the outer surface of the hull – in ship with shell plating of any other material.

BP – base plane – horizontal plane which crosses amidships the top of a flat keel or the intersection of the inner surface of the plating with the bar keel or – in the case of box keel – the intersection of the inner surface of the plating with the surface of the centre bottom longitudinal. In ships with wooden or partially wooden hull or with hull made of any material other than metal, the base plane crosses amidships the bottom surface of the flat keel or the intersection point of the plating inner surface with the bar keel.

CP – centre plane.

D – displacement of ship, [t] – mass of water, in tonnes, of the volume equal to the volume of the submerged part of the ship's hull. Unless otherwise specified, the seawater mass density shall be taken as 1.025 t/m^3.

E – longitudinal modulus of elasticity (Young's modulus), [MPa]:
– for steel: $E = 2.06 \cdot 10^5$, MPa,
– for aluminium alloys: $E = 0.69 \cdot 10^5$, MPa.

FP – forward perpendicular – the perpendicular at the intersection of the summer load waterline with the fore side of the stem.

G – modulus of volume elasticity, [MPa]:
– for steel: $G = 7.9 \cdot 10^4$, MPa,
– for aluminium alloys:$G = 2.45 \cdot 10^4$, MPa.

g – *standard acceleration of gravity,* [m/s^2] – shall be taken as 9.807 m/s^2 for calculations.

H – moulded depth of ship, [m] – vertical distance measured amidships from the base plane to the top of the uppermost continuous deck beam at side. In ships having a rounded gunwale, the moulded depth shall be measured to the point of intersection of the moulded lines of the deck and side.

If the uppermost continuous deck is stepped and the raised part of the deck extends over the point at which the moulded depth shall be determined, the moulded depth shall be measured to a line of reference extending from the lower part of the deck along a line parallel with the raised part.

Where thick garboard strakes are applied, the distance is measured from the intersection of the extended – towards the centre plane – line of the bottom flat part with the side surface of the keel.

k – material factor – factor depending on the material yield strength – see 2.2 and 2.3.

L–length of ship, [m] – means 96% of the total length of hull measured on the waterline at 85% of the least moulded depth measured from the top of the keel, or the length from the fore side of the stem to the axis of the rudder stock on that waterline, whichever is greater. Where the stem line in the ship's centre plane is concave above that waterline, both the stem outer point of the total length of hull and the fore side of the stem shall be taken at the point determined by vertical projection – on such a waterline plane – of the aftermost point on the stem line above that waterline (see Fig. 1.2.2). In ships designed with a rake of keel, the waterline on which this length is measured shall be parallel to the design waterline.

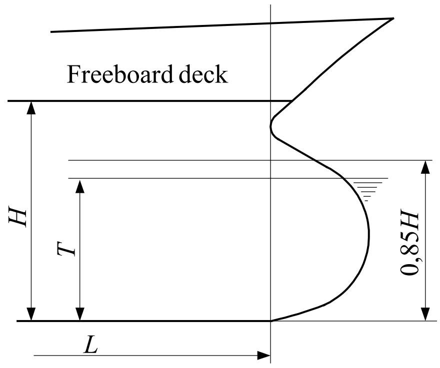


Fig. 1.2.2 Definition of length of ship L for ships with unconventional stem curvature

L_0 – *design length of ship*, [m] – distance measured on the summer load waterline from the fore side of the stem to the axis of the rudder stock. The adopted value of L_0, shall not be taken less than 96% of the overall length of hull measured on the summer load waterline, however not more than 97% of that length. For ships with unconventional stem or stern curvature, length L_0 shall be determined in agreement with PRS.

L_c – *length overall*, [m] – distance measured from the foremost part of the stem to the aftermost part of the stern including any fixed projections extending beyond the stem and stern, measured parallel to the design waterline.

L_{PP} – *length between perpendiculars* – distance measured between the forward perpendicular and after perpendicular.

L_W – *length of ship measured on summer load waterline,* [m] – distance measured on summer load waterline from the fore side of the stem to the aftermost point on the transom line.

Midship section – ship hull section by the vertical plane, perpendicular to the centre plane, at the midspan of design length L_0.

R_e – *material yield point*, [MPa] – see *Rules for the Classification and Construction of Sea-going Ships*, *Part IX – Materials and Welding*.

T – *moulded draught*, [m] – vertical distance measured amidships from the base plane to the summer load waterline.

v – *ship speed,* [knots] – maximum service speed at draught T.

V – *volume of moulded displacement,* [m^3] – volume of ship body defined by the external edges of frames at draught T.

x, y, z – *co-ordinates of a point in the ship,* [m] – see 1.2.3.

δ – *moulded block coefficient* – coefficient calculated in accordance with the formula below:

$$\delta = \frac{V}{L_0 BT}.$$

1.2.3 Co-ordinate System

1.2.3.1 In this part of the *Rules*, the co-ordinate system shown in Fig. 1.2.3.1 has been assumed for ships. The following reference planes have been assumed for the system: base plane, centre plane and midship section.

The intersection of the centre plane and the base plane forms x axis of the positive sense forward.

The intersection of the base plane and midship section forms *y* axis of the positive sense towards port side.

The intersection of the centre plane and midship section forms *z* axis of the positive sense upwards.

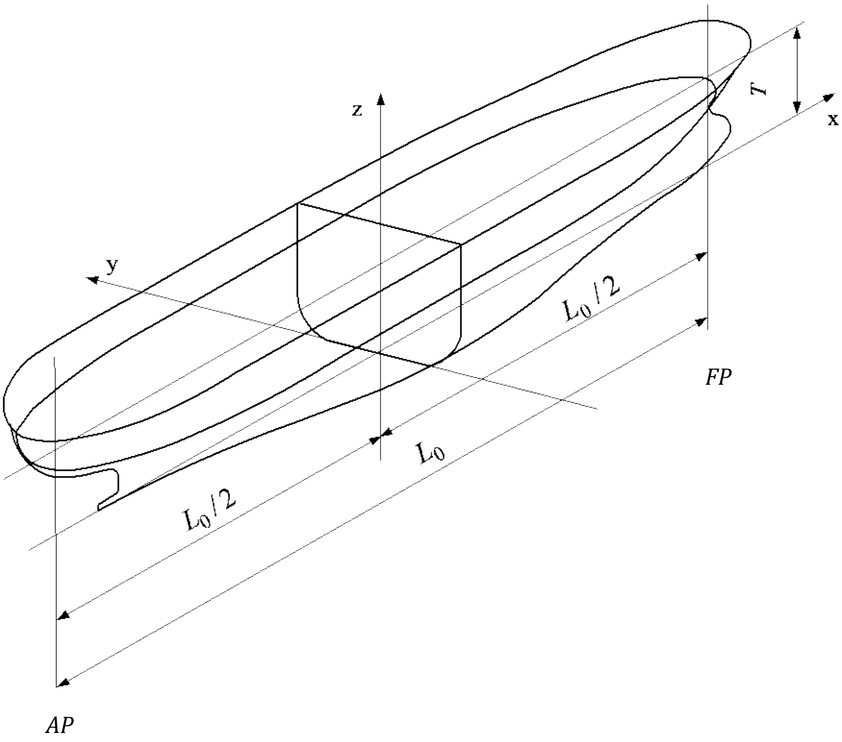


Fig. 1.2.3.1 Ship co-ordinate system

1.2.3.2 In this part of the *Rules*, other ship co-ordinate systems – defined individually – are also applied.

1.2.4 General Definitions

Bulkhead deck – the uppermost deck up to which transverse watertight bulkheads are led.

Deck – continuous deck, to which bulkheads are led, extending over the full length of the ship.

Deck erection – superstructure or deckhouse.

Deckhouse – a decked structure on the freeboard deck or on the superstructure deck with the sides being inboard of one or both ship sides more than 0.04 *B*.

Enclosed superstructure – superstructure with boundaries having sufficient strength and the following characteristics:

– any access holes in such boundaries, if any, are permanently fixed with weathertight doors having strength equivalent to that of such a boundary and capable of being open from both sides;
– holes providing access from the top, if any, are capable of weathertight closing from both sides,
– any other side, end or top openings are fitted with weathertight means of closing.

Forecastle – erection extending aft of the bow.

Freeboard deck – deck to which the freeboard is measured and calculated in accordance with the *International Convention on Load Lines, 1966*.

Height of superstructure – the minimum distance measured vertically on the outside boundary from the uppermost edge of the superstructure beam to the uppermost edge of the deck beam.

Lower deck, 'tween deck – deck situated below the upper deck. Where there are several lower decks, they are named: the second deck, the third deck, etc., counting from the upper deck towards the bottom.

Midship portion – ship portion of length equal to 0.4 L_0 (within $-0.2L_0 < x < 0.2L_0$) symmetrical to the midship section. Where the extent of the portion in question has a different length, its co-ordinates are defined in each particular case.

Midship superstructure – an erection located partly or totally within the midship portion of the ship; it may be an extension of the forecastle or the poop.

Moulded deck line – intersection line of surfaces defined by the external edges of deck beams and side frames. In the case of rounded deck corner, this is an intersection of extensions of these surfaces.

Platform deck – lower deck extending over a part of the ship's length or breadth (untight construction).

Poop – an erection extending forward of the stern.

Raised quarter deck – aft portion of the upper deck raised, as a step, less than the deck height.

Strength deck – upper deck. Where it is covered by a midship superstructure having a length not less than $3(0.5B + h)$, the midship superstructure deck is considered as the strength deck within this portion (h [m] – the vertical distance between the upper deck and midship superstructure deck in question). Another deck may be defined as the strength deck within the given length of the ship subject to PRS acceptance of continuity of the ships sides with respect to shear strength in each particular case.

Ship end – fore and after portions of the ship within $0.05L_0$ off the perpendiculars toward amidships.

Summer load waterline – the waterline corresponding to the Summer Load Line defined in accordance with the Regulations of the *International Convention on Load Lines – 1966*.

Superstructure – a decked structure on the freeboard deck, extending from side to side of the ship or with one side or both sides being inboard of the ship sides not more than $0.04B$.

Superstructure (deckhouse) deck – the deck forming the top of a superstructure (deckhouse). Where the superstructure (deckhouse) is divided into several tiers, the superstructure (deckhouse) decks are named: first tier superstructure (deckhouse) deck, second tier superstructure (deckhouse) deck, etc., counting from the upper deck.

Trunk – decked structure on a deck with at least one side being inboard of a ship side more than $0.04B$ and having no door, window or another opening in its vertical boundaries.

Upper deck – the uppermost continuous deck extending over the full length of the ship.

Weather deck (open) – each deck or part thereof, which may be exposed to the effects of sea and weather.

1.2.5 Definitions of Structural Members

Bulkhead structure – transverse or longitudinal bulkhead plating, including stiffeners and girders.

Deck structure – deck plating, including stiffeners and girders.

Double bottom structure – shell plating and inner bottom plating including stiffeners, girders and other elements below the top of the inner bottom.

Girders – general name for structural members supporting the stiffener systems or other girders.

Main frames – side frames located outside the peak area connected to the floors or the double bottom and led to the lowest deck or side stringer if it constitutes the frame support.

Side structure – shell plating, including stiffeners and girders, between the uppermost deck reaching the side and upper turn of bilge in the case of single bottom or inner bottom plating in the case of double bottom

Simple girder – a girder, the conditions of ends fixation of which are known with sufficient accuracy and therefore it may be regarded as a member separated from the adjacent structure.

Single bottom structure – bottom shell plating with stiffeners and girders. If a ship has bilge, the single bottom structure extends to the upper turn of bilge.

Stiffeners – general name for structural members supporting the plating directly.

Superstructure (deckhouse) structure – wall and deck plating, including the stiffeners and girders.

Tween deck frames – frames located between the supporting side stringers, between the supporting side stringer and the nearest deck or between the two decks, including superstructure decks.

Wash bulkhead – perforated or partial bulkhead in a tank.

Watertight bulkhead – transverse bulkhead dividing the hull into watertight compartments.

Note: The general names for structural members as defined above (girder, stiffener) are hereinafter used interchangeably with traditional terms due to the location and function of a given member (e.g. frame, longitudinal, beam, stringer, floor).

1.2.6 Other Definitions

Other definitions specific to particular chapters or sub-chapters are provided in these chapters or sub-chapters.

1.3 Survey and Classification

1.3.1 Survey and classification are performed in accordance with the requirements specified in *Part I – Classification Regulations*.

1.3.2 Hull structure as a whole, as well as the parts specified below, is surveyed under construction:
- superstructures and deckhouses,
- trunks and propeller shaft tunnels,
- seatings for main engines and bearers for boilers,
- seatings for auxiliary engines and associated machinery components subject to PRS survey,
- shaft brackets, fixed propeller nozzles,
- coamings, companionways and other boundaries of openings in hull,
- movable ramps and platforms.

1.3.3 During construction, the structures mentioned in paragraph 1.3.2 are subject to survey for:
- compliance with the approved technical documentation,
- compliance with the requirements of this *Part* of the *Rules* within the scope not indicated in the technical documentation,
- compliance with the requirements specified in *Part IX – Materials and Welding* of the *Rules for the Classification and Construction of Sea-going Ships*.

1.3.4 PRS survey also includes the issues of prevention of the ship hull vibration in accordance with *Publication No. 2/I – Prevention of Vibration in Ships*.

1.3.5 Each ship hull under construction shall be subjected to tightness and strength tests within the scope and using the methods specified in *Publication No. 21/P – Testing of Hull Structure*, and for non-metallic hull, the requirements specified in 1.5 shall be fulfilled. Ship hull tightness tests shall be performed in accordance with the programme agreed with the relevant PRS Branch Office or Survey Station.

1.3.6 Supervision activities performed during the survey of construction (see 1.3.2) include inspections, measurements and tests.

PRS Surveyor details the scope of the above mentioned activities based on the classification documentation approved by PRS Head Office and the requirements specified herein.

1.3.7 For ships assigned, in accordance with paragraph 2.4.3, additional mark **PAC** in the symbol of class, complete documentation of the corrosion protection system shall be submitted for approval. Scantling of structural members with and without corrosion allowances shall be indicated in the design drawings.

1.4 Technical Documentation

1.4.1 Classification Documentation of Ship under Construction

Prior to commencement of the ship hull construction, the documentation specified in 1.4.1.1 shall be submitted to PRS Head Office for reference and the hull documentation specified in 1.4.1.2, in the scope depending on the ship type, equipment and outfitting shall be submitted to PRS Head Office for approval. PRS may extend the scope of classification documentation after consideration the ship technical specifications and general arrangement plan.

1.4.1.1 General Documentation (for reference):

- ship technical specifications including her operating area and the intended symbol of class;
- general arrangement plan showing the escape routes;
- report on the ship hull strength calculations including the description of the assumptions for loads and calculation models adopted as well as the results obtained.

1.4.1.2 Hull Documentation:

.1 Data on the longitudinal, zone and local strength:
- basic theoretical data: body lines, hydrostatic curves,
- calculation of maximum still water bending moments and shear forces, if required by PRS,
- mass of light ship and its longitudinal distribution,
- intended load conditions and mass distribution of cargo and provisions on the ship; minimum and maximum draught of ship in service and corresponding trim,

- load on deck, hatch covers and inner bottom if different from those specified in the *Rules*,
- type, density and angle of repose of dry bulk cargo,
- maximum density of liquid cargo intended to be carried in tanks,
- heights of air pipes, measured from the tank tops or from the decks above which these pipes are led,
- mass of heavy machinery components,
- other local loads or forces which will affect the hull structure.

.2 Midship section with characteristic cross-sections, including main dimensions of ship, full requested symbol of class, equipment number and other data such as speed, number of crew and passengers.

.3 Longitudinal section with specified frame spacings, location of watertight bulkheads, pillars, superstructures and deckhouses.

.4 Shell expansion, including:
- arrangement of girders, stiffeners, bulkheads, decks and platforms,
- arrangement and scantlings of shell openings,
- positions of the integral tanks,
- the extent of bottom flat portion of ship fore and after parts,
- for ships with ice strengthening – the extent of ice belt upper and lower boundaries and the corresponding bow draft and stern draft (taking account of trim) as well as the arrangement of intermediate frames;
- for ships with glass-reinforced plastic hull, the shell expansion is required only when the thickness changes along the ship length or the ship breadth.

.5 Drawings of decks and platforms, including the arrangement and dimensions of the openings.

.6 Drawings of the single bottom.

.7 Drawings of longitudinal and transverse bulkheads, as well as the tank bulkheads, including the height of tank overflow and air pipes.

.8 Drawings of engine room region, including foundations of main engines and boilers, as well as the bottom structure under the foundations, tanks, pillars, strengthenings, e.g. for upper fastening of the engine; type and rating of the engine shall be given, and the guidelines of the engine manufacturer concerning the foundation shall be taken into account; the height of tank overflow pipes and air pipes shall be specified.

.9 Drawings of aft portion and stern indicating the distance from the propeller to stern and rudder.

.10 Drawings of forward portion and stem.

.11 Drawings of supports and exits of propeller shafts, suspension of rudder and fixed propeller nozzles.

.12 Drawings of superstructures and deckhouses.

.13 Hull welding tables unless all data and dimensions concerning the welding are specified in the design drawings.

Moreover, the following technical documentations shall be submitted:

.14 For ro-ro ships:
- plan of the arrangement and securing of the carried vehicles, including the maximum axle load and forces in sockets and lashing eyes of the vehicle securing equipment,
- type and data on vehicles used for ro-ro handling, including the axle loads, detailed data on wheels and their print.

.15 For container ships:
- arrangement plan of containers, including the data on their maximum mass and strength standard,
- securing plan of containers, including sockets, stays and supports,

– drawings of supporting structures, including cell guide structures and adjacent structures of hull, as well as container sockets and other support with necessary reinforcements of hull structure,
– calculations of maximum forces and stresses in container supports, in adjoining hull structures, cell guides, lashing, etc.

.16 For ships mooring to other ships at sea:
– data on means attenuating hull impacts.

.17 For ships with glass-reinforced plastic hull:
– diagram of reinforcements and the hull manufacturing process particulars.

.18 For ships with wooden hull:
– hull manufacturing process particulars.

1.4.2 Classification Documentation of Ship under Alteration

Prior to commencement of the ship alteration, the documentation of ship parts to be altered shall be submitted to PRS Head Office for approval.

1.4.3 Workshop Documentation of Ship

Upon approval of the classification documentation by PRS Head Office, the following workshop documentation shall be submitted to the relevant PRS Branch Office or Survey Station for consideration and agreement:

– diagram of hull subdivision into sections and blocks, as well as the plan of assembling sequence,
– the table of welding and the plan of non-destructive tests of welded joints,
– plan of hull tightness tests,
– drawings showing passage of pipelines, ventilation ducts and cables through the hull plating, bottom, decks, bulkheads, girders, etc.,
– drawings of local strengthenings under gear and machinery not shown in classification documentation,
– specification, drawings and test programme for innovative engineering processes, solutions of structural nodes, etc.,
– programme of mooring and sea trials.

1.5 Ship Hull Testing

1.5.1 General

The scope and methods of metallic hulls testing shall be in accordance with the requirements specified in *Publication No. 21/P – Testing of the Hull Structures* – see 1.3.5.

Tests of non-metallic ship hulls shall be performed in accordance with the requirements specified in sub-chapter 1.5.

1.5.2 Tests of Glass-reinforced Hull Structures

.1 Collision bulkhead shall be subjected to a tightness test with the test pressure of the water head equal to the upper edge of the forepeak tank. Hydraulic test may be replaced by a pneumatic test using a pressure not less than 21 kPa.

.2 Machinery space bulkheads shall be subjected to a hose test with the pressure of 200 kPa or a pneumatic test using a pressure not less than 21 kPa.

.3 Tanks shall be subjected to the hydraulic test by flooding them up to the top edge of the vent pipe or to the height equal 2/3 of the distance between the tank top plating and the main deck or the tanks shall be subjected to a pneumatic test using a pressure not less than 21 kPa.

.4 Hull equipment, such as doors, windows, scuttles, etc. as well as means of closing of openings shall be subjected to tests like in the case of metallic hulls (see *Publication No. 21/P – Testing of Hull Structure*).

.5 Hydraulic tests may be performed only when the ambient temperature is above +1°C. For lower ambient temperatures, the test method is subject to PRS agreement in each particular case.

1.5.3 Wooden Hull Tightness Tests

.1 Tightness tests shall be performed after all the hull equipment has been installed in the plating. Ships which are subject to such tests may be tested afloat.

.2 Bottom plating tightness shall be tested by flooding up to the upper edges of floors.

.3 Side shell plating, bulkheads, decks, coamings and deckhouses shall be tested by hosing at the pressure of 200 kPa.

.4 Tightness test of the bottom and shell plating below the waterline may also be performed by launching the ship and verification of the plating tightness from inside after an 8-hour staying afloat.

.5 Hydraulic tightness test may be performed only when the ambient temperature is above +1°C. For lower ambient temperatures, the test method is subject to PRS agreement in each particular case.

2 METALLIC MATERIALS AND CORROSION PROTECTION

2.1 General

Materials intended for structures covered by the provisions of this Chapter shall fulfil the requirements specified in *Part IX – Materials and Welding* of the *Rules for the Classification and Construction of Sea-going Ships*.

Where aluminium alloys are used for the structural members, the requirements specified in 2.3.1 shall be taken into account.

2.2 Hull Structural Steels

2.2.1 Normal strength structural steel NW of grade A shall be used in the ship hull construction. In justified cases, higher strength steel may be used (see Table 2.2.2).

2.2.2 In Table 2.2.2 are indicated the applied notations of hull structural steel, division into grades and the corresponding values of yield point R_e (in accordance with the requirements specified in the above mentioned *Part IX – Materials and Welding*) as well as the values of material factor k determined in accordance with formula 2.2.3.

Higher steel grades than A or AH may be required by PRS separately depending on the structure specificity or the assumed ship operating conditions.

Table 2.2.2
Hull steel characteristics

Notation	Steel grade				R_e [MPa]	k
NW	A	B	D	E	235	1.00
PW32	AH32	–	DH32	EH32	315	1.28
PW36	AH36	–	DH36	EH36	355	1.39

2.2.3 Material factor k for steels with a yield point exceeding 235 MPa – other than those mentioned in 2.2.2 – which may be used subject to PRS consent in each particular case, shall be determined in accordance with the following formula:

$$k = \frac{R_e + 60}{295} \qquad (2.2.3)$$

2.2.4 If a steel with a yield point less than 235 MPa is used for special structures, then material factor k shall be determined in accordance with the following formula:

$$k = \frac{R_e}{235}. \qquad (2.2.4)$$

2.3 Other Structural Materials

2.3.1 Aluminium Alloys

2.3.1.1 Aluminium alloys of grade specified in *Part IX – Materials and Welding* may be used for construction of:
– hull structure,
– superstructures and deckhouses,
– bulwarks, windscreens, masts, wave breakers, etc.,
– hatch covers, closing appliances, stairs, ladders, and gangways,
– masts.

2.3.1.2 Strength of aluminium structure shall not be worse than that required for steel structures[1].

To satisfy this condition, the requirements specified in 2.3.1.6 and 12.3 shall be fulfilled.

2.3.1.3 Material factor k for aluminium alloys shall be determined in accordance with the following formula:

$$k_{al} = \frac{R_{mal} + R_{eal}}{635} \qquad (2.3.1.3)$$

where the value of R_{eal} shall not be taken greater than $0.7R_{mal}$ for calculations.

The symbols have the following meaning:

R_{eal} – aluminium alloy yield point, [MPa];
R_{mal} – aluminium alloy tensile strength, [MPa].

For welded aluminum structures, the expected strength characteristics of aluminium alloys after welding shall be assumed, i.e. for series 5000 alloys – in soft condition (without strain hardening), and for series 5000 alloys – in the condition after natural ageing irrespective of their supply condition.

2.3.1.4 Butt joints of plates shall be arranged in such locations where are the minimum stress values so that the strength after welding be sufficient. Where this condition cannot be fulfilled, post-weld values of R_{eal} and R_{mal} shall be taken to determine material factor k.

2.3.1.5 When determining material factor k_{al} for the post-weld values of R_{eal} and R_{mal} , their values shall not be taken greater than specified in Table 2.3.1.5-1 – for rolled products and in Table 2.3.1.5-2 – for extruded products of both open and closed sections. The symbols are consistent with those used in *Part IX – Materials and Welding*.

[1] See also 2.3.1.3.

Table 2.3.1.5-1
Minimum mechanical properties of post-weld aluminium alloy rolled products

Aluminium alloy	Material condition	Thickness [mm]	R_{eal} [MPa]	R_{mal} [MPa]
EN AW – 5083	O or H111	t ≤ 40	125	275
EN AW – 5083	H116, H321	t ≤ 40	130	280
EN AW – 5383	H116, H321	t ≤ 40	140	290
EN AW – 5059	O or H111	t ≤ 40	160	300
EN AW – 5059	H116, H321	t ≤ 40	185	325
EN AW – 5086	O or H111	t ≤ 40	95	240
EN AW – 5086	other	t ≤ 40	95	240

Table 2.3.1.5-2
Minimum mechanical properties of post-weld aluminium alloy extruded products (sections)

Aluminium alloy	Material condition	Thickness [mm]	R_{eal} [MPa]	R_{mal} [MPa]	Section type
EN AW – 5083	O or H112	t ≤ 40	125	275	open
EN AW – 5083	H111	t ≤ 40	110	270	open
EN AW – 5086	O or H111	t ≤ 40	95	240	open
EN AW – 5086	O or H111	t ≤ 40	95	240	open
EN AW – 5086	H112	t ≤ 40	95	240	open
EN AW – 6082	T6	t ≤ 15	110	170	closed

2.3.1.6 The required scantlings of aluminium alloy members shall be determined based on the scantlings of equivalent steel members (which does not, however, apply to the minimum scantlings) using the formulae specified in Table 2.3.1.6.

Table 2.3.1.6
Scantling of aluminium alloy members

Item	Scantling being determined	Applicable formula
1	Thickness of shell plating, deck plating (without coating), bulkhead plating and internal divisions and other parts made of plates	$t_{al} = 0.9\frac{t}{\sqrt{k_{al}}}$ [mm] – for the whole hull $t_{al} = \frac{t}{\sqrt{k_{al}}}$ [mm] – for superstructures
2	Sectional modulus of stiffeners or girders	$W_{al} = \frac{W}{k_{al}}$ [cm³]
3	Cross-section moment of inertia of stiffeners, girders or pillars	$I_{al} = I\frac{E}{E_{al}} \cong 3I$ [cm⁴]
4	Cross-sectional area of pillars or cross-sectional area of the member webs	$S_{al} = \frac{S}{k_{al}}$ [cm²]

where:
k_{al} – material factor for aluminium alloy determined in accordance with 2.3.1.3,
t – required thickness of member made of NW steel, [mm],

t_{al} – required thickness of member made of aluminium alloy, [mm],
W – required section modulus for NW steel, [cm^3],
W_{al} – required section modulus for aluminium alloy, [cm^3],
I – required moment of inertia for steel girder, [cm^4],
I_{al} – required moment of inertia for aluminium alloy girder, [cm^4],
S – required cross-sectional area for steel pillar or girder web cross-sectional area, [cm^2],
S_{al} – required cross-sectional area for aluminium alloy pillar, [cm^2],
E – modulus of elasticity for NW steel, [MPa],
E_{al} – modulus of elasticity for aluminium alloy applied, [MPa].

2.3.2 Alternative Materials

Application of alternative materials for ship structure is subject to PRS consent in each particular case.

The requirements for glass-reinforced plastic structures are specified in Chapter 22, whereas for wooden structures – in Chapter 23.

2.4 Corrosion Protection

2.4.1 For new constructions of steel hull ships, all the ballast tanks whose boundaries are formed by the shell plating shall be provided with adequate protective coating, either epoxy or equivalent, applied in accordance with the manufacturer's guidelines. It is recommended that the coating be of bright colour.

2.4.2 All surfaces of the steel ship structure shall be provided with corrosion protection paint, applied in accordance with the paint manufacturer's requirements or otherwise effectively protected against corrosion.

When deciding on the type of protective coating, the intended service conditions (among others, the cargo) shall be taken into account.

2.4.3 On the Owner's request, the corrosion allowances required in 2.5 may be reduced or neglected subject to PRS consent in each particular case on condition that effective corrosion protection of the structure has been provided. In that case, the ship may be assigned additional mark PAC in the symbol of class.

2.4.4 In steel tanks intended for the carriage of ballast water or liquid cargo (oil) or in cargo holds intended for the carriage of dry cargo or ballast water, the thickness of structural members shall be increased by the corrosion allowances in accordance with sub-chapter 2.5.

2.4.5 If the corrosion protection is achieved by cement coating, the construction shall be carefully cleaned of scale, rust and old paint coating first.

2.4.6 The requirements for corrosion protection coatings and cathodic protection are specified in *Publication No. 55/P – Survey of corrosion protection and anti-fouling systems*.

2.5 Corrosion Additions for Steel Hulls

2.5.1 Thickness of plating of vertical and horizontal bulkheads forming boundaries of the tanks, mentioned in paragraph 2.4.4, shall be increased by corrosion addition t_k determined in accordance with the formula below:

$$t_k = t_w + t_z \quad \text{[mm]} \tag{2.5.1}$$

t_w – corrosion addition determined in accordance with paragraph 2.5.5 for the inner side of plating for the particular type of liquid carried in the tank, [mm];

t_z – corrosion addition determined in accordance with paragraph 2.5.5 for the outer side of the plating, taking account of the designation of the adjacent space, [mm].

2.5.2 Thickness of face plates, webs and brackets of stiffeners and girders, situated inside the tanks mentioned in paragraph 2.4.4, shall be increased by corrosion addition t_k determined in accordance with the formula below:

$$t_k = 2t_w \text{ [mm]} \tag{2.5.2-1}$$

Where stiffeners or girders of the tank bulkhead are at its outer side, the corrosion addition t_k shall be determined in accordance with the formula below:

$$t_k = 2t_z \text{ [mm]} \tag{2.5.2-2}$$

t_w and t_z– see 2.5.1.

For stiffeners made of rolled sections, the corrosion addition shall be determined taking account of the requirements specified in 12.6.1

2.5.3 For horizontal webs or face plates of stiffeners or girders, the corrosion allowance shall be additionally increased by 0.5 mm.

2.5.4 Corrosion additions t_w and t_z depend on area (A, B) of the tank or cargo hold in which the considered structural element is installed, as well as on the type of the agent acting on the considered side of the structural element in question.

Where the upper side of tank or cargo hold is closed by the weather deck, then A area of this tank or cargo hold is the area extending vertically from the weather deck (open deck) to the level 1.0 m below this deck. All other areas of tanks and cargo holds are B areas.

2.5.5 Depending on the type of agent acting on the considered side of the structural element, corrosion additions t_w or t_z are as follows:

- for A area
  1.5 mm – for ballast water;
  1.0 mm – for oil;
  0.5 mm – for dry cargo;
  0.0 mm – for (external) outboard water or air;
- for B area
  0.75 mm – for ballast water;
  0.50 mm – for oil;
  0.25 mm – for dry cargo;
  0.0 mm – for (external) outboard water or air.

2.6 Corrosion Additions for Aluminium Alloy Hulls

For aluminium alloy hull structures, corrosion additions are not required.

3 STRUCTURE PARTICULARS AND MODELLING OF STRUCTURAL MEMBERS

3.1 General

Methods of determining the geometrical and strength parameters of the hull structure members, specified in this Chapter, apply to the strength analysis of members unless stated otherwise in other chapters of this *Part* of the *Rules*.

3.1.1 Rounding-off Scantlings

3.1.1.1 In general, scantlings are rounded up.

3.1.1.2 Rounding off the plate thickness to the nearest lower standard value within a margin of 0.25 mm is permitted.

3.1.1.3 The values of section modulus, moment of inertia and cross-sectional area shall not be decreased by more than 3% of the required value.

3.2 Modelling of Structural Members

3.2.1 Span of Girders and Stiffeners

3.2.1.1 Design span *l* of girders and stiffeners shall be determined as shown in Fig. 3.2.1.1. It is assumed that brackets are effectively supported by the adjacent structure. Design span *l* of curvilinear girders and stiffeners is measured as the length of chord between the supporting points.

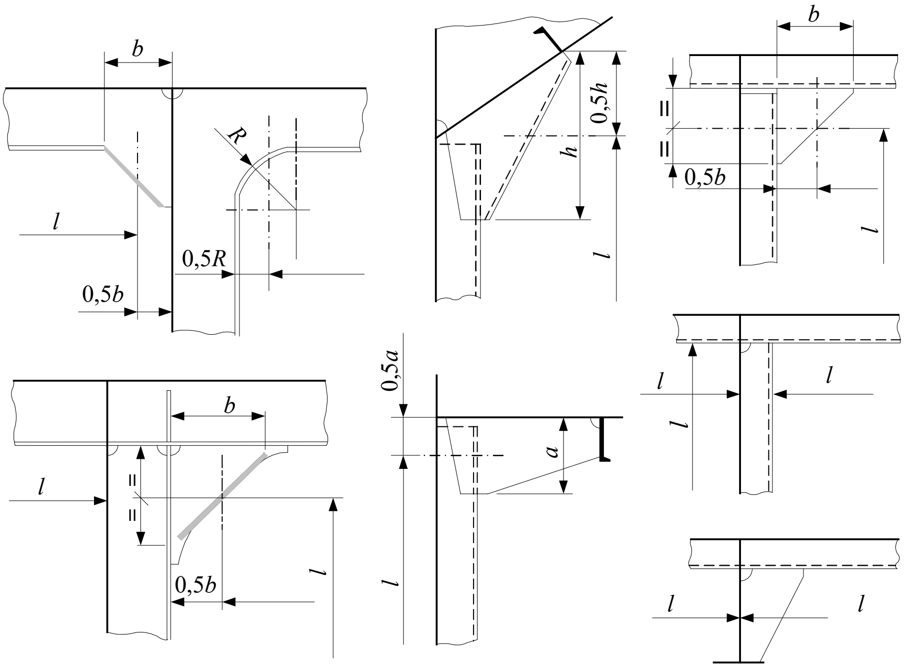


Fig. 3.2.1.1 Determining the span of structural members

3.2.2 Effective Flange

3.2.2.1 Cross-sectional area of the effective plate flange for stiffener or simple girder shall be determined in accordance with the following formula:

$$A_p = 10 b_e t \quad [\text{cm}^2] \tag{3.2.2.1}$$

t – mean thickness of the effective flange, [mm];
b_e – effective flange breadth, [m].

Continuous stiffeners, parallel to the web of girder in question and located within b_e width, may be included with 50% of their cross-sectional area in the effective plate flange area of the girder.

3.2.2.2 In general, the effective plate flange area shall not be less than the sectional area of the free flange.

3.2.2.3 Effective flange width b_e of plating stiffener shall be taken equal to the lesser of the two values determined in accordance with the following formulae:

$$b_e = \frac{1}{6}l \quad [\text{m}] \qquad (3.2.2.3\text{-}1)$$

$$b_e = 0.5(s_1 + s_2)\ [\text{m}] \qquad (3.2.2.3\text{-}2)$$

where:
l – stiffener span, [m];
s_1, s_2 – distances from stiffener in question to the adjacent stiffeners fitted at its both sides, [m].

Where extruded plates are used, s_1 and s_2 represent the widths of flat portions of the plates on both sides of the extrusion playing the role of stiffener.

3.2.2.4 Effective flange width of simple girder shall be determined in accordance with the following formula:

$$b_e = Kb\ [\text{m}] \qquad (3.2.2.4\text{-}1)$$

where:

$$b = 0.5(b_1 + b_2)\ [\text{m}] \qquad (3.2.2.4\text{-}2)$$

b_1, b_2 – distances from girder in question to the nearest girders of the same type, or divisions, fitted at its both sides, [m];
K – coefficient, taken from Table 3.2.2.4, depending on span l_z of the girder, as well as on number n of evenly spaced perpendicular stiffeners supported by the girder in question;

$l_z = l$ – for girder simply supported at its both ends, [m],

$l_z = 0.6l$ – for girder fixed at its both ends, [m].

Table 3.2.2.4
Values of *K*

Number of stiffeners n	l_z / b ratio							
	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0 and more
≥ 6	0.0	0.38	0.67	0.84	0.93	0.97	0.99	1
5	0.0	0.33	0.58	0.73	0.84	0.89	0.92	0.93
4	0.0	0.27	0.49	0.63	0,74	0.81	0.85	0.87
≤ 3	0.0	0.22	0.40	0.52	0.65	0.73	0.79	0.80

For intermediate values of l_z/b ratio, coefficient K may be obtained by linear interpolation.

3.2.2.5 Effective flange width b_e of corrugated bulkhead girders perpendicular to the corrugations shall be taken as follows:
$b_e = 15t$ for trapezoidal corrugations (see Fig. 3.2.4-a);
$b_e = 20t$ for undulated corrugations (see Fig. 3.2.4-b);

or 0.1 b for both cases, whichever value is lesser;

where:
b – effective flange width, calculated in accordance with paragraph 3.2.2.4,
t – corrugated bulkhead plating thickness.

Girder web cross-sectional area of a corrugated bulkhead shall not be greater than the effective flange cross-sectional area.

3.2.2.6 Effective flange width b_e of hatchway coaming shall be taken equal to 1/12 of its span. The assumed value of b_e shall not be greater than half the distance from hatchway coaming to the ship's side for longitudinal coamings or half the distance between the coaming and the nearest transverse bulkhead for transverse coamings.

3.2.3 Effective Cross-sectional Area of Web

Effective cross-sectional area of simple girders shall be determined in accordance with the formula below:

$$A_s = 0.01 h_s t_s \quad [\text{cm}^2] \tag{3.2.3}$$

t_s – web thickness, [mm];
h_s – net web height, [mm].

Net web height h_s shall be determined by deduction of cut-outs and openings in the cross-section being considered. If the edge of web opening is located at a distance less than $h/3$ from the cross section considered, h_s shall be taken as the smaller of two values: h_s and (h_1+ h_2), as shown in Fig. 3.2.3.

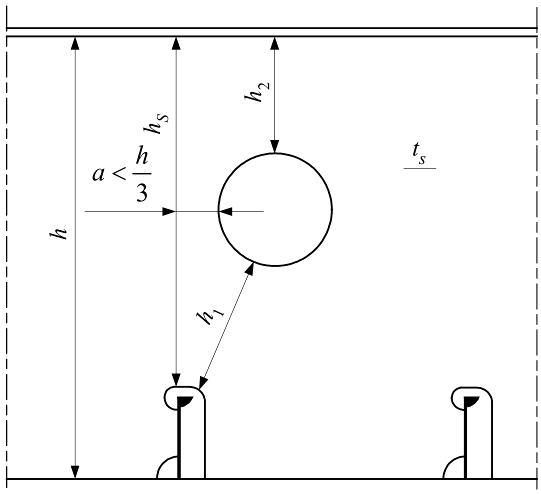


Fig. 3.2.3 Determining of net web height

3.2.4 Section Moduli and Moments of Inertia of Stiffeners and Girders

Section moduli and moments of inertia of cross-sections of stiffeners and girders required by this part of the *Rules* refer to the neutral axis parallel to the plating.

Where the web of structural member is not perpendicular to the plating, the value of the section modulus about the axis parallel to the plating for α < 15° (α – angle between the plane perpendicular to the plating and the web plane) may be determined approximately by multiplying the section modulus of the stiffener or girder assumed to be perpendicular to the plating by cosα.

For $\alpha \le 15°$, it may be assumed that the section modulus is the same as for $\alpha = 0°$.

Unless provided otherwise, the effective flange taken for the calculation shall be determined in accordance with 3.2.2.

Section modulus of corrugated bulkhead members may be calculated using the following approximate equations:

– for corrugated bulkhead member of trapezoidal cross-section and width equal to s_1 (Fig. 3.2.4 a):

$$W = \frac{ht}{2}\left(s_2 + \frac{s_3}{3\sin\alpha}\right)\ [\text{cm}^3] \qquad (3.2.4\text{-}1)$$

h, t – see Fig. 3.2.4 a), [mm];
s_2, s_3 – see Fig. 3.2.4 a), [m];
α – see Fig. 3.2.4 a, [°], $\alpha \geq 40°$ shall be taken;

– for corrugated bulkhead member of undulated cross-section and width equal to s (Fig 3.2.4 b):

$$W = ctr^2\ \ [\text{cm}^3] \qquad (3.2.4\text{-}2)$$

where:

$$s = 4r\sin\beta$$

$$c = 2\frac{\beta + 2\beta\cos^2\beta - 1.5\sin 2\beta}{1 - \cos\beta}$$

t, r, β – see Fig. 3.2.4-b; t, r – [cm], β – [rad].

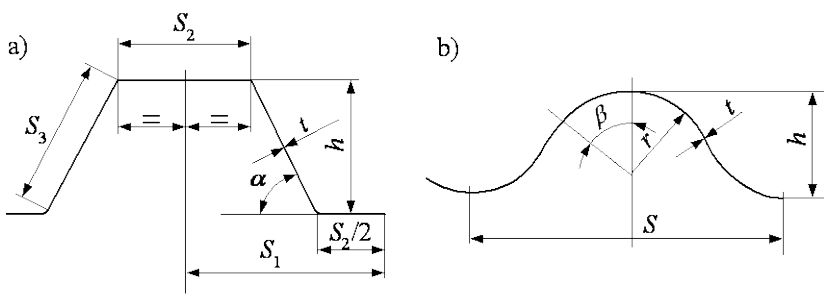


Fig. 3.2.4 Corrugated bulkhead profiles

3.3 Details of Welded Structures. Arrangement of Welded Joints and Connecting Welds of Plating and Webs and Face Plates of Girders

3.3.1 Local concentration of welds, crossing of welds at an acute angle, as well as close location of parallel butts or fillet welds and parallel butt welds shall be avoided. Distances between parallel welded joints, irrespective of their direction, shall not be less than:
– 150 mm between butt welds,
– 100 mm between a fillet weld and a butt weld,

The distance of joints (butts) of shell and deck plating panels from bulkheads, decks, inner bottom plating, girders, etc., arranged parallel to the joints, shall not be less than 75 mm.

For assembly joints (butts), this distance shall not be less than 150 mm.

The distance between two butt welds of elements forming a T-joint may be selected freely.

Fillet joints on the edge of scallop having a radius $r \geq 30$ mm situated over a butt joint in an element transverse to the scalloped one shall not be closer to the butt weld than 5 mm.

The angle between butt welds shall not be less than 60° (see Fig. 3.3.1). The butt weld shall be continued either in line or side-shifted by at least 100 mm.

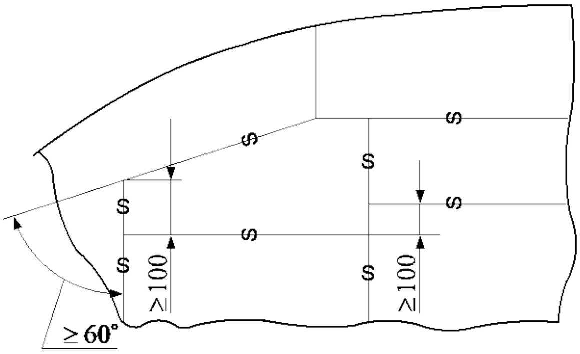


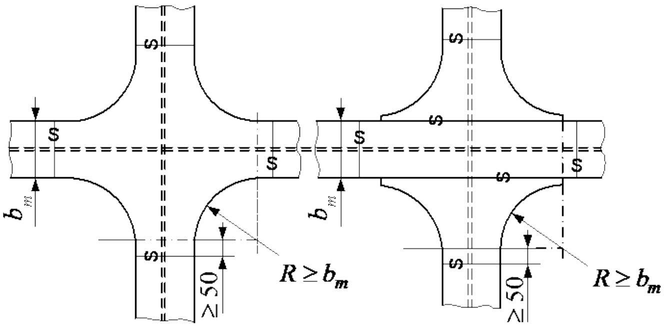
Fig. 3.3.1 Arrangement of welded joints

3.3.2 Assembly joint (butt) of framing girder shall be shifted by at least 100 mm off the web butt.

Intersection of girder web butt and one face plate butt is permitted if at least one of the following conditions is fulfilled:

– full penetration is applied in the web and face plate joint at the length not less than 100 mm in both directions from the intersection;
– an additional element – extending in both directions from the intersection at least as long as the face plate width – is applied coplanar with the web of the other element (e.g. bracket).

3.3.3 Face plate joints of crossing girders subjected to dynamic loads and girders of strength decks and single bottom in the midship portion of the ship, as well as other highly loaded girders shall be made with smooth transition by means of diamond plates (see Fig. 3.3.3).



b_m – narrower face plate width

Fig. 3.3.3 Joints of girder face plates

3.4 Structure Continuity

3.4.1 General Requirements

Any changes in the shape of sections and in the member thickness shall be smooth.

3.4.2 Continuity of Longitudinal Members

3.4.2.1 Continuity of as many as possible basic longitudinal members shall be ensured. All the necessary changes in the cross-section and/or their thickness shall be stepped smoothly so as to avoid excess stress concentration.

3.4.2.2 In watertight and non-watertight structures located in the areas where increased vibration may be expected, the applied design solutions shall prevent occurrence of sharp notches in the plating of shell, sides, bulkheads and decks as well as in way of transitions or ends of framing elements.

3.4.2.3 The areas where increased vibration may be expected, in terms of this *Part* of the *Rules*, are:

.1 in way of the afterbody:
- fore-and-aft – from the section at the distance (measured from the after edge of the stern tube) equal to half the propeller diameter to the section at the distance (measured forward) not less than twice the propeller diameter, however at least to the afterpeak bulkhead;
- vertically – from the keel to the closest continuous deck or platform above the propeller shaft;

.2 machinery space:
- fore-and-aft – between bulkheads forming the machinery space boundaries;
- vertically – from the bottom to the deck;

.3 positions where unbalanced machinery components or engines are installed.

3.5 Openings in Structural Members

3.5.1 General Requirements

3.5.1.1 The distance between edges of all openings in girder and edges of single slots in way of stiffeners shall be as little as practicable and shall have rounded corners.

Total height of openings (lightening holes, wash holes, single cut-outs in way of stiffeners and minor members, etc.) in one cross-section of a member shall not exceed 0.4 of its depth. In justified cases, this value may be increased in the centre of span to no more, however, than 0.6 of the member depth. In the outer parts of the member cross-section, the web cross-section decrement shall be compensated by connection lugs. The connection lugs shall have a thickness not less than 75% of the web plate thickness.

3.5.1.2 The distance between edges of all openings in girder and edges of single slots in way of stiffeners shall, in general, not be less than the depth of these stiffeners.

3.5.1.3 Holes in webs of stiffeners and girders shall not be arranged at a distance less than the web depth from the toe of end bracket.

3.5.1.4 Openings in member webs for free flow of liquid to the sucking terminals and for free flow of air to the air pipes shall be arranged inside the tanks.

These openings shall be as close to the bottom and deck as practicable. It is recommended that openings in bottom and deck longitudinals be elliptical or oval and located at a distance 10÷15 mm from the bottom and deck plating not less than 20 mm.

The height of the cuts extending to the plating as well as openings not extending to the plating shall not be greater than 0.25 of the web height and shall not exceed 75 mm. The length of openings and cuts along the plating shall not be greater than 15 times the member thickness and shall not exceed 150 mm.

3.5.1.5 Corners of any openings in members shall be rounded to a radius of curvature not less than twice the plate thickness.

3.5.1.6 Openings in side shell, longitudinal bulkheads and longitudinal girders shall be located below the strength deck or termination of rounded deck corners at a distance not less than twice the opening breadth.

3.5.1.7 Small openings shall generally be kept well clear of other openings in longitudinal strength members. Unreinforced edges of small openings shall be located at a transverse distance not less than four times the opening breadth from the edge of any other opening.

3.5.1.8 Openings in longitudinals shall be of elliptical shape and shall be kept clear of the connecting welds on these longitudinals.

3.5.2 Reinforcement of Openings' Edges

3.5.2.1 The requirements specified below apply to openings in strength deck and outer bottom in the middle portion of ship's hull within $-0.3L_0 < x < 0.3L_0$.

3.5.2.2 Circular openings with diameter greater than 0.325 m shall have edge reinforcement. Cross-sectional area of edge reinforcements shall not be less than:

$$A_0 = 2.5\,dt \text{ [cm}^2\text{]} \qquad (3.5.2.2)$$

d – opening diameter, [m];
t – plate thickness, [mm].

3.5.2.3 Elliptical openings with breadth greater than 0.5 m shall have edge reinforcement if their length/breadth ratio is less than 2. The reinforcement shall be as required in 3.5.2.2 for circular openings where *d* shall be taken equal to the opening breadth.

3.5.2.4 Rectangular or approximately rectangular openings, other than hatch openings or machinery casings, shall have edge reinforcement in accordance with 3.5.2.2 where *d* shall be taken equal to the opening breadth.

Corners of such openings shall have a radius not less than that determined in accordance with the following formula:

$$R = 0.05\,b \text{ [m]} \qquad (3.5.2.4)$$

however not less than 50 mm; *b* – breadth of opening, [m].

4 JOINTS OF STRUCTURAL ELEMENTS

4.1 General

4.1.1 The requirements concerning types and size of welds, welded joints and steel-aluminium joints are specified in this Chapter.

4.1.2 Irrespective of the requirements set forth in this Chapter, the requirements concerning welding materials, welding methods, welders qualifications, quality control of welds and protection against atmospheric effects during welding, specified in *Part IX – Materials and Welding*, shall be fulfilled.

4.2 Types and Sizes of Welds

4.2.1 Butt Joints

4.2.1.1 Edges of butt-welded plates of equal thickness shall be prepared as shown in Fig. 4.2.1.1.

Preparation plate edges and welding procedure are subject to PRS approval in each particular case (see 1.4.1.2-13).

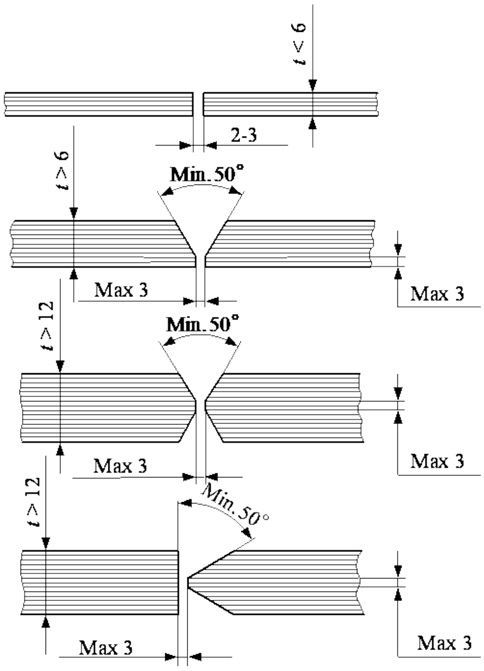
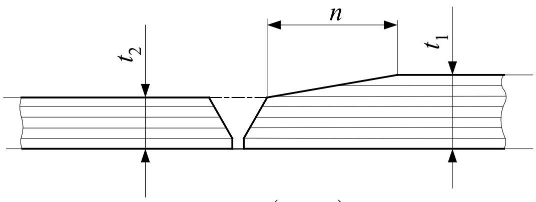


Fig. 4.2.1.1 Edge preparation for manual butt welding

4.2.1.2 Where two butt-welded plates are different in thickness by more than 3 mm, the thickness of the thicker plate shall be reduced by bevelling not exceeding 1:3. Upon reduction of the thickness, the edges shall be prepared for welding like the plates of equal thickness (see Fig. 4.2.1.2).



$$n_{min} = 3(t_1 - t_2)$$

Fig. 4.2.1.2 Edge preparation for welding plates of different thickness

4.2.1.3 All types of butt welds shall be, in general, double side welded joints. Prior to welding the other side, the weld root shall be cut out to clean metal. In the case of butt joints of steel elements, the use of one-side welding on a ceramic backing and in the case of aluminium-alloy elements – on the stainless steel backing is permitted. Subject to PRS consent in each particular case, one side welding may be used, for low loaded structures or the structures where sealing weld is impracticable.

4.2.2 Lap and Slot Welds

4.2.2.1 Lap Welds

Lap welds, as shown in Fig. 4.2.2.1a may be used for welding brackets to ends of stiffeners for joints exposed to moderate stress, except the areas where increased vibration may be expected, while lap welds, as shown in Fig. 4.2.2.1b – for welding thin divisions having 3÷4 mm in thickness to aprons.

Lap welds shall be made as continuous welds at the perimeter taking α = 0.4 – see 4.2.3.1. Lap breadth, b, shall not be less than that determined in accordance with the following formula:

$$b = 2t + 20 \ \text{[mm]} \tag{4.2.2.1}$$

and not less than 30 mm, however it need not exceed 40 mm; t is the thinner element thickness, [mm].

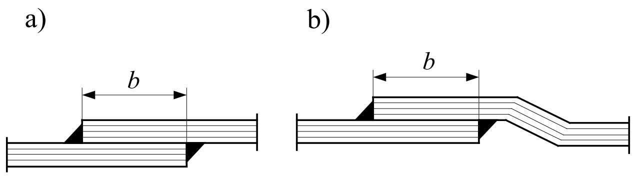


Fig. 4.2.2.1 Lap welds

4.2.2.2 Slot Welds

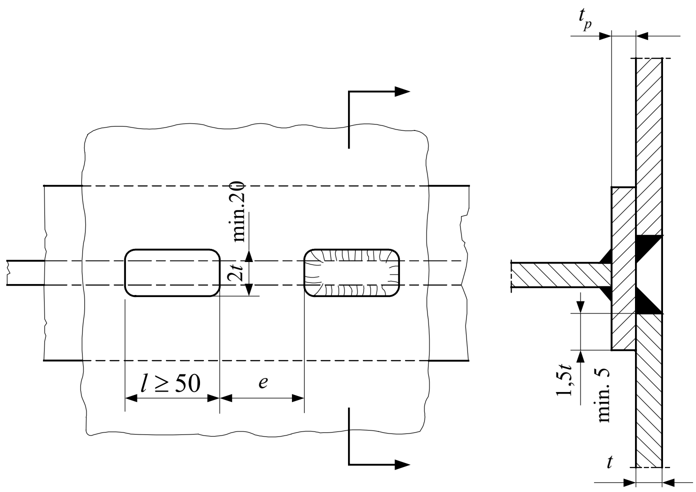


Fig. 4.2.2.2 Slot weld

Slot welds (see Fig. 4.2.2.2) may be applied for joining the plating and inner stiffeners using a permanent backing where fillet welding from the structure interior is impracticable.

Backing thickness, t_p, shall not be less than t. Weld thickness a = 0.7 t (see 4.2.3.1) shall be applied.

Typical slot weld shall have the dimensions as follows:
– slot length: l = 75 mm,
– slot spacing: $p = l + e$ = 150 mm,
– slot rounding radius: $R \geq$ 10 mm.

4.2.2.3 Pin Slot Welds

Conditions for the application of pin slot welds (see Fig. 4.2.2.3), slot dimensions, spacing and radius R are the same as for a slot weld shown in Fig. 4.2.2.2. The pin shall be welded around through the full plate thickness, and then the portion protruding above the plate shall be cut off.

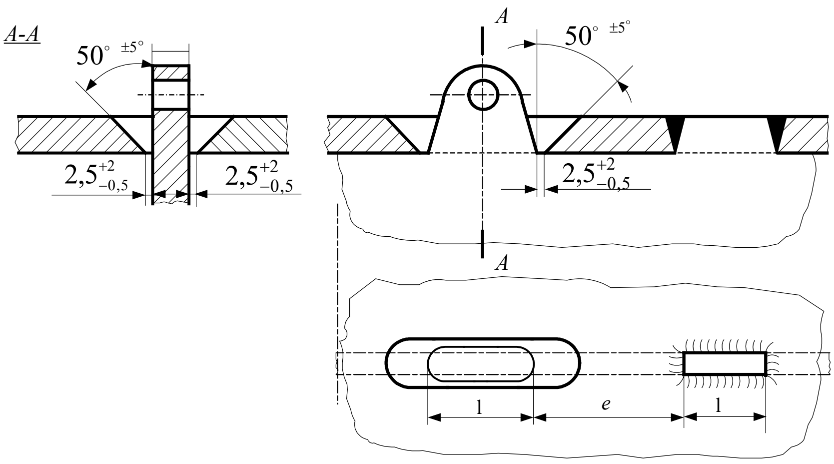


Fig. 4.2.2.3 Pin slot weld

4.2.2.4 Slot Welding on Backing

Slot welding on backing may be applied for joining the plating and inner stiffeners where fillet welding from the structure interior is impracticable. In the areas where increased vibration may be expected, slot welding on backing shall be applied instead of regular slot welding or pin slot welding. Backing thickness shall fulfil the condition that $t_p \geq t$ (see Fig. 4.2.2.4) and the weld shall have thickness $a \geq 0.7t$.

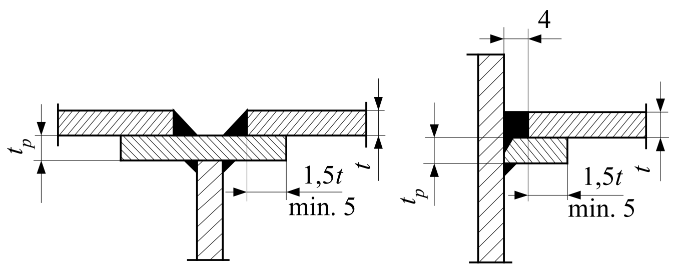


Fig. 4.2.2.4 Slot Welding on Backing

4.2.3 Fillet Welds

4.2.3.1 Design thickness *a* of fillet welds (see Fig. 4.2.3.1-1) made manually or using a semi-automatic procedure shall not be less than the value determined in accordance with the following formula:

$$a = \alpha\beta t \qquad (4.2.3.1)$$

where:

α – weld strength coefficient in accordance with Table 4.2.3.1-1;
β – coefficient determined in accordance with Table 4.2.3.1-2;
t – thinner component thickness, [mm].

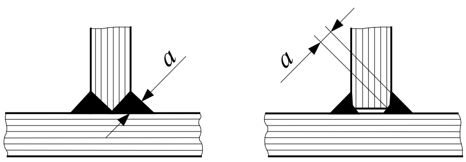


Fig. 4.2.3.1-1 Fillet weld thickness

Fillet weld thickness a shall not be less than:
2.0 mm for $t \leq 4.0$ mm,
2.5 mm for $4.0 < t \leq 6.5$ mm,
3.0 mm for $6.5 < t \leq 8.0$ mm,
3.5 mm for $8.0 < t \leq 15.0$ mm,
0.25 t for t > 15 mm.

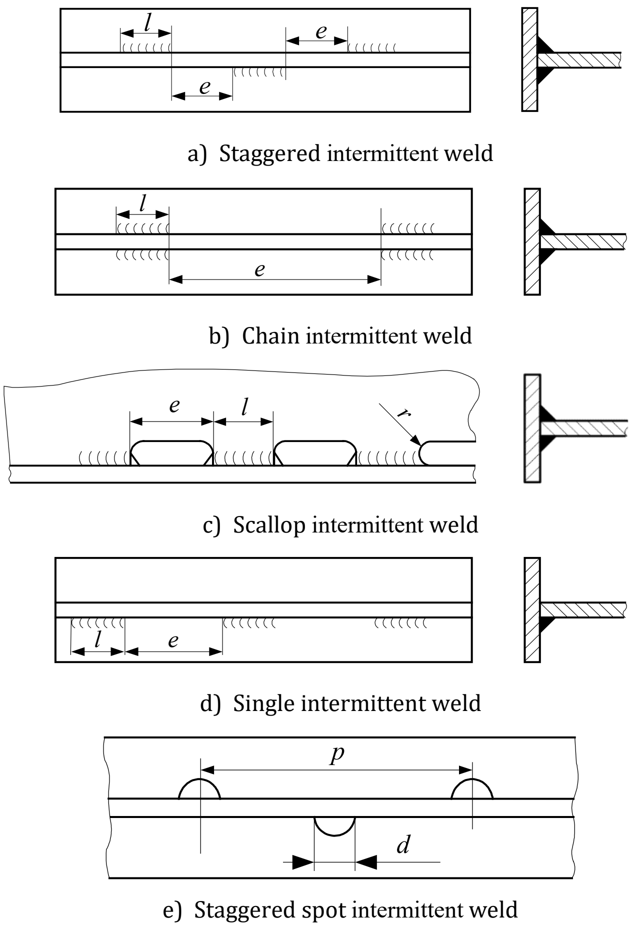


Fig. 4.2.3.1-2 Types of intermittent fillet welds

Table 4.2.3.1-1
Coefficient α

Item	Connection definition	α 1)
1	**Bottom structure**	
1.1	Central girder to keel plate	0.40
1.2	Central girder to bar keel	0.25
1.3	Floors to central girders under engines, thrust bearings and within $0.25L_0$ aft of the fore perpendicular	0.35
1.4	Above specified joints in remaining areas	0.35
1.5	Floors and webs of side bottom stringers to the outer bottom plating under machinery and thrust bearings as well as after perpendicular	0.30
1.6	Above specified joints in the remaining areas	0.25
1.7	Watertight floors and parts of bottom girders forming boundaries of tanks, walls and bottoms of scupper wells to each other, to outer bottom plating, to floors and to side bottom stringers	0.30

Item	Connection definition	α [1)]
1.8	Floors and webs of side bottom stringers to their face plates under engines and thrust bearings as well as after perpendicular	0,25
1.9	Above specified joints in remaining areas	0.20
2	**Side framing**	
2.1	Frames, web frames and side stringers to shell plating within 0.25 L_0 from the fore perpendicular, in tanks, in machinery space, in way of ice strengthening as well as in the area of side reinforcements in ships intended for mooring at sea	0.17
2.2	Above specified joints in the remaining areas	0.13
2.3	Frames, web frames and side stringers to their webs in the areas specified in 2.1	0.13
2.4	Above specified joints in the remaining areas	0.10
2.5	Frames, web frames and side stringers to shell plating in the after perpendicular	0.25
2.6	Above specified members to their webs	0.17
2.7	Side stringers to web frames	0.25
2.8	Tank side brackets to floor webs	0.30 [2]
2.9	Above specified elements to frames	0.25
3	**Deck and deck framing**	
3.1	Transverse and longitudinal deck girders to plating	0.17
3.2	Above specified members to their face plates	0.13
3.3	Webs of deck transverses to deck stringers and bulkheads	0.25
3.4	Deck beams and stiffeners in way of after peak tank and fore peak tank	0.15
3.5	Above specified joints in remaining areas	0.10
3.6	Stringer plate of strength deck to shell plating	0.45 [3]
3.7	Other decks and platforms to shell plating	0.35 [4]
3.8	Hatch coamings to deck at hatch corners	0.40 [3, 4]
3.9	Above specified joints in remaining areas	0.35 [3, 4]
3.10	Face bars of hatch coamings to coamings	0.25
3.11	Outer walls and bulkheads of superstructures and deckhouses to upper deck	0.35 [3, 4]
3.12	Above specified elements to inner decks	0.30 [4]
3.13	Other walls and bulkheads of superstructures and deckhouses to deck	0.25
3.14	Pillars to webs of the following: floors, bottom girders, deck girders as well as pillars to decks and other members	0.35 [3]
3.15	Brackets of pillars	0.35
3.16	Bulwark stiffeners to bulwark plates	0.20
3.17	Bulwark stiffeners to bulwark rail	0.30
4	**Bulkheads and partitions**	
4.1	Collision bulkhead, after peak bulkhead, bulkheads forming boundaries of tanks – at the perimeter	0,30 [4]
4.2	Other watertight bulkheads to bottom plating	0.30 [4]
4.3	Above specified elements to ship sides and deck	0.25 [4]
4.4	Vertical and horizontal girders to plating of bulkheads and wash bulkheads – in peaks	0.30 [4]
4.5	Above specified joints in remaining areas	0.17
4.6	Elements specified above in 4.4. and 4.5 – to their flange plates	0.13
4.7	Bulkhead stiffeners to plating	0.15
4.8	Transverse bulkheads to longitudinal bulkheads	0.35 [4]
5	**Foundations of main machinery**	
5.1	Web plates of foundations to shell plating, tank top and deck	0.35 [5]
5.2	Web plates of foundations to their face plates	0.45 [3]
5.3	Foundation brackets to foundation web plates, outer plating, bottom and deck	0.35 [5]
5.4	Brackets to their face plates	0.25

Item	Connection definition	α [1)]
6	**Other joints**	
6.1	Ends of girders within 0.15 of their span from the supporting points	0.25
6.2	Joints of members to structure webs on which they are cut	0.35 [3, 4]
6.3	Brackets joining framing components together	0.35 [2]
6.4	Joints of regular stiffeners to member webs in way of stiffener supporting points by member webs	0.35 [4]

[1] All joints of watertight structures shall be made with double continuous weld.
[2] Fillet welds joining flange plates of framing components to webs shall have, throughout the bracket arm length, thickness determined for α = 0.35.
[3] Full penetration welds shall be used (see Fig. 4.2.3.1-1).
[4] Double continuous weld is required.
[5] For main machinery foundations, full penetration welds shall be used (see Fig. 4.2.3.1-1). Ship hull structure members under webs of foundation stiffeners, members and brackets shall be joined to bottom and decks with double continuous weld having thickness determined for α = 0.35.

Table 4.2.3.1-2
Coefficient β

Item	Type of fillet weld	β
1	Double continuous weld	1.0
2	Staggered weld, chain weld and scallop weld	$\frac{l+e}{l}$
3	Single continuous weld	2.0
4	Single intermittent weld	$2.0\ \frac{l+e}{l}$

e – gap between welds (see Fig. 4.2.3.1-2);
l – weld length (see Fig. 4.2.3.1-2);
$p = l + e$ – weld pitch.

4.2.3.2 Intermittent welds (see Fig. 4.2.3.1-2) may be used for less loaded joints – inside dry spaces. In tanks, continuous or scalloped double welds (see 4.2.3.5) shall be used.

4.2.3.3 Scallops shall be welded at the perimeter over length l (see Fig. 4.2.3.1-e). Scallops in frames, The distance from scallops of frames, deck beams, stiffeners, etc. to the ends of these elements and supports (decks, longitudinal deck girders, longitudinal bulkhead girders) shall not be less than double depth of the stiffener section, and the distance to the bracket ends shall be at least equal to the value resulting from Fig. 4.2.3.8-1.

4.2.3.4 Length of intermittent weld l (see Fig. 4.2.3.1-2) shall not be less than 15a, however at least 50 mm. Distance e between the weld sections shall not exceed 25t or 150 mm whichever is lesser (t – thickness of the thinner element, [mm]). The depth of scallops shall be in accordance with the requirements specified in 3.5.1.4, and the scallop length shall not exceed the weld length, i.e. e ≤ l (see Fig. 4.2.3.1-2-c).

4.2.3.5 Inside ballast, cargo or fresh water tanks, inside the spaces where water may be accumulated or condensed, as well as inside empty spaces exposed to corrosion (such as rudder blades), continuous welds shall be applied for heavy or dynamically loaded joints.

Double continuous welds are required:

– for watertight, oiltight and weathertight joints;
– within 0.25 L_0 from the fore perpendicular – for welding structural members to the bottom plating;

– within ice belt of ships with ice strengthening;
– for welding side framing to the outer plating;
– in the area of pillars and at the ends of structural elements;
– in machinery foundation and supporting structures;
– for all joints in the after peak;
– for joints inside the rudder blade, except the cases where slot welding or pin slot welding is necessary;
– for connecting bottom central girder to the keel plate.

4.2.3.6 In heavy loaded joints, the plate edges shall be bevelled to ensure full penetration or deep fusion weld. The following joints shall be welded with full penetration:
– strength deck stringer to sheer strake,
– in way of machinery foundations (see Table 4.2.3.1-1),
– hatch coamings with deck at hatch corners,
– rudder horns and propeller shaft brackets to shell plating,
– rudder blade plating to the flange connecting the rudder blade with rudder stock.

4.2.3.7 Structural elements and parts of members cut at the plating or at the crossing structures shall be coplanar. The maximum shift of the planes of interrupted structural elements and members (see Fig. 4.2.3.7) shall not be greater than half the thickness of the thinner element, and for heavy loaded joints – not more than one third of the thinner element. Shift c_1 shall not exceed that determined in Fig. 4.2.3.7.

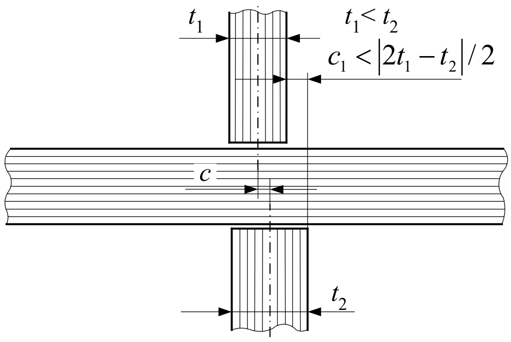
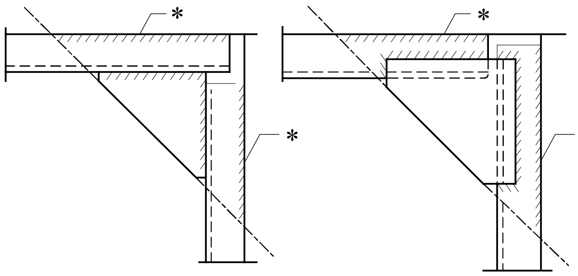


Fig. 4.2.3.7 Shift of the planes of interrupted structural elements and members

If continuity of the members is achieved through their direct welding to the webs or plates of the structure on which they are interrupted, then the weld thickness shall be determined depending on the interrupted member thickness or welding shall be performed with the edge preparation.

4.2.3.8 Double continuous welds shall be used in the area of pillars, at ends of structural members and at the places where supporting members (transverse and longitudinal deck girders, floors, etc.) pass through structural members. The length of double continuous weld sections (see Figures 4.2.3.8-1 and 4.2.3.8-2) shall not be less than:
– bracket length;
– double depth of element – where brackets are not applied;
– member depth on both sides of the intersection of members.



* - double continuous weld

Fig. 4.2.3.8-1 Minimum range of double continuous welding in way of bracket

l – weld length equal to the frame girder depth

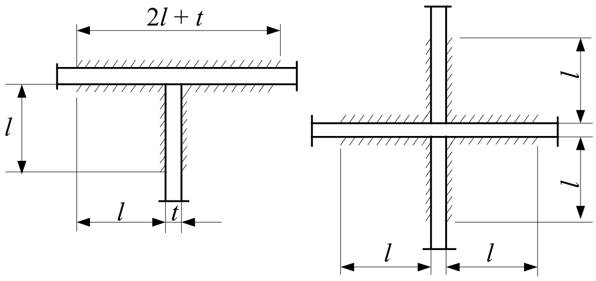


Fig. 4.2.3.8-2
Minimum range of double continuous welding in way of intersection of members

4.2.3.9 Staggered spot welds, as well as single intermittent welds may be applied for joints in the second and higher tier of superstructures and deckhouses, as well as for elements in enclosed deck areas in the first tier of superstructures.

4.2.3.10 Where the thickness of section (plate) with extruded or corrugated stiffeners is less than 5 mm, spot welds may be used for joints in structures of casings and walls in these areas of hull, where neither variable nor impact loads nor strong corrosive agents occur.

4.2.3.11 Intermittent welds shall not be used:
– in the areas where increased vibration may be expected (see 3.4.2.3);
– for welding structural members to the bottom plating – within 0.25 L_0 from the fore perpendicular.

4.2.3.12 Single continuous welds shall not be used:
– within 0.20 L_0 from the fore perpendicular for welding side framing and within 0.25 L_0 from the fore perpendicular – for welding side framing to the bottom plating;
– in the areas where increased vibration may be expected (see 3.4.2.3);
– in joints subjected to high tensile and bending loads;
– in joints where the angle between the section web and plate differs from the right angle by more than 10°.

4.2.3.13 Scallop welding shall not be used:
– in the fore end of ship within 0.20 L_0 from the fore perpendicular for welding side framing and within 0.25 L_0 from the fore perpendicular – for welding bottom framing;
– for welding side framing and bottom framing members in way of ice belt as well as side framing in ships intended for mooring at sea to other ships or facilities;
– in the areas where increased vibration may be expected (see 3.4.2.3).

4.2.3.14 In way of cuts made to provide for air circulation or in way of penetration of sections or weld seams through non-watertight members, fillet welds shall be double welded having at least 50 mm in length in way of the cut edges.

4.2.3.15 For welding aluminium alloy components the following requirements shall be taken into account:
- intermittent welds shall not be used (except for scallop welding) in T-joints specified in Table 4.2.3.1-1;
- scallop welds shall not be used in the areas where increased vibration may be expected;
- fillet weld thickness shall not be less than 2 mm and shall not exceed half the thickness of the thinner element.

4.3 End Connections of Structural Members

4.3.1 End connections of structural members shall be, in general, butt joints. Subject to PRS consent in each particular case, lap joints may be applied, except for:
- areas where increased vibration may be expected (see 3.4.2.3);
- joints of web frames and girders;
- areas subjected to great concentrated loads.

4.3.2 Stiffeners of any kind shall be terminated with brackets in accordance with the requirements specified in 12.9.2. In special cases, bracketless connection may be permitted (see 12.9.2.1).

4.3.3 Connections of plating stiffeners with coplanar structural members or brackets (e.g. connections of lower frame ends to bilge keels or single bottom floors) shall be arranged in accordance with one of the patterns shown in Fig. 4.3.3-1. In double-skin structures (e.g. double bottom), bracket connection as shown in Fig. 4.3.3-2 shall be used.

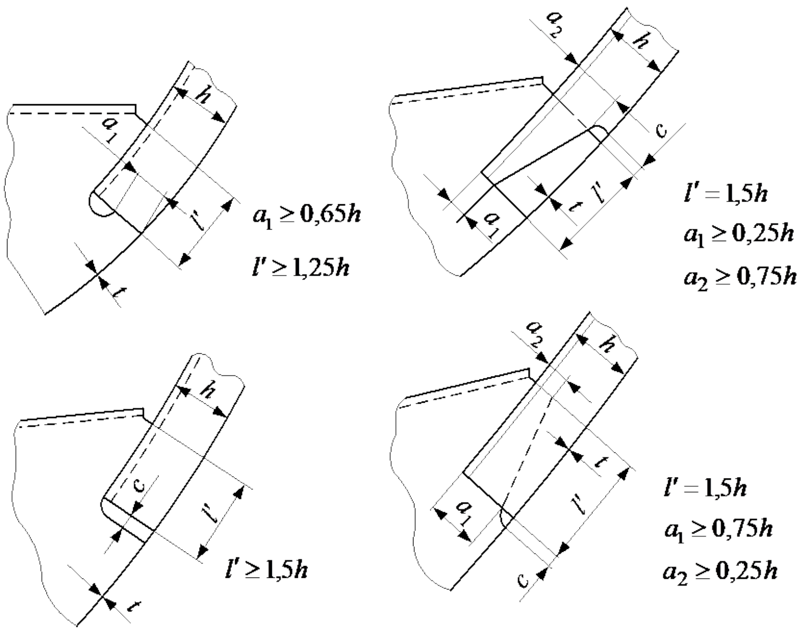


Fig. 4.3.3-1 Connection of plating stiffener termination

Dimension *c* indicated in Fig. 4.3.3-1 shall exceed neither 30 mm nor 5 *t* (*t* – plating thickness).

The dimensions indicated in Fig. 4.3.3-2 shall fulfil the following conditions:
$c \geq 1.5\ h$, however not less than 90 mm
$c_1 \geq 0.1l$
$e \leq 30$ mm

where:
l – stiffener span determined in accordance with 3.2.1.1;
t – bracket thickness as required in 12.9.2.6.

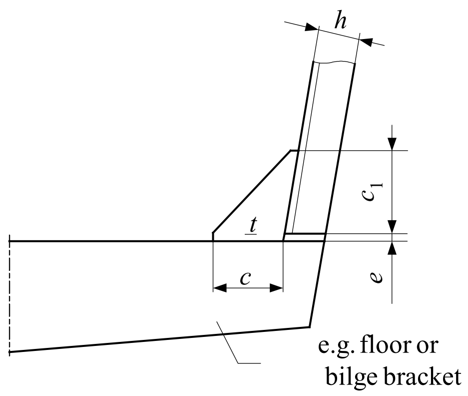


Fig. 4.3.3-2 Connection of lower frame termination in ship with double bottom

4.3.4 Corners of the webs of frames, sections, brackets and divisions in non-watertight structures shall be cut as shown in Fig. 4.3.4.

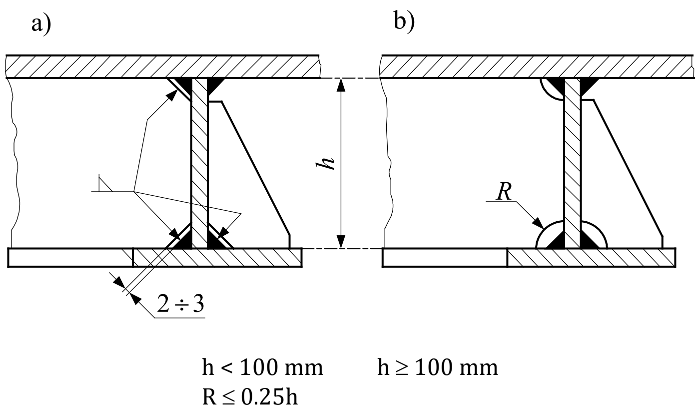


Fig. 4.3.4 Corner cuts of webs, brackets and divisions

4.3.5 Depending upon the design of the detail, the ends of face plates and/or webs of the structural members shall be snipped at ends over a length equal to 1.5 times the face plate width or 1.5 times the web depth. The blunting at the snipped free end shall be as follows:
– for face plate – equal to web thickness increased by 20 mm,
– for web – 10 ÷ 15 mm.

4.3.6 Connection of regular stiffeners to girder web plates where stiffeners are supported by girder shall be made with double continuous fillet weld having thickness determined in accordance with 4.2.3.1 for $\alpha = 0.35$.

Recommended patterns of the above mentioned connections are shown in Fig. 4.3.6.

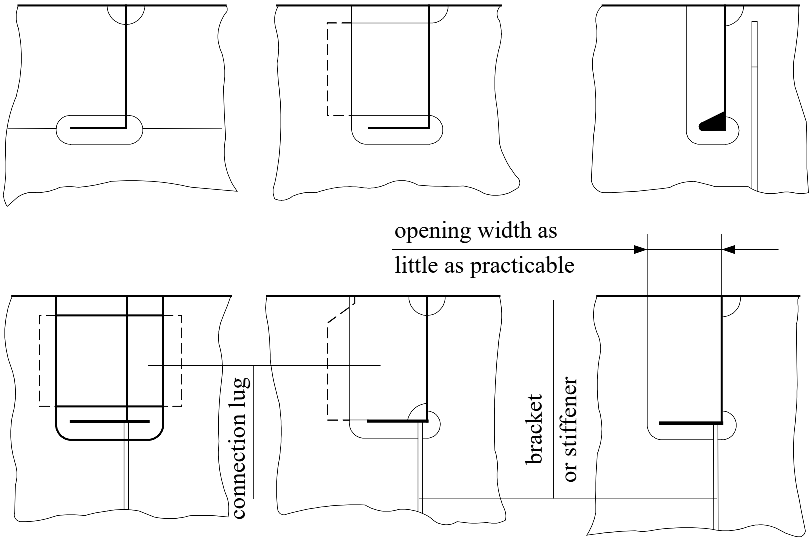


Fig. 4.3.6 Connection of stiffener to girder web plate

4.4 Connection of Aluminium Alloy Structure and Steel Structure

4.4.1 Connections of aluminium-alloy structure with steel structure shall be made with a bimetal bar (steel-aluminium fastener) having a width not less than 24 mm, and for a tubular pillar – with a disk, square or rectangle with rounded corners to be mechanically cut from a bimetallic plate of a minimum diameter (width/length) equal to the pillar diameter (width/length) increased by 25 mm.

4.4.2 In the case of typical connection of an aluminium-alloy structure (superstructure, deckhouse, bulwark, windscreen, wave breaker, etc.) with connection lug put on the lower steel structure, an aluminium-alloy structure shall be fixed from outside with two rows of bolts or rivets to the vertical steel plate of 150 ÷ 200 mm in height.

4.4.3 To prevent galvanic corrosion, a non-hygroscopic insulant, non-metallic distance sleeves or stainless steel bolts (made of A4 steel grade, acc. to ISO, of a strength class not less than 70 – AISI type 316L) shall be used between steel and aluminium-alloy structures.

The spacing of bolts or rivets shall not exceed their quadruple diameter.

5 BOTTOM STRUCTURES

5.1 General

The requirements specified in this chapter apply to the single bottom structures with transverse stiffening. For single bottom with longitudinal stiffening or double bottom, the bottom structure is subject to PRS consideration in each particular case.

5.2 Structural Arrangement

5.2.1 Arrangement of Bottom Girders

5.2.1.1 Bottom Centre Girder

5.2.1.1.1 Bottom centre girder shall, in general, extend throughout the ship length. It shall extend fore and aft as far as practicable. It may be continuous or cut at floors.

5.2.1.1.2 In the machinery space, the bottom centre girder may be waived if the main engine foundation members extend from the fore bulkhead to the after bulkhead of the machinery space and these members are terminated with brackets.

5.2.1.1.3 Outside the bulkhead to which the bottom centre girder extends, such girder shall be terminated by a bracket having an arm length equal to double depth of this girder, however not less than double frame spacing.

The above requirement also applies to the termination of main engine foundation longitudinals.

5.2.1.2 Arrangement of Bottom Side Girders

5.2.1.2.1 Intercostal side girders shall be used if the distance between the bottom centre girder and the ship side exceeds 2.2 m.

5.2.1.2.2 In the forebody within 0,25L0 from the forward perpendicular, the spacing between longitudinals shall not exceed 1.1 m. Bottom side girders shall extend as far as practicable forward.

5.2.1.2.3 In justified cases, PRS may waive the requirement for bottom side girders.

5.2.1.3 Floors

Floors shall be used at each frame. Other design solutions (e.g. longitudinally stiffened bottom) are subject to PRS consideration in each particular case.

5.2.2 Manholes, Holes and Cut-outs

5.2.2.1 Maximum depth (diameter) of all holes (including lightening holes) in floors and girders shall not exceed half the depth of these members, and for the bottom centre girder – 0.4 of its depth in the relevant section.

5.2.2.2 Distance between edges of two adjacent holes shall not be less than half the breadth of the greater hole.

5.2.2.3 Dimensions of all the intended holes shall be indicated on the drawings submitted to PRS for consideration.

5.2.2.4 Holes shall not be cut in:

– bottom side girders and floors in the immediate vicinity of supports;
– bottom centre girder and in side girders in the immediate vicinity of bulkheads;
– floors in areas adjacent to the side girders and centre girder (the distance between the hole edge and members shall not be less than half the depth of the bottom centre girder, and in the wing – it shall not be less than twice the depth of frame including the bracket);
– in floors – in way of toes of transverse brackets supporting seatings of the main machinery.

5.2.2.5 Exceptionally, openings may be cut in the members mentioned in 5.2.2.4 if such members are reinforced by either by a flat bar welded on the whole perimeter or by a stiffener in the immediate vicinity of the hole.

5.2.2.6 Holes cut in floors shall not have a height (diameter) exceeding half the floor depth in the relevant section. The distance between the hole edge and the floor flange plate shall not be less than a quarter of the floor depth in the relevant section. The distance between the edges of adjacent holes shall not be less than the floor depth.

5.2.2.7 Floor plates in which holes are cut shall be reinforced by vertical stiffeners of a thickness not less than 0.8 times the floor thickness and width about 10 times the floor thickness. Other equivalent reinforcements of the structure are permitted.

5.2.2.8 In the floors, holes shall be provided for the carried liquid flow.

5.3 Scantlings of Structural Members

5.3.1 Plating

5.3.1.1 Bottom plating thickness in the midship portion, within $0.5L_0$ (i.e. in the interval: $-0.25L_0 < x < 0.25L_0$), shall not be less than that determined in accordance with 12.3.2 and 12.5.2, however not less than:

$$t_d = Ka\left(0.7 + 0.1\frac{\sqrt{LT}}{H}\right) \text{ [mm]} \qquad (5.3.1.1)$$

where:
$K = 10.5 + 0.1L_0$,
a – spacing of transverse members, [m], (see 12.2.2).

It is assumed that the bottom plating extends to the level located at distance r_c from the base plane (see Fig. 5.3.1.1).

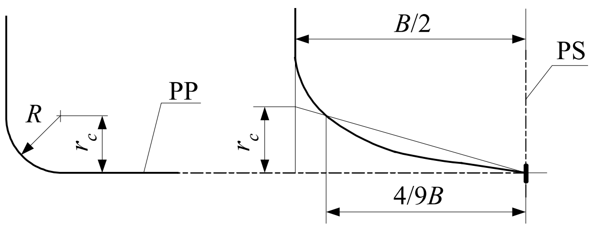


Fig. 5.3.1.1 Determining of r_c (bilge height)

5.3.1.2 Bottom plating thickness in restricted service ships may be reduced by 5% for operating area II and by 10% for operating area III. However, the minimum thicknesses specified in 12.3.2 remain in force.

5.3.1.3 Keel plate thickness within 0.15L0 from the after perpendicular may be lesser by 1 mm than that in the midship portion of the ship.

5.3.1.4 Breadth, b, of the sand strake (plating panel in the immediate vicinity of the bar keel) shall not be less than:

$$b = 300 + 2.5\,L_0 \text{ [mm]} \qquad (5.3.1.4)$$

5.3.1.5 Sand strake thickness within 0.7L0 from the forward perpendicular shall be greater by 1 mm than the bottom plating thickness in the midship portion of the ship as determined in accordance with 5.3.1.1.

5.3.1.6 Bilge strake thickness (up to the top boundary of curvature as shown in Fig. 5.3.1.1) shall be taken equal to the bottom plating thickness.

5.3.1.7 Bottom plating thickness in the forebody and afterbody, within $0.25L_0$ from the forward and after perpendiculars, shall not be less that that determined in accordance with 12.3.2 and 12.5.2.

5.3.2 Bottom Girders

5.3.2.1 Bottom Centre Girder

5.3.2.1.1 Height of centre girder and attached plate floors shall not be less than that required for floors in the centre plane (see 5.3.2.3.1).

5.3.2.1.2 Thickness of the bottom centre girder plates in the midship portion of the ship, t, shall not be taken less than:

$$t = 0.06L_0 + 4.0 \text{ [mm]} \tag{5.3.2.1.2}$$

At the ship ends, within $0.1L_0$ from the perpendiculars, the bottom centre girder thickness may be less than that determined above by 2 mm.

5.3.2.1.3 Face plate of the bottom centre girder shall be connected to the face plates of floors where the bottom centre girder and the floors are of the same height (see Fig. 3.3.3). Where the bottom centre girder is higher than the floors in the centre plane, proper design solutions shall be applied to ensure structural continuity of the floors' face plates.

5.3.2.1.4 Cross-sectional area of the bottom centre girder shall be at least twice the cross-sectional area of the floor face plate. The face plate thickness shall exceed the thickness of the bottom centre girder web by at least 2 mm.

5.3.2.1.5 The bottom centre girder web and its face plate shall be welded to bulkheads and vertical brackets with flange or face plate on their free edge shall be applied at bulkheads. The height of brackets shall not be less than half the bottom centre girder height.

5.3.2.1.6 If the face plate is not welded to the bulkhead, the bracket height shall not be less than the bottom centre girder height.

5.3.2.1.7 The bracket length shall not be less than the bottom centre girder height.

5.3.2.1.8 As an alternative to using brackets, the face plate of at least double width may be used in way of its contact with the bulkhead provided that a member which forms the face plate extension is behind such a bulkhead.

5.3.2.2 Bottom Side Girders

5.3.2.2.1 Plate thickness of single bottom side girders, t, in the midship portion of the ship shall not be less than:

$$t = 0.05L_0 + 4.0 \text{ [mm]} \tag{5.3.2.2.1}$$

5.3.2.2.2 Thickness of bottom side girders within 0.1L0 from the perpendiculars may be less, by 1 mm, than that required in the midship portion of the ship.

5.3.2.2.3 Cross-sectional area of the bottom side girders shall not be less than that of the floor face plates.

5.3.2.2.4 Face plate thickness of the bottom side girders shall exceed the web thickness by 2 mm, however it need not exceed the floor face plate thickness.

5.3.2.2.5 Bottom side girder face plates shall be welded to the floor face plates.

5.3.2.2.6 Construction of the bottom side girders in way of their ends shall be the same as the construction of the bottom centre girder end (see 5.2.1.1.3). Holes and cuts shall be provided in the bottom side girders to enable flow of liquid carried in the tank.

5.3.2.2.7 Outside the portion of 0.25L0 from FP, bottom side girders made of T-bars or other sections laid on the floors and welded to the floor face plates are permitted. Cross-sectional area of such side girders, *S*, shall not be less than that determined in accordance with the following formula:

$$S = 0.7(B + 10)\ [\text{cm}^2] \qquad (5.3.2.2.7)$$

5.3.2.2.8 Connections of the bottom side girders to transverse bulkheads shall be in accordance with the requirements specified in paragraphs 5.3.2.1.5 to 5.3.2.1.8.

5.3.2.2.9 Rolled sections forming bottom side girders (laid on the floors) shall be welded to bulkheads using brackets having an arm length equal not less than depth of such rolled sections.

5.3.2.3 Floors

5.3.2.3.1 Floor height in the centre plane, h_d, shall not be less than:

$$h_d = 0.055B_1\ [\text{m}] \qquad (5.3.2.3.1)$$

B_1 – breadth of ship in the relevant cross-section at the floor face plate level, [m].

5.3.2.3.2 In the distance equal to 3/8 of breadth of ship B_1 (see 5.3.2.3.1), measured from the centre plane, the floor depth shall be at least 50% of the depth required in the centre plane. In special cases, PRS may approve relaxations from this requirement provided that an adequate cross-sectional area is maintained taking account of the shear strength.

Within 0,05*B*, [m], from the ship sides, the floor web cross-sectional area, *A*, shall not be less than:

$$A = 0.1B_1\,(B_1+7)\ [\text{cm}^2] \qquad (5.3.2.3.2)$$

5.3.2.3.3 Where bilge brackets are applied, their cross-sectional area may be taken into account for determining area *A* in accordance with formula 5.3.2.3.2.

5.3.2.3.4 Floor thickness, *t*, shall not be less than:

$$t = 0.02ah_d + 2\ [\text{mm}] \qquad (5.3.2.3.4)$$

where:
h_d – floor depth in the centre plane, [mm], (see formula 5.3.2.3.1);
a – floor spacing, [m],

however it need not exceed the plate thickness.

5.3.2.3.5 Floor sectional modulus, *W*, shall not be less than:

$$W = KaT_1 B_1^2\ [\text{cm}^3] \qquad (5.3.2.3.5)$$

K = 7.0 – 0.2B_1;
a – floor spacing, [m];
T_1 – ship draught, however a value not less than 0.65*H* shall be taken for calculations, [m];
B_1 – see 5.3.2.3.1.

5.3.2.3.6 Cross-sectional area of the face plate of floor having thickness determined in accordance with formula 5.3.2.3.1 shall not be less than:

– in cargo spaces: $A = 3.5T$ [cm^2] (5.3.2.3.6-1)
– within the machinery space: $A = 5.0T$ [cm^2] (5.3.2.3.6-2)

5.3.2.3.7 Floor face plate thickness shall exceed its web thickness by 1 mm. The face plate width shall not be less than 50 mm.

In ships with a length $L_0 < 10$ m the floor face plate width of 40 mm is permitted.

5.3.2.3.8 Floor sectional modulus under the engine foundations shall be at least twice as great as that required in 5.3.2.3.5.

5.3.2.3.9 If floors are interrupted on the bottom centre girder, their webs shall be welded to the bottom centre girder web.

5.3.2.3.10 Floor face plates shall be connected to the bottom centre girder face plate by means of the butt weld and the floor face plate width shall be doubled in way of its connection to the bottom centre girder face plate.

5.3.2.3.11 Floor face plate may be replaced by the flange provided the floor sectional modulus is increased by 5%; the flange shall be at least ten times as wide as the floor web thickness. Flanged floors shall not be applied in the machinery space and after peak.

5.3.2.3.12 In the cargo space, frames shall be connected to floors in accordance with the requirements specified in 4.3.3.

5.3.2.3.13 Scantlings and construction of floors in peaks shall fulfil the requirements specified in 5.4.2 and 5.4.3.

5.3.2.3.14 Watertight and oiltight floors forming tank boundaries shall have thickness not less than that determined in accordance with 12.5.2, where p and σ shall be taken like for tank bulkheads.

5.3.3 Double Bottom Tanks

5.3.3.1 Double bottom tanks are understood as tanks located on the outer bottom plating whose height is equal to, or slightly exceeds, the bottom centre girder height.

5.3.3.2 Double bottom tanks shall fulfil the following requirements:
– thickness of the tank top plating shall not be less than that determined in accordance with 12.3.5 and 12.5.2 (where p and σ shall be taken like for tank bulkheads), however, it need not exceed the shell plating thickness in the relevant portion of the ship;
– if a floor or bottom girder forms the tank boundary, its thickness shall fulfil the requirements specified in 5.3.2.3.14;
– on the double bottom tank boundaries having more than 600 mm in height and situated within $0.25L_0$ aft of the forward perpendicular vertical stiffeners shall be used and their spacing shall not exceed 0.9 m. The stiffeners shall not have thickness less than 0.8 of the stiffened division thickness and their depth shall be around ten times the stiffener thickness.

5.3.4 Sea Chests

5.3.4.1 Thickness of floors and girders forming boundaries of the sea chest shall be greater, by 2 mm, than that required in 5.3.2.3.14, and the sea chest top plating thickness shall be greater, by 2 mm, than that required in 5.3.3.2.

5.3.4.2 In any case, the strength of the sea chest boundaries shall not be less than the local strength assumed for the outer plating arranged in the relevant portion of the ship.

5.3.4.3 Thickness of the sea chest boundaries shall also be greater, by 2 mm, than the minimum thickness required in 12.3.2 and 12.3.3 for the bottom or side shell plating.

5.3.5 Bilge Keel

5.3.5.1 Bilge keel shall be attached to the plating by an intermediate member (flat bar or angle bar). Weld connection of the bilge keel to the intermediate member shall have less strength than the member connection to the shell plating. The connection shall, however, be strong enough to maintain the bilge keel in normal service conditions which is particularly important where the bilge keel has been taken into account in the ship stability criterion check.

5.3.5.2 Bilge keel and the intermediate member shall be made of steel or aluminium alloy of the same yield point as the shell plating in way of the keel connection.

5.3.5.3 Bilge keel ends shall be smoothly rounded and shall be in line with inner supports of the hull – see Fig. 5.3.5.3.

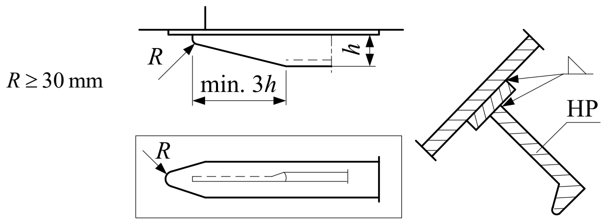


Fig. 5.3.5.3 Bilge keel

5.4 Bottom Strengthening in Forebody and Afterbody

5.4.1 Strengthening Extent

Additional strengthening provisions shall be made in the forebody and afterbody in accordance with the requirements specified in sub-chapters 5.4.2 to 5.4.6.

5.4.2 Bottom Strengthening in Forebody

5.4.2.1 Bottom strengthening shall be provided within 0.25L from FP in ships with flat bottom. The difference in thickness between the adjacent plating panels shall not exceed 2 mm.

5.4.2.2 Slamming pressure value, p_u, used to determine the bottom thickness (in accordance with 5.4.2.3) as well as the sectional modulus and cross-sectional area of the bottom stiffener webs (in accordance with 5.4.2.4 and 5.4.2.5) shall be calculated in accordance with the following formula:

$$p_u = 3.45L_0 \text{ [kPa]} \quad (5.4.2.2)$$

The above formula applies to the bottom forward portion within $0.25L_0$ from FP to the level of $z = 0.004L_0$ for the ship draught of $T > 0.025L_0$ at FP.

For the ship draught exceeding $0.025L_0$ at FP, the value of p_u for the above mentioned portion of the bottom shall be taken in accordance with Table 5.4.2.2.

Table 5.4.2.2
Values of p_u for $T \leq 0.025L_0$

T	$\leq 0.015L_0$	$0.0175L_0$	$0.020L_0$	$0.0225L_0$	$0.025L_0$
p_u [kPa]	$7.5L_0$	$5.90L_0$	$4.90L_0$	$3.90L_0$	$3.45L_0$

For intermediate values of T, pressure p_u shall be determined by linear interpolation.

5.4.2.3 Bottom plating thickness in the region defined in 5.4.2.1 and 5.4.2.2 shall not be less than the value determined in accordance with the following formula:

$$t_u = 15.8\, a k_l k_r \sqrt{\frac{p_u}{\sigma}} + C + t_k \text{ [mm]} \qquad (5.4.2.3\text{-}1)$$

k_1 – plating thickness reduction coefficient considering the plating panel sides' ratio b/a to be determined in accordance with the following formula:

$$k_1 = -0.22\left(\frac{b}{a}\right)^2 + 0.87\frac{b}{a} + 0.14 \qquad (5.4.2.3\text{-}2)$$

k_r – coefficient considering the curvature of plating panels (convex outside; for concave plating panels $k_r = 1$ shall be taken):

$$k_r = \left(1 - 0.5\frac{s}{r}\right) \qquad (5.4.2.3\text{-}3)$$

r – plating panel curvature radius, [m];
s – spacing between stiffening measured along the plating, [m];
p_u – slamming pressure, determined in accordance with 5.4.2.2, [kPa];
a – length of the shorter side of bottom plating panel, [m];
b – length of the longer side of bottom plating panel, [m];
σ = 160k [MPa] – allowable stress;
C = 1.25 [mm]– for $L_0 \leq 15.0$ m,

C = 1.7 [mm] – for 15.0 m < $L_0 \leq 24.0$ m

In the ship portion of $x < 0.25L_0$, the thickness of bottom plating panels shall be gradually reduced to the values required in 5.3.1.1 taking account of the limitation specified in 5.4.2.1.

5.4.2.4 Sectional modulus of additional bottom longitudinal members and plate floors which may be applied in the region defined in 5.4.2.1 shall not be less than:

$$W = \frac{1000 a_1 p_u l^2}{m\sigma} \quad \text{[cm}^3\text{]} \qquad (5.4.2.4)$$

where:
a_1 – spacing of additional bottom longitudinal members and plate floors, [m];
l – span of additional bottom longitudinal members (spacing of floors or taken in accordance with the requirements specified in 3.2.1.1), [m];
p_u – slamming pressure, determined in accordance with 5.4.2.2, [kPa];
$\sigma = 190k$ [MPa] – allowable stress;
m = 11.8 – for uninterrupted bottom longitudinal members penetrating floors or longitudinal members interrupted at floors without brackets installed,
m = 22.5 – for longitudinal members interrupted at floors with their ends connected to floors with brackets having an arm length not less than 1.5 their web height,
m = 6.3 – to determine sectional modulus connecting interrupted longitudinal member to the floor.

5.4.2.5 Cross-sectional area of the additional bottom longitudinal member or cross-sectional area of the welds connecting interrupted longitudinal members to the floor shall not be less than:

$$A = \frac{K_A a_1 p_u l}{\tau} \text{ [cm}^2\text{]} \qquad (5.4.2.5)$$

K_A = 6.1 – for uninterrupted bottom longitudinal members penetrating floors or longitudinal members interrupted at floors without brackets installed;

K_A = 4.7 – for uninterrupted bottom longitudinal members penetrating floors or longitudinal members interrupted at floors but in both cases having their ends connected to floors with brackets having an arm length not less than 1.5 time the member section height;

$\tau = 110k$ [MPa] – allowable shear stress;

a_1, p_u, l – see 5.4.2.4.

5.4.2.6 Floor spacing shall fulfil the requirements specified in 12.2.2.3 and 12.2.2.4. Floor height, h_{dd}, in the fore peak shall not be less than:

$$h_{dd} = 1.5h_d \qquad (5.4.2.6)$$

h_d – prescribed floor height in the centre plane amidships, [m].

5.4.2.7 Floor web thickness within 0.25L0 from FP shall not be less than the amidship thickness of floors having the prescribed height, however not less than 4.0 mm.

5.4.2.8 Floor face plate thickness in the hull portion defined in 5.4.2.7 shall not be less than the floor thickness and width – not less than their tenfold thickness, however not less than 50 mm.

5.4.2.9 Flanged floors shall not be applied in the fore peak.

5.4.2.10 In the fore peak, an intercostal girder with face plate shall be applied in the centre plane to form an extension of the bottom centre girder.

5.4.2.11 Height and thickness of the bottom girder web in the centre plane as well as thickness and width of its face plate shall be such as determined in paragraphs 5.4.2.7 to 5.4.2.9 for floors.

5.4.2.12 Where application of the bottom centre girder in the fore peak is impossible, floor face plates shall be connected together in the centre plane with angle bar, or T-bar or another section having a flange of width and thickness not less than the scantlings of floor face plates required in 5.4.2.8.

5.4.3 After Peak

5.4.3.1 Floor spacing in the after peak shall fulfil the requirements specified in paragraphs 12.2.2.3 and 12.2.2.4.

5.4.3.2 Floor height shall fulfil the requirements specified in paragraph 5.4.2.6. In single-screw ships, the top edges of floors shall be at least 0.6 m above the stern tube. Floors shall have face plates in the after peak.

Openings in floors for the penetration by stern tube shall be reinforced by a flat bar welded on the whole circumference. Openings in floors under the stern tube shall be reinforced by a flat bar welded on the whole circumference or the floor shall be reinforced by stiffeners welded on in way of such an opening.

5.4.4 Stern Counter Reinforcements

5.4.4.1 Floors shall have sufficient height determined in accordance with the requirements specified in paragraphs 5.3.2.3.1 to 5.3.2.3.3, where B_1 represents the breadth of ship in the relevant frame section at the floor face plate level.

In the centre plane, an intercostal girder of the height equal to the floor height shall be applied.

5.4.4.2 Thickness of floors and the centre plane girder shall not be less than the floor thickness determined in accordance with the requirements specified in 5.3.2.3.4.

5.4.5 Afterbody Reinforcements

Plating panels adjacent to the stern tube as well as panels in way of fixing propeller bracket arms shall have a thickness not less than:

$$t = 0.1L_0, + 4.0 \text{ [mm]} \quad (5.4.5)$$

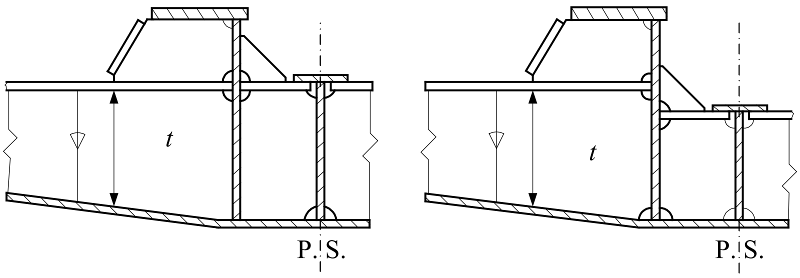
with the prescribed spacing of structural members in the afterbody in accordance with the requirements specified in paragraphs 12.2.2.1 to 12.2.2.4.

Plating inserts having increased thickness in way of the brackets shall extend:
- for at least double bracket thickness, however not less than 200 mm beyond each side of the bracket – transversely;
- for half the bracket length, however not less than 300 mm fore and aft of the bracket – longitudinally.

5.4.6 Bottom Reinforcements in Machinery Spaces

5.4.6.1 Thickness of floors and bottom side girders in machinery spaces shall not be less than the required thickness of the bottom centre girder specified in 5.3.2.1.2. If a bottom side girder also forms the engine foundation web, then its thickness shall not be less than that required in 11.2.1.3.

5.4.6.2 Floor height shall be increased with respect to the construction of foundations for engines and machinery (see Fig. 5.4.6.2). Floor web height between the foundation longitudinal members shall not be less than 0.65 the height required in the centre plane and the floor sectional modulus shall not be less than that required in 5.3.2.3.5 increased by 10%.



P.S. = centre plane

Fig. 5.4.6.2 Floors in way of foundations in machinery space

6 SIDE STRUCTURES

6.1 Openings in Side Shell

6.1.1 Openings in sheer strake shall be avoided in the midship portion of $0.5L_0$ in length (i.e. the interval: $-0.25L_0 < x < 0.25L_0$).

6.1.2 Where necessary, openings may be arranged in sheer strake for sidescuttles or for other purposes. The centre of such an opening shall be situated at a distance (measured from the top edge of the sheer strake or from the centres of other openings) equal to at least double diameter of such an opening and not less than the diameter of the larger diameter out of the adjacent openings. If the diameter of round openings in the sheer strake exceeds 20 times the sheer strake thickness, then such a opening shall be reinforced with horizontal stiffeners above and below it. Cross-sectional area of such stiffeners shall not be less than:

$$A = 0.7rt_1 \text{ [cm}^2\text{]} \quad (6.1.2)$$

where:
r – opening radius, [cm];
t_1 – sheer strake thickness, [cm].

6.1.3 Where the required width of the area for an opening exceeds the frame spacing, such an opening shall also be reinforced by vertical stiffeners having cross-sectional area as required in 6.1.2.

6.1.4 Horizontal reinforcements of the opening shall extend from its centre in both directions for a distance not less than the opening diameter and shall be welded to the closest frames.

6.1.5 Openings located below the sheer strake (e.g. openings for valves) shall have rounded corners and shall possibly not be situated in way of the curvature.

6.1.6 Corners of the openings mentioned in 6.1.1.5 shall have a radius not less than 50 mm. Construction of such openings is subject to PRS consent in each particular case.

6.2 Structural Arrangement

6.2.1 Fixing of Frame Ends and Span of Frames

6.2.1.1 Main frames shall be connected to floors in accordance with the requirements specified in 4.3.3. If lower bracket is applied, its height shall not be less than 0.1l; l – frame span (see Fig. 4.3.3-2 and Fig. 6.2.1.5 b and c).

6.2.1.2 Main frames shall be connected to deck beams in accordance with the requirements specified in 12.9.2. The frame upper bracket shall have a height not less than 0.07 l; l – frame span (see Fig. 6.2.1.5 b and c).

6.2.1.3 Upper ends of the 'tween deck frames, poop frames and forecastle frames shall be connected to deck beams with brackets in accordance with the requirements specified in sub-chapter 12.9.2.

6.2.1.4 Fixing of frame lower ends in poop and forecastle with anti-sweat flat bars having not less than 80 mm in width welded to the frame flanges and to the deck is permitted.

6.2.1.5 Main frame span and superstructure frame span necessary to calculate the required frame sectional modulus in accordance with 12.6.1 shall be determined in accordance with Fig. 6.2.1.5.

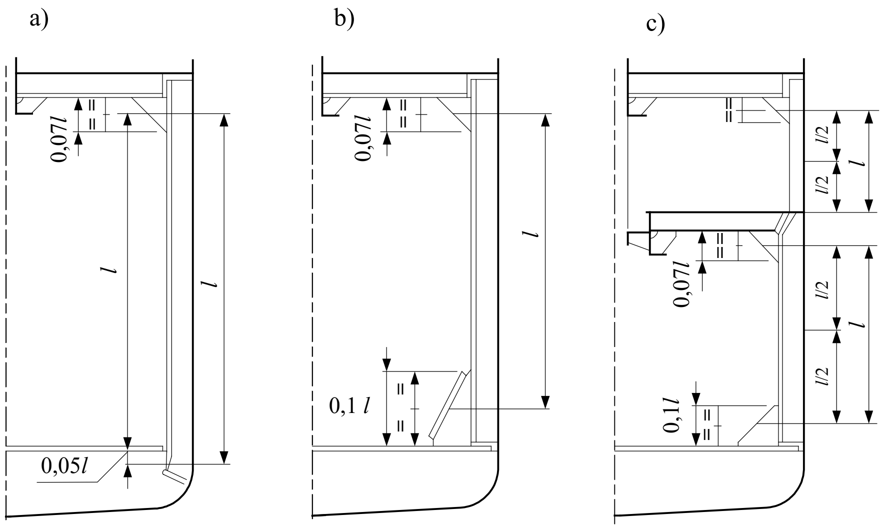


Fig. 6.2.1.5 Frame span determination

6.3 Scantlings of Structural Members

6.3.1 Plating

6.3.1.1 Side plating thickness shall not be less than that required in 12.3.3, 12.5.2 or that determined in accordance with formula 5.3.1.1 for:

$$K = 10.0 + 0.08L_0 \qquad (6.3.1.1)$$

The value of design pressure *p* required in 12.5.2 shall be determined for the load application point (see 12.1.2) in accordance with the requirements specified in Chapter 14.

6.3.1.2 Side shell plating thickness in restricted service ships may be reduced:
– by 5% for operating area **II**,
– by 10%for operating area **III**.

6.3.2 Sheer Strake

6.3.2.1 Sheer strake thickness shall not be less than that of side shell plating whereas its breadth shall not be less than 0.1H, however not less than 0.3 m.

6.3.2.2 Rounded gunwale is permitted and the rounding radius shall not be less than 15-fold sheer strake thickness.

6.3.3 Frames

6.3.3.1 Prescribed frame spacing and possibilities for application of a different spacing are determined in 12.2.2.

6.3.3.2 Sectional modulus of main frames (also in peaks) shall not be less than that determined in accordance with 12.6.1 for various design pressures and allowable stresses specified as items 1.1, 1.2 and 1.3 in Table 12.6.2.1.

Bending moment factor m = 10 and the value of l not less than 2.2 m shall be taken.

Pressure *p* shall be determined in the point of load application (see 12.1.2) in accordance with the requirements specified in Chapter 14. The value taken for calculations shall not be less than 15 kPa.

The value of design pressure may be reduced:
- by 5%– for operating area **II**,
- by 10% – for operating area **III**.

6.3.3.3 The applied main frame sectional modulus shall not be less than that of the 'tween deck frame situated above the main frame on the main deck.

6.3.3.4 Side frames supporting the hatch end beams or deck cantilevers (for longitudinally framed decks) shall be reinforced.

Their strength shall be checked by direct calculations in accordance with the requirements specified in 12.7.

6.3.3.5 Sectional modulus of side frames in 'tween deck shall not be less than the value determined in accordance with 12.6.1 for the load patterns and allowable stresses specified as items 1.4 and 1.5 in Table 12.6.2.1 where m = 10 and $l \geq 2.2$ m shall be taken for calculations.

The method for determination of the design stresses and their reduction for restricted service ships is the same as in 6.3.3.2.

6.3.3.6 Sectional modulus of side frames in 'tween deck below the upper deck in way of the poop and forecastle shall be increased by at least 15% against the value obtained in accordance with the requirements specified in 6.3.3.5.

Sectional modulus of side frames in superstructures (including the poop and forecastle) shall be determined in accordance with the requirements specified in 6.3.3.5, except for the allowable stresses whose values shall be taken in accordance with item 1.6 in Table 12.6.2.1.

6.3.4 Side Stringers

6.3.4.1 Where the frame span exceeds 2.5 m, it is recommended that side stringer be applied. In that case the strength of side stringer, web frames supporting such stringers and ordinary frames shall be checked by direct calculations in accordance with the requirements specified in 12.7.

Allowable stress for ordinary frames shall be taken in accordance with Table 12.6.2.1.

6.3.4.2 At the level of fore peak stringers, intercostal side stringers shall be applied as their aftward extension over the stretch of 3 frame spacings. Such stringers shall be made of the same section as the frames. Flanges of the side stringers shall have cut ends and shall not be welded to the frame flanges.

6.3.5 Stern Counter

In the stern counter, sectional modulus of the frames shall not be less than that of frames in the after peak.

Spacing between ordinary frames or after frames shall, in general, fulfil the requirements specified in 12.2.2.3. If the spacing is greater than the prescribed spacing in accordance with 12.2.2.3 but it fulfils the requirements specified in 12.2.2.4, then the side shell plating thickness shall be increased in accordance with 12.3.1.2.

6.4 Afterbody Reinforcements

In multi-propeller ships, sides shall be reinforced by means of the local increase in the side frames, application of intercostal stringers, brackets etc. in way of stern tube fixing and propeller brackets' fixing.

6.5 Reinforcements in Machinery Space

6.5.1 Within the machinery space at least 2 web frames shall be applied where rated power of the main engine installed exceeds 150 kW. Web frames shall be situated in way of both fore and after ends of the main engine foundation. Subject to PRS consent in each particular case, ordinary frames having an increased sectional modulus may be applied instead of web frames.

6.5.2 Web frames shall have thickness, h_{WR}, not less than:

$$h_{WR} = 0.1l \text{ [mm]} \quad (6.5.2\text{-}1)$$

and web thickness, t_S, not less than:

$$t_S = 0.01h_{WR} + 2 \text{ [mm]} \quad (6.5.2\text{-}2)$$

it need not, however, exceed the side shell plating thickness in this region;
l – frame span in accordance with 6.2.1.5.

6.5.3 Web frame flange thickness shall exceed its web thickness by at least 2 mm. The flange width shall be equal to 10÷15 times the web thickness.

6.5.4 In the web frame plane, deck girders having not less than half the web frame depth shall be provided.

6.5.5 Web frames need not be applied where rated power of the main engine installed is less than 150 kW. In that case, frame sectional modulus within the machinery space shall be increased by 15% against that required in 6.3.3.

6.5.6 Within ballast deep tanks and fuel tanks, the sectional modulus of frames shall be increased by 15% compared to that required in 6.3.3.

7 DECKS

7.1 General

The requirements specified in this chapter apply to transversely stiffened decks. Structural arrangement of longitudinally stiffened decks is subject to PRS consideration in each particular case.

7.2 Structural Arrangement

7.2.1 Connection of Deck Stringers to Bulkheads

7.2.1.1 Deck stringer webs shall be welded to transverse bulkheads. Furthermore, deck stringers shall be connected to stiffeners or structural members of bulkheads with brackets fitted with face plate or flanged on the free edge.

7.2.1.2 Bracket thickness shall be equal to that of the deck stringer web. Deck stringer bracket height and its length measured along the stringer shall not be less than the stringer height.

7.2.2 Connection of Deck Beams to Frames and Deck Girders

7.2.2.1 Deck beams shall be connected to frames with brackets in accordance with the requirements specified in 12.9.2 (see also 6.2.1.2).

7.2.2.2 The bracket thickness shall not be less than 0.8 the beam web thickness.

7.2.2.3 If deck beams run through cuts in the deck girder, then the beam webs shall be connected to the edge of the deck girder cut with double weld or on the deck girder web either stiffeners or brackets shall be used to support such girders.

7.2.2.4 If deck beams are cut at the deck girder, then the beams shall be connected to the girder with brackets welded to the girder web.

Width of the brackets measured along the deck beam shall be determined in accordance with the requirements specified in 12.9.2.

7.2.2.5 Bracket ends shall be led to the deck girder face plate.

7.2.2.6 If the deck girder height is less than 2.2 the deck beam height, then the beams cut at the girder shall be welded to the girder web, and the brackets – to the girder web and face plate. If the deck girder height is more than 2.2 the deck beam height, then the beams cut at the girder need not be welded to the girder web and the brackets will suffice.

7.2.2.7 Transverse girder web shall be welded to the frame. Furthermore, the transverse girder shall be connected to the frame with bracket. The bracket construction and dimensions shall be in accordance with the requirements specified in sub-chapter 12.9.2.

7.3 Scantlings of Structural Members

7.3.1 Plating

7.3.1.1 Plating shall, in general, be continuous throughout the deck. Deck break, however, is permitted in accordance with the requirements specified in sub-chapter 7.4.1.

7.3.1.2 Thickness of the upper deck plating panels in the midship portion of the ship, t , shall not be less than the value obtained in accordance with the following formula:

$$t = a\,(0.2L_0 + 6.0)\ \text{[mm]} \qquad (7.3.1.2)$$

where:
L_0 – design length of ship, [m];
a – beam spacing, [m];

however not less than the thickness determined in accordance with sub-chapter 12.5.2, where pressure p shall be determined in accordance the requirements specified in sub-chapter 14.2.2.3, and allowable stress σ shall be taken from Table 12.5.3.1.

The requirements for stringer plates are specified in sub-chapter 7.7.

7.3.1.3 Deck plating thickness shall not be less than the minimum thickness specified in sub-chapter 12.3.

7.3.2 Stiffeners

7.3.2.1 Sectional modulus of beams and deck stiffeners, W, shall not be less than the value obtained in accordance with the following formula (see also 12.6.1):

$$W = \frac{1000apl^2}{m\sigma}\, w_k\ [\text{cm}^3] \qquad (7.3.2.1)$$

where:

m – bending moment factor taking the following values (see Figures 7.3.2.1-1 and 7.3.2.1-2):

14.2 – single-span of two-span open deck beam, both outer ends fixed with bracket, as well as two- or three-span beam of a superstructure deck fixed with bracket at outer ends and supported on pillars (Fig. 7.3.2.1-1 *a*, *b* and *c*);
12.3 – two-span beam in the superstructure: fixed with bracket at outer ends continuously running on the supports or welded to them (Fig. 7.3.2.1-1 *d* and *e*);
12.3 – three-span beam in the superstructure: fixed with bracket at outer ends continuously running on the supports or welded to them (Fig. 7.3.2.1-1 *b*);
11.2 – short ($l \leq 0.25B_1$) single-span beam in the superstructure fixed with bracket at outer ends (Fig. 7.3.2.2-2 *a*);
9.8 – short ($l \leq 0.33B_1$) beam with both ends running on the supports or welded to them (Fig. 7.3.2.1-2 *b* and *c*);
8.8 – short ($l \leq 0.25B_1$) single-span beam with both ends welded (Fig. 7.3.2.1-2 *d*);
7.5 – short stiffener, boosting the deck stiffness locally between beams with neither end fixed (cut) (Fig. 7.3.2.1-2 *e*);

σ – allowable stress in accordance with Table 12.6.2.1, item. 5;
a – spacing of beams and stiffeners, [m] (see 12.2.2);
p – design load in accordance with 14.2.2.3, [kPa];
l – span determined in accordance with the requirements specified in 3.2.1, [m]; for transversely framed system, the span taken for calculations shall not be less than 0.25 the breadth of ship in the relevant section, except for short stiffeners boosting the deck stiffness locally between beams;
w_k – corrosion addition factor (see 12.6.1);
B_1 – breadth of deck in the relevant beam position, [m].

The applied value of the beam sectional modulus shall not be less than 7 cm^3.

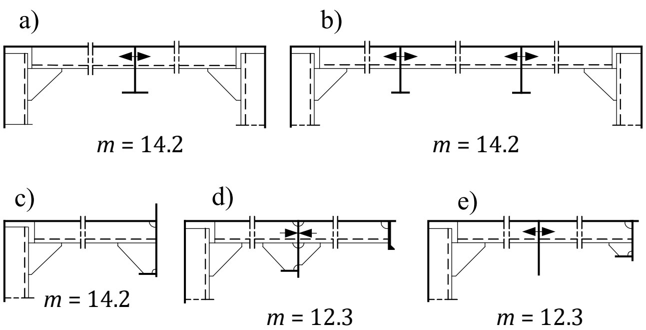


Fig. 7.3.2.1-1 Beam bending moment factors

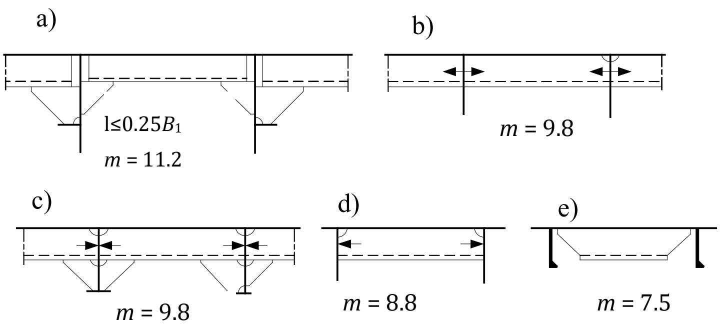


Fig. 7.3.2.1-2 Beam and stiffener bending moment factors

The requirements regarding stringer plates are specified in sub-chapter 7.7.

7.3.3 Longitudinal Deck Girders

7.3.3.1 Longitudinal deck girder sectional modulus, W, shall not be less than the value determined in accordance with the following formula:

$$W = n\frac{1000bpl^2}{m\sigma}w_k \text{ [cm}^3\text{]} \qquad (7.3.3.1\text{-}1)$$

where:

b – mean breadth of deck portion supported by longitudinal deck girder including hatches in the relevant portion of the ship, [m];
l – longitudinal deck girder span measured between their support points (centres of pillars, bulkheads, hatch-end beams), [m];
p – design load in accordance with 14.2.2.3, [kPa];
n – factor taking the following values:
n = 1.55 – for open deck (which may be a cargo deck) and forecastle deck longitudinal girders within $0.2L_0$ from FP;
n = 1.18 – for open deck longitudinal girders within the portion aft of $0.2L_0$ from FP, for pressure p determined in accordance with 14.2.2.3;
n = 1.1 – for longitudinal coaming of 'tween deck which forms longitudinal deck girder;
n = 1 – for longitudinal girders of open deck being a cargo deck within the portion aft of $0.2L_0$ from FP, and for longitudinal girders of other decks, for pressure p determined in accordance with 14.4.1 or 14.4.2;
σ – allowable stress taking the following values:
σ = 140k, [MPa] – in the midship portion;
σ = 160k, [MPa] – in peaks;
for intermediate portions between the midship portion and peaks, the values of σ shall be determined by linear interpolation;
m = 10.5 – bending moment factor;
w_k – corrosion addition factor determined in accordance with the requirements specified in sub-chapter 12.6.1.

If in line of the longitudinal deck girder a pillar is applied (placed on that girder), the design load shall be increased by the following value:

$$\Delta p = \frac{8cd}{l^2}\frac{N}{lb} \quad \text{[kPa]} \qquad (7.3.3.1\text{-}2)$$

where:

N – girder load induced by the pillar placed on it, [kN];
c – distance between the pillar and the closer support of girder;
d – distance between the pillar and the further support of girder.

7.3.3.2 Longitudinal deck girder web height shall not be less than 0.04 of its span.

7.3.3.3 Longitudinal deck girder web height shall not be less than the value obtained in accordance with the following formula:

$$t = 0.01h + 3 \text{ [mm]} \qquad (7.3.3.3)$$

however, it need not exceed the deck plating thickness in that region; h is the web height, [mm].

7.3.3.4 Longitudinal deck girder face plate height shall not exceed the triple web thickness.

7.3.3.5 Total width of longitudinal deck girder face plate shall not be less than its tenfold thickness. The requirements specified in 12.7.2 shall also be fulfilled.

7.3.4 Hatch End Beams

7.3.4.1 Sectional modulus of a hatch end beam supported by pillar in the centre plane shall not be less than the value obtained in accordance with the following formula:

$$W = \frac{1000pl}{m\sigma}(l_1 b_1 + l_2 b_2)w_k \quad [\text{cm}^3] \tag{7.3.4.1-1}$$

m – bending moment factor determined in accordance with the following formula:

$$m = \frac{10.17}{1 - 1.48(\frac{b}{2l} - 0.4)^2} \tag{7.3.4.1-2}$$

σ = $110k$, [MPa] – allowable stress;
l – hatch end beam span, determined in accordance with 3.2.1, assuming that it is supported in the centre plane and at the side, [m];
p – design load determined in accordance with 14.2.2.3, [kPa];
l_1 – half the hatch length, [m];
b_1 – breadth of the area supported by the longitudinal deck girder (hatch coaming) in the middle of length l_1, [m];
l_2 – half the distance between the hatch end beam and the next pillar or transverse bulkhead, [m];
b_2 – breadth of the area supported by the longitudinal deck girder (hatch coaming) in the middle of length l_2, [m];
b – hatch breadth, [m];
w_k – corrosion addition factor (see 12.6.1).

7.3.4.2 For other design patterns of the hatch end beam support (i.e. with no support in the centre plane), its strength shall be checked by direct calculations assuming p and σ in accordance with 7.3.4.1.

7.3.4.3 Height and breadth of hatch end beam brackets shall not be less than the hatch end beam height at the side.

7.3.5 Deck Cantilevers

7.3.5.1 The requirements specified in this sub-chapter apply to scantling of hatch deck cantilevers together with the associated web frames.

7.3.5.2 For the purpose of this sub-chapter, the following symbols have been used:

a, e – web frame and deck cantilever scantlings at the side (see Fig. 7.3.5.2), [m];
b_e – face plate effective breadth, determined in accordance with the requirements specified in 7.3.5.4, [cm];
b – half the actual breadth of face plate, [cm];
l – deck cantilever span (see Fig. 7.3.5.2), [m];
P – concentrated force induced by the cargo on the hatch cover and transversely stiffened deck, applied at the intercrossing of deck cantilever and hatch coaming, [kN];
Q – distributed load induced by the cargo on the longitudinally stiffened deck:
$Q = plb_0$, [kN];
$Q = 0$ for transversely stiffened deck;
b_0 – loaded area breadth equal to the spacing of cantilevers, [m];
p – design pressure due to cargo, calculated in accordance with the requirements specified in Chapter 14, [kPa];
u – distance between the relevant cantilever cross-section and its end (see Fig. 7.3.5.2), [m].

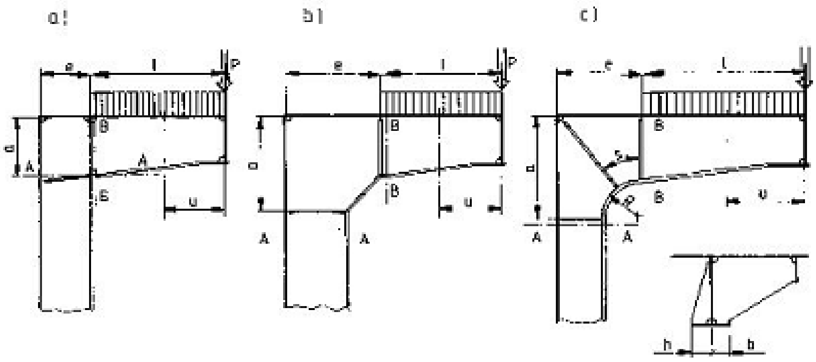


Fig. 7.3.5.2 Deck cantilevers in way of the hatch

7.3.5.3 Sectional moduli of a cantilever and web frame (sections A–A and B–B, see Fig. 8.3.5.1) shall not be less than:

$$W = \frac{6}{k} l(P + 0{,}5Q) \text{ [cm}^3\text{]} \quad (7.3.5.3)$$

7.3.5.4 Face plate effective width, b_e, shall be determined as follows:

– for not rounded connection of the cantilever to the web frame (see Fig. 7.3.5.2 *a* and *b*):

$$b_e = 2b \text{ [cm]} \quad (7.3.5.4\text{-}1)$$

– for rounded connection of the cantilever to the web frame (see Fig. 7.3.5.2 *c*):

$$b_e = 2Kb \text{ [cm]} \quad (7.3.5.4\text{-}2)$$

$$K = 1 - k_1\left(1 - \frac{2}{c+2}\right) \quad (7.3.5.4\text{-}3)$$

k_1 – coefficient taken from Table 7.3.5.4;
c – coefficient determined in accordance with the following formula:

$$c = \frac{b^2}{Rt_m} \quad (7.3.5.4\text{-}4)$$

R – radius of curvature, [cm];
t_m – face plate thickness; to be taken as: $t_m \ge \frac{b}{10}$, [cm].

Table 7.3.5.4
Values of coefficient k_1

s/b	k_1
$0 < s/b \le 2$	$0.1\ s/b$
$2 < s/b \le 4$	$0.1\ (3\ s/b - 4)$
$4 < s/b \le 8$	$0.05\ (s/b + 12)$

s – spacing of stiffeners according to Fig.7.3.5.2 *c*, measured along the face plate edge, [cm].

7.3.5.5 Width of the effective flange of the deck and shell plating shall be taken as 0.4*l*. The assumed width shall exceed neither the spacing between the cantilevers nor the distance *e* (see Fig. 7.3.5.2).

7.3.5.6 The net sectional area, A_s, of the cantilever web shall not be less than:

$$A_s = \frac{0.12}{k}\left(P + Q\frac{u}{l}\right) \text{ [cm}^2\text{]} \quad (7.3.5.6)$$

7.3.5.7 Thickness of the corner web plate in way of sections A–A and B–B in Fig. 7.3.5.2 shall not be less than:

$$t = \frac{0.012}{k}(P + 0.5Q)\frac{l}{ae} \quad [\text{mm}] \tag{7.3.5.7}$$

The corner web plate made in accordance with Fig. 7.3.5.2 (a) and (b) shall be additionally strengthened if dimensions a and e exceed 70t.

7.4 Additional Requirements

7.4.1 Strengthening at Upper Deck Break

7.4.1.1 Upper deck may be stepped. Where the upper deck is stepped in way of the afterbody, the upper deck stringer plate shall extend aftwards beyond the step bulkhead by at least 2 frame spacings and the deck stringer plate width shall decrease from its full width to that equal to the depth of the frame to which the stringer plate is to be welded (see Fig. 7.4.1.2*a*).

Similar construction is required for the upper deck step in the forebody.

7.4.1.2 Where the upper deck is stepped in way of the afterbody, the raised upper deck stringer plate shall extend forwards beyond the step by the application of a bracket narrowing gradually towards the ship side over the stretch of at least 3 frame spacings (see Fig. 7.4.1.2 *b*). The raised upper deck stringer plate extending beyond the step shall be strengthened by stiffeners whereas the free edge shall be strengthened by means of flat bar of flange.

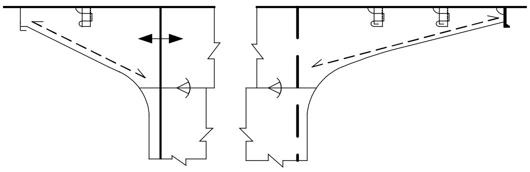


Fig. 7.4.1.2 Decrease of stringer plate width in way of the upper deck step

Similar construction is required for the upper deck step in the forebody.

7.4.1.3 Sheer strake at the raised deck shall extend beyond the step bulkhead forwards by at least 1.5 the step height and evolve into the sheer strake upper edge.

7.4.1.4 Between the decks, vertical brackets of the construction as shown in Fig. 7.4.1.4 shall be used in way of the step from the side to side with the spacing not exceeding 0.6 m or in line with the superstructure boundary above the step.

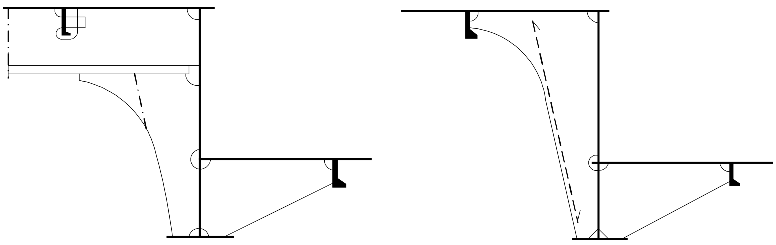


Fig. 7.4.1.4 Brackets in way of the deck step

7.5 Openings in Decks

7.5.1 Width of single hatch openings shall not, in general, exceed 0.7 of the ship breadth. Where the opening width is greater or there are double or triple openings situated transversely, the deck structure is subject to PRS consideration in each particular case.

7.5.2 Corners of large openings (more than 2.5 m in length or 1.2 m in width) in the strength deck, other decks and superstructure decks shall be rounded with a radius not less than 150 mm.

7.5.3 The longer side of the opening shall be oriented along this ship. Otherwise, the construction of opening corners is subject to PRS consideration in each particular case.

7.5.4 To hatch openings, machinery casings and other large openings, the requirements specified in paragraph 7.5.2 apply.

7.5.5 If the casing length is greater than the ship breadth, then it is recommended that a continuous deck transverse girder be applied in the casing midspan. Unless such a girder is applied, the construction of casing and deck strengthening in way of the casing is subject to PRS consideration in each particular case.

7.5.6 If the width of hatch opening, machinery casing, etc. exceeds 0.6B1, (B1 is the least breadth of ship throughout the machinery casing), then the strength deck thickness shall be increased respectively to make up for the reduction of the deck cross-section. Amidships, the required cross-sectional area of deck shall be ensured in accordance with the requirements specified in sub-chapter 13.4.

7.5.7 Corners of all minor rectangular openings in each deck shall be rounded in accordance with the requirements specified in paragraph 3.5.2.4.

7.6 Coamings

7.6.1 Hatchway Coaming Structure

7.6.1.1 Coamings whose height above the deck is 0.6 m or more, shall be reinforced by a flat bar of the width not less than 120 mm welded on the whole perimeter within 0.25 m from the coaming upper edge. Lower edges of the coaming face plates under the deck shall be rounded inside the opening.

7.6.1.2 The structure of coamings which are not in line with deck stringers or hatch end beams shall extend, below the deck, to the nearest deck girders after which a bracket connected to the nearest beam or intercostal stiffener shall be applied.

7.6.2 Scantlings of Hatchway Coamings

7.6.2.1 Thickness of hatchway coaming vertical plates on the open deck shall not be less than:

$$t = 0.2L_0 + 3 \text{ [mm]} \quad (7.6.2.1)$$

and shall be greater than the deck plating thickness by at least 1 mm.

7.6.3 Ventilator Coamings

7.6.3.1 Thickness of ventilator coamings situated on the upper deck, raised quarterdeck and forecastle deck shall not be less than that determined in accordance with the following formula:

$$t = 0.01d + C \text{ [mm]} \quad (7.6.3.1)$$

where:
C = 4 mm within $0.25L_0$ from FP;
C = 3 mm elsewhere;
d – inside diameter or length of the longer side of the ventilator coaming cross-section, [mm].

Thickness t shall not be less than 4 mm.

7.6.3.2 Thickness of ventilator coamings on the superstructure deck situated outside the region $0.25L_0$ from *FP* need not exceed the deck plating thickness in way of the coaming.

7.6.3.3 If a ventilator coaming is higher than 900 mm, brackets shall be used to fix such a coaming to the deck.

7.6.3.4 Ventilator coaming shall be determined in accordance with the requirements specified in *Part III – Hull Equipment*.

7.6.4 Coamings of Companion-hatches and Skylights

7.6.4.1 The structure of the coamings of companion-hatches and skylights shall have strength equivalent to that of the superstructure.

7.6.4.2 Coaming thickness shall not be less than 4 mm. It need not, however, exceed the deck plating thickness in way of the coaming.

7.7 Stringer Plate

7.7.1 If the deck plating thickness is less than the shell plating thickness, a stringer plate shall be applied.

7.7.2 Stringer plate thickness shall not be less than 400 mm. In the case of rounded deck corner, this dimension shall be measured from the deck transition into curvature.

7.7.3 Stringer plate width in the forebody and afterbody shall not be less than 0.65 the stringer plate thickness in the midship portion of the ship.

7.7.4 Stringer plate thickness in the midship portion of the ship shall not be less than the shell plating thickness.

7.7.5 Stringer plates may have holes only for penetration of drain pipes, sounding pipes and vent pipes.

7.8 Decking

7.8.1 Types of Decking

7.8.1.1 Steel plating of open decks shall be provided with one of the following types of decking:
– inorganic decking (e.g. cement decking);
– paint coating or plastic coating;
– planking.

7.8.1.2 Decking material (paint, plastic or wood) shall fulfil the requirements specified in *Publication No. 40/P – Non-metallic Materials*.

7.8.2 Requirements for Planking

Where planking is provided, it is recommended that:
– planking thickness be at least 40 mm;
– each plank/woodstave be fixed to the deck plating on every other beam with welded stud bolts of 8 mm in diameter and nuts locked in the holes;
– welded flat bars of scuppers shall have not less than 5 mm in thickness, and their height shall be such that the height of plating above such flat bar be not more than 10 mm.

8 BULKHEADS

8.1 General

8.1.1 Application

8.1.1.1 The requirements specified in this Chapter apply to the structure and arrangement of bulkheads as defined in 1.2.5.

8.1.1.2 Application of corrugated bulkheads or bulkheads made of plates having extruded stiffeners is permitted.

8.1.1.3 The requirements regarding the number of bulkheads and their arrangement are specified in sub-chapter 8.2.

8.1.2 Definitions and Symbols

For the purposes of Chapter 8, the following definitions and symbols are introduced:
L_F = L – length of ship, as defined in 1.2.2, [m];
T_F – ship draught, to be taken as $0.85H_F$, [m];
H_F – minimum moulded depth measured from the freeboard deck, [m];
δ_F – moulded block coefficient corresponding to draught T_F;

$$\delta_F = \frac{V_F}{L_F B T_F} \qquad (8.1.2)$$

FP_F – forward perpendicular, determined for the waterline on which length L_F is measured (see Fig. 8.2.2.1);
V_F – volume of the submerged part of the ship, determined on the outer edges of frames for draught T_F, [m].

8.2 Subdivision

8.2.1 General

8.2.1.1 The requirements regarding the hull subdivision into watertight compartments specified in Part IV – Stability and Subdivision shall be fulfilled.

8.2.1.2 Each ship shall have the following transverse watertight bulkheads extending to the bulkhead deck:
- forepeak bulkhead (collision bulkhead),
- after peak bulkhead,
- bulkheads bounding the machinery space (after peak bulkhead may form the after bulkhead of machinery space).

8.2.2 Position of Collision Bulkhead

8.2.2.1 Distance l_c from perpendicular FP_F to the collision bulkhead shall be within the following limits:

$$0.05L_F - l_r \le l_c \le 0.08L_F - l_r \ \text{[m]}$$

where:
L_F = L – length of ship, as defined in 1.2.2 (see Figures 1.2.2 and 8.2.2.1);
l_r – parameter taking the following values:
- for ships with ordinary bow shape:
  $l_r = 0$

– for ships having any part of the underwater body extending forward of FP_F:
$l_r = 0.5\ l_b$, [m],
$l_r = 0.015 L_F$, [m],
$l_r = 3.0$, [m];

l_b – as indicated in Fig. 8.2.2.1.

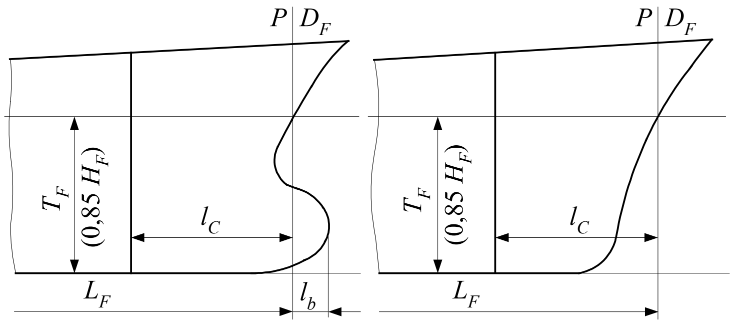


Fig. 8.2.2.1 Determining collision bulkhead position

8.2.2.2 In special cases, the distance between the collision bulkhead and FP may – subject to PRS consent in each particular case – exceed 0.08 L_F if the damage waterline remains below the freeboard deck after the forepeak has been flooded.

8.2.3 Vertical Extent of Watertight Bulkheads

8.2.3.1 Collision bulkhead shall extend to the bulkhead deck. If the forecastle extends beyond the collision bulkhead aftwards, then the collision bulkhead shall extend to that forecastle deck.

8.2.3.2 Afterpeak bulkhead shall extend to the bulkhead deck. In special cases, the collision bulkhead may extend to the 'tween deck situated above the waterline (watertight structure between such a bulkhead and the after end of ship).

8.2.4 Cofferdams

8.2.4.1 Width of vertical cofferdams shall not be less than one frame spacing and the height of the horizontal cofferdams shall not be less than 0.6 m, unless otherwise specified elsewhere in the Rules. This height may – subject to PRS consent in each particular case – be reduced; however access shall be provided for ship repair and inspection.

8.2.4.2 Cofferdams are required between:
– fuel oil and accommodation and service spaces as well as fresh water tanks and lubrication oil tanks;
– lubrication oil tanks and accommodation and service spaces as well as lubrication oil tanks and fresh water tanks;
– fresh water tanks and fuel oil and lubrication oil tanks.

8.2.5 Minimum Bow Height

8.2.5.1 Required bow height H_b, as defined in the *International Convention on Load Lines, 1966*, as vertical distance measured at forward perpendicular FP_F from the summer load waterline to the exposed deck upper edge at the side shall be determined in accordance with the following formula:

$$H_b = 56 L_1 \left(1 - \frac{L_1}{500}\right) \frac{1.36}{\delta_F + 0.68} \quad \text{[mm]} \qquad (8.2.5.1)$$

L_1 = L_F [m], (L_F – see 8.1.2);
δ_F – moulded block coefficient, the value taken for calculations shall not be less than 0.68.

8.2.5.2 If the minimum bow height has been achieved by an increase of the upper deck sheer, then the deck sheer shall extend throughout the distance not less than $0.15L_F$ aftwards from the fore end of length L_F.

8.2.6 Extent of Forecastle

Forecastle shall extend throughout the distance not less than $0.07L_F$ aftwards from the fore end of length L_F.

8.3 Structural Arrangement

8.3.1 General Requirements

8.3.1.1 Collision bulkhead may have steps or protrusions, the requirements specified in 8.2.2 shall be fulfilled.

8.3.1.2 If watertight bulkheads, including the collision bulkhead and the after peak bulkhead as well as their steps form boundaries of tanks, the construction of such bulkheads shall fulfil the requirements specified in 8.5.2.

8.3.1.3 Distance between the after peak bulkhead and after perpendicular shall be determined with respect to the construction of afterbody and stern tube.

8.3.1.4 Openings are permitted in watertight bulkheads, provided that such openings and their closing appliances fulfil the requirements specified in Part III – Hull Equipment.

8.3.1.5 In ships with machinery space situated amidships and with restricted service – mark II or III in the symbol of class – a watertight shaft tunnel need not be applied provided the shafting is otherwise effectively protected. Bearings and stuffing boxes shall be accessible.

8.3.1.6 If it is necessary to cut stiffeners or increase their spacing to arrange a watertight door or for another reason, the bulkhead shall be so reinforced there that such a bulkhead be equivalent to an intact bulkhead in respect of stiffness and strength.

8.3.2 Corrugated Bulkheads

8.3.2.1 Where longitudinal bulkheads are arranged as corrugated bulkheads, they shall have plane portions for a distance not less than $0.13H$ measured from the bottom and deck, respectively.

Transverse corrugated bulkheads with vertical corrugations shall be plane for a distance not less than $0.08B$ measured from the ship sides.

8.3.2.2 Design spacings of stiffenings in corrugated bulkheads to be used for plate thickness calculation in accordance with 8.4.1.1 shall be assumed as follows (see Fig. 8.3.2.2):

– for corrugated bulkhead member of trapezoidal cross-section, where $s_2 \neq s_3$, the greater of the following two vales shall be taken:

$$a = 1.05\ s_2 \qquad (8.3.2.2\text{-}1)$$

$$a = 1.05\ s_3 \qquad (8.3.2.2\text{-}2)$$

– for corrugated bulkhead member of trapezoidal cross-section where $s_2 = s_3$:

$$a = s_2 = s_3 \qquad (8.3.2.2\text{-}3)$$

– where the web plates are perpendicular to the attached plating, the greater of the following two vales shall be taken:

$$a = s_2 \quad (8.3.2.2\text{-}4)$$

$$a = s_3 \quad (8.3.2.2\text{-}5)$$

For calculation of the required sectional modulus of corrugated bulkhead member of trapezoidal cross-section:

$$a = s_1 \quad (8.3.2.2\text{-}6)$$

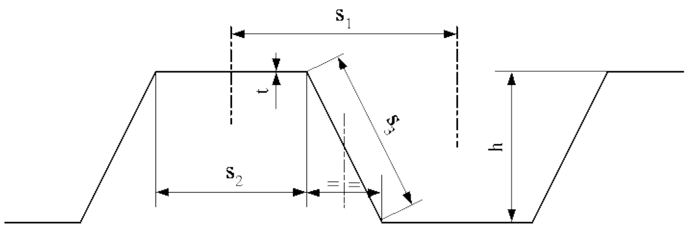


Fig. 8.3.2.2 Corrugated bulkhead

8.4 Scantling of Structural Members of Watertight Bulkheads and Fixing of Stiffener Ends

8.4.1 Plating

8.4.1.1 Plane bulkhead plating thickness shall not be less than the value obtained in accordance with the following formula:

$$t = 15.8\, na\sqrt{\frac{p}{\sigma}} + C + t_k \text{ [mm]} \quad (8.4.1.1)$$

a – spacing of vertical or horizontal stiffeners, [m]; for corrugated bulkhead of trapezoidal cross-section determined in accordance with 8.3.2.2; and for corrugated bulkhead of undulated cross-section $a = s$ (see Fig. 3.2.4);
p – design pressure, determined in accordance with 14.3.2.1;
σ = $190k$ – allowable stress, [MPa];
C = 0.8 – for lower strake of bulkhead plating,
C = 0.0 – for other strakes of bulkhead plating;
n – coefficient taking the following values:
n = 1.25 for collision bulkhead,
n = 1.00 for watertight bulkheads;
t_k – corrosion addition, determined in accordance with 2.5 or 2.6.

For tank bulkheads, the plating thickness shall be determined in accordance with 8.5.2.

8.4.1.2 Width of the lower strake of plane bulkhead plating measured from the outer bottom shall not be less than:
0.4 m – in ships of a length $L_0 \leq 20$ m,
0.6 m – in ships of a length $L_0 > 20$ m.

In way of penetration of the stern tube and shaft stuffing, the bulkhead plating thickness shall be at least doubled against that required in 8.4.1.1.

8.4.1.3 Plating thickness of corrugated bulkhead with trapezoidal cross-section shall not be less than the value obtained in accordance with the following formulae:

$$t = \frac{s_2}{0.05} \text{ [mm] for } \frac{s_2}{s_3} = 0.5 \qquad (8.4.1.3\text{-}1)$$

$$t = \frac{s_2}{0.07} \text{ [mm] for } \frac{s_2}{s_3} \geq 1.0 \qquad (8.4.1.3\text{-}2)$$

s_1, s_2, s_3, – see Figs. 8.3.3.1, [m].

For intermediate values of ratio s_2/s_3, required minimum thickness t shall be determined by linear interpolation.

Where the sectional modulus of the corrugated bulkhead member exceeds the required value, the bulkhead plating thickness may be reduced by multiplying it by the following factor:

$$\sqrt{\frac{W\ required}{W\ actual}} \qquad (8.4.1.3\text{-}3)$$

For corrugated bulkhead of undulating cross-section, the following condition shall be fulfilled (see Fig. 3.2.4 *b*):

$$\frac{r}{t} \leq \frac{17}{R_e} \qquad (8.4.1.3\text{-}4)$$

r – undulation radius in the neutral axis of the plating thickness, [m],
t – plating thickness, [mm].

8.4.1.4 Plating thickness of corrugated watertight bulkhead of undulated cross-section shall not be less than the value obtained in accordance with the following formula:

$$t = 16.5\beta r\sqrt{\frac{p}{\sigma}} + C + t_k \quad \text{[mm]} \qquad (8.4.1.4)$$

β, r – see Fig. 3.2.4 *b*) (β [rad], r [m]);
p – design pressure, [kPa], determined in accordance with formula 14.3.2.1;
σ – allowable stress; to be taken as $\sigma = 160k$, [MPa];
C = 1.25 – for lower strake of bulkhead plating,
C = 0.25 – for other strakes of bulkhead plating.

8.4.2 Stiffeners

8.4.2.1 Plane bulkheads shall be reinforced with vertical or horizontal stiffeners. Spacing of vertical or horizontal stiffeners shall not exceed 0.5 m for the collision bulkhead and 0.6 m – for other bulkheads.

8.4.2.2 Scantlings of vertical and horizontal stiffeners as well as elements of corrugated bulkheads shall be determined in accordance with the requirements specified in 8.4.2.4 and 8.4.2.6.

8.4.2.3 Collision bulkhead stiffeners shall have the sectional modulus greater than that required for other bulkheads by at least 15%, with the same all other conditions.

8.4.2.4 Vertical stiffeners of watertight bulkheads shall have sectional modulus not less than that determined in accordance with 12.6.1, where p shall be taken in accordance with 14.3.2.1 and σ – in accordance with Table 12.6.2.1, item 2 (in damaged condition).

Span l taken for calculations shall not be less than 2.0 m.

The values of m are as follows:
16.0 – where both ends are fixed with brackets;
12.0 – where upper end is fixed by welding to the deck plating or where the stiffener runs continuously to the compartment located above and the lower end is fixed with bracket;

9.5 – where both ends are fixed by welding to the deck plating or bottom plating or where the stiffener runs continuously to the compartments located above or below;
7.5 – where both ends of the stiffeners are not fixed (are bevelled).

When determining the sectional modulus of tank bulkhead stiffeners, the requirements specified in sub-chapter 8.5.2 shall be taken into account.

8.4.2.5 Sectional modulus of stiffeners of bulkhead supporting deck stringers shall be greater than that determined in accordance with 8.4.2.4 by at least 25%. These stiffeners shall also fulfil the requirements for pillars specified in sub-chapter 12.8.

8.4.2.6 Horizontal stiffeners of watertight bulkheads shall have sectional modulus not less than that determined in accordance with 12.6.1, where p shall be taken in accordance with 14.3.2.1 and σ – in accordance with Table 12.6.2.1, item 2 (in damaged condition).

The following values of m shall be taken (see also Fig. 8.4.2.6):
16.0 – where both ends are fixed with brackets (see Fig. 8.4.2.6 *a*));
12.0 – where one end is fixed by welding or the stiffener runs continuously through the pillar and the other is fixed with bracket (see Fig. 8.4.2.6 *b*));
8.0 – where both ends are fixed by welding or the stiffener runs continuously through pillars at both ends (see Fig. 8.4.2.6 *c*)).

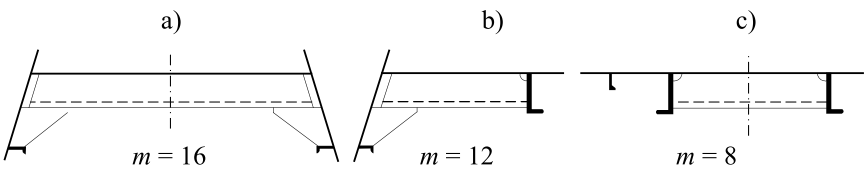


Fig.8.4.2.6 Factors for bulkhead horizontal stiffeners

When determining sectional modulus of tank bulkheads, the requirements specified in sub-chapter 8.5.2 shall be taken into account.

8.4.3 Fixing of Stiffener Ends

8.4.3.1 Bracket scantlings shall be determined in accordance with the requirements specified in sub-chapter 12.9.2. Brackets fixing stiffeners to the deck plating or to the outer bottom plating shall be welded to the beam, floor or frame situated nearest the bulkhead.

8.4.3.2 Height of lower brackets shall not be less than 1/12 of the bulkhead stiffener span.

8.4.3.3 Bracket thickness shall not be less than that of the bulkhead stiffener web.

8.4.3.4 Brackets having a shorter arm not exceeding 250 mm need not have a flange or face plate.

8.4.3.5 Stiffener ends may be bevelled – instead of being fixed with brackets or being welded – only in ships with moulded depth not exceeding 3 m. In that case, bulkhead plating thickness shall not be less than that required in 12.9.2.2.

8.4.3.6 Collision bulkhead stiffener ends may be welded without bracket only in that part of bulkhead above the upper deck.

8.4.3.7 Horizontal stiffener ends shall be fixed to the ship sides with brackets extending to the nearest frame which will be welded to that frame. The bracket width measured along the stiffener shall not be less than 1.5 times the stiffener height.

8.5 Additional Requirements

8.5.1 Watertight Steps of Bulkheads

Bulkhead step plains shall have plating and stiffeners ensuring strength equivalent to that of plane bulkheads.

8.5.2 Bulkheads, Sides and Decks Forming Deep Tank Boundaries

8.5.2.1 Deep tanks are all tanks other than double bottom tanks defined in 5.3.3.1.

8.5.2.2 Plating of Deep Tank Bulkheads

Thickness of deep tank bulkhead plating shall not be less than the value obtained in accordance with the following formula:

$$t = 15{,}8\, a \sqrt{\frac{p}{\sigma}} + C + t_k \text{ [mm]} \qquad (8.5.2.2)$$

a – spacing of vertical or horizontal stiffeners (see 8.4.1.1), [m];
σ – allowable stress of the values taken in accordance with Table 12.5.3.1, item 5;
C = 1.25 – for lower strake of bulkhead plating and tank top plating (platform or deck forming the tank boundary);
C = 0.25 – for other strakes of bulkhead plating;
p – design pressure, determined in accordance with 14.3.2.2.

The width of lower strake of deep tank bulkhead plating shall fulfil the requirement specified in 8.4.1.2.

8.5.2.3 Deep Tank Bulkhead Stiffeners

Sectional modulus of deep tank bulkhead vertical stiffeners shall not be less than the value obtained in accordance with 12.6.1, where p has been taken in accordance with 14.3.2.2 and σ – in accordance with Table 12.6.2.1, items 2.1, 2.3, 3 or 4.

The following values of factor m shall be taken:
14.0 – tanks without horizontal framework, both stiffener ends fixed with bracket;
9.5 – tanks with one horizontal framework, both stiffener outer ends fixed with bracket.

8.5.2.4 Frames

Sectional modulus of frames within deep tanks shall fulfil the requirements specified in 6.3.3 and 8.5.2.3.

8.5.2.5 Beams

Sectional modulus of beams of platforms or decks forming the tank boundary shall not be less that required in 12.6.1, where p has been taken in accordance with 14.3.2.2 (the applied value shall not be less than 12.0 kPa) and the following values: σ = 140k [MPa] and m = 9.5 shall be taken for calculations.

Beam scantlings shall not be less than those required in 7.3.2.

It is recommended that the deep tank top be located below the open deck.

9 SUPERSTRUCTURES AND BULWARKS

9.1 Application

The requirements specified in this Chapter apply to superstructures (forecastles, midship superstructures, poops), deckhouses and trunks as well as to bulwarks, coamings, companion-hatches, skylights etc.

9.2 Structural Arrangement

9.2.1 Openings

9.2.1.1 Corners of rectangular openings in the outer side boundaries and decks of deckhouses, superstructures, companionways, etc. shall be rounded with a radius not less than 30 mm and reinforced by a flat bar welded on the whole perimeter.

9.2.2 Additional Requirements

9.2.2.1 Adequate strengthening of side boundaries of and decks in deckhouses shall be provided in those places where life boats, boat davits, masts, hoisting winches are situated, as well as in other places where excessive local loads are likely to occur.

9.3 Scantlings of Structural Members

9.3.1 Plating of Walls and Decks

9.3.1.1 Thickness of plating of side boundaries of forecastle, midship superstructure, poop, etc. shall not be less than that required in 12.5.2, where σ = 160k, [MPa] shall be taken, and pressure p for the plating of poop, midship superstructure and forecastle shall be determined in accordance with 14.2.2.1 and 14.2.2.2 like for double-deck ship taking H0 = H, where H – moulded depth measured to the upper deck.

9.3.1.2 Thickness of plating of end bulkheads of the forecastle, midship superstructure, poop as well as deckhouse walls shall not be less than the value obtained in accordance with the following formula:

$$t = 15.8\, a \sqrt{\frac{p}{\sigma}} + C \text{ [mm]} \qquad (9.3.1.2\text{-}1)$$

where:

a – spacing of stiffeners, [m] (for walls made of corrugated plates with trapezoidal cross-section, a shall be taken in accordance with 8.4.1.1);

σ – allowable stress of the following values:
$\sigma = 140k$, [MPa] – for exposed fore end of poop and midship superstructure,
$\sigma = 160k$, [MPa] – for other walls;

p – design pressure determined in accordance with the following formulae:
– for the fore end:

$$p = 17.0 + 0.07L_0 \text{ [kPa]} \qquad (9.3.1.2\text{-}2)$$

– for other walls:

$$p = 8.5 + 0.07L_0 \text{ [kPa]} \qquad (9.3.1.2\text{-}3)$$

(for the walls situated above the first tier, the design pressure may be reduced by 15%);

C = 1.0 – for the lower strake of the lower tier,
C = 0.25 – for the other strakes of the lower tier,

C = 0.0 – for the other strakes of other tiers.

Plate width of the lower strake of plating 0.5 m.

9.3.1.3 Plating thickness of superstructure (forecastle, midship superstructure, poop) decks shall not be less than:

–for poop deck and midship superstructure deck:

$$t = a\,(0.15L_0 + 5.2)\ [\text{mm}] \qquad (9.3.1.3\text{-}1)$$

–for forecastle deck:

$$t = a\,(0.2L_0 + 5.2)\ [\text{mm}] \qquad (9.3.1.3\text{-}2)$$

however, it shall not be less than:

$$t = 15{,}8\,a\sqrt{\frac{p}{\sigma_k}}\ [\text{mm}] \qquad (9.3.1.3\text{-}3)$$

where:
L_0 – design length of ship, [m];
a – spacing of beams, [m];
p – design pressure determined in accordance with 14.2.2.3, [kPa];
σ = 160k, [MPa].

Formula 9.3.1.3-3 also applies to the deck plating of deckhouses, trunks and companionways.

9.3.2 Wall Stiffeners

9.3.2.1 Sectional modulus of end bulkheads shall not be less than that required in 12.6.1 and the following values shall be taken to calculations:
l – stiffener span, defined as the distance between the decks, however not less than 2 m;
σ – allowable stress taking the following values:
  σ= 140k, [MPa] – for exposed fore end bulkhead of poop and midship superstructure,
  σ= 160k, [MPa] – for other walls;
p – design pressure determined in accordance with 14.2.4, [kPa];
m – coefficient taking the following values (see Fig. 9.3.2.1):
  14.3 – where the upper end is fixed to the beam with bracket, and the lower end is welded,
  12.5 – where the upper end is fixed with bracket, and the lower end is welded or fixed with flat bar,
  9.5 – where the upper end is welded and is continued above and the lower end is fixed with flat bar,
  8.0 – where the upper end is fixed to the transverse deck stiffener with bracket, and the lower end is bevelled (this may be applied only on the aft walls of single-tier superstructure, on steps, in trunks and small deckhouses),
  7.5 – where both ends are bevelled (this may be applied only in trunks or small deckhouses from which no access inside the ship is provided);
  for m = 7.5, allowable stress σ=140k, [MPa] shall be taken).

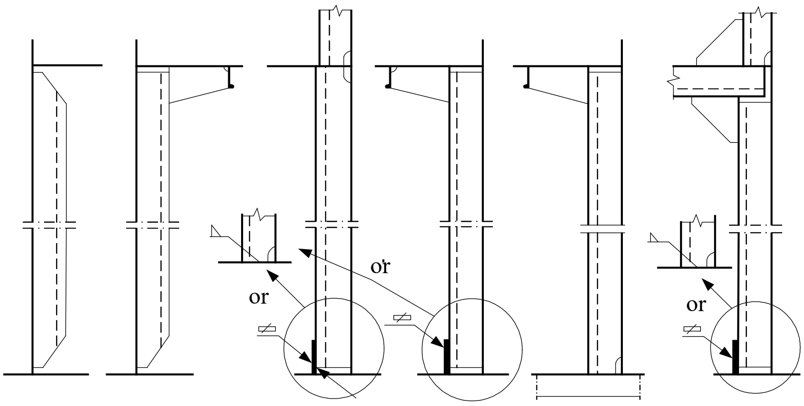


Fig. 9.3.2.1 Bending moment factor m for superstructure stiffeners

9.3.2.2 Sectional modulus of the side frames in the forecastle, midship superstructure and poop shall fulfil the requirements specified in 6.3.3.6.

9.3.3 Casings

9.3.3.1 Openings in decks and platforms above the machinery spaces shall be arranged inside casings.

Casings may be waived only when a compartment situated on the deck forms a part of the machinery space.

Openings in deck for the machinery casing shall be arranged in accordance with the requirements specified in 7.5.2.

9.3.3.2 Plating thickness of protected machinery casings below the bulkhead deck shall not be less than the value obtained in accordance with the following formulae:

– in way of cargo spaces:

$$t = 8.5a, \text{ however } t \geq 5 \text{ [mm]} \qquad (9.3.3.2\text{-}1)$$

– in way of accommodation spaces:

$$t = 6.5a, \text{ however } t \geq 4 \text{ [mm]} \qquad (9.3.3.2\text{-}2)$$

where:
a – spacing of stiffeners, [m]; $a \leq a_0$ shall be taken for calculations;
a_0 – prescribed spacing of structural members, [m], in accordance with 12.2.2.1.

9.3.3.3 Sectional modulus of the casing wall stiffeners shall not be less than:

$$W = 3l^2a \text{ [cm}^3\text{]} \qquad (9.3.3.3)$$

where:
l – stiffener span, to be taken as $l \geq 2.5$ m,
a – spacing of stiffeners, [m].

The applied value of W shall be greater than 70% of the sectional modulus required for the watertight bulkhead stiffeners of the same span situated at the same height.

Stiffener lower ends shall be welded to the casing coaming webs below the deck level. The minimum thickness of such coaming shall not be less than 6 mm.

9.3.3.4 Casings inside the superstructure or deckhouse may have plating of a thickness less by 0.5 mm than that required for the casing plating on the 'tween deck, however not less than 4.5 mm, and the coaming thickness shall not be less than 5.5 mm.

Sectional modulus of the stiffeners of such casings and coamings shall not be less than 55% of that required for the watertight bulkhead stiffeners of the same span situated below the bulkhead deck.

9.3.3.5 If the casing portion situated below the bulkhead deck forms a part of the watertight bulkhead taking into account in the ship subdivision calculations, then its strength shall not be less than that of transverse bulkhead situated at the same height.

9.3.3.6 Machinery casing plating thickness on the exposed upper deck shall be greater by 15%, and its sectional modulus – by 50% than those required for the deckhouse in the same location. Thickness of the lower strake (at least 500 mm in width) of casing plating within the lower tier shall be additionally increased by 1 mm.

9.3.3.7 Machinery casing plating thickness at the height of the second and higher tiers shall be greater by at least 10%, and the stiffener sectional modulus shall be greater by at least 20% than those required for the deckhouse of such a tier.

9.4 Bulwarks

9.4.1 General Requirements

9.4.1.1 Robust bulwarks or rails shall be arranged on all exposed parts of the deckhouse deck and other decks if they are working decks. The height of bulwark, bulwark with railing on the upper edge and barriers shall be determined in accordance with the requirements specified in *Part III – Hull Equipment*. The minimum height measured from the top surface of the deck plating or deck planking is 1.0 m.

9.4.1.2 Where, in some place, the bulwark is welded to the sheer strake, the smooth transition with a radius of at least 100 mm between the bulwark plating and the sheer strake shall be maintained.

9.4.2 Bulwark Thickness

9.4.2.1 Bulwark plate thickness shall not be less than the value determined in accordance with the following formula:

$$t = 0.065L_0 + C \text{ [mm]} \quad (9.4.2.1)$$

however not less than 3 mm, but it need not be more than the thickness required for the superstructure side walls.

The following values of C shall be taken:
C = 2.25 for bulwark plates on open deck and forecastle deck within $0.25L_0$ from *FP*,
C = 2.00 for bulwark plates on the open deck and the first tier deck located from $0.25L_0$ from *FP* aftwards,
C = 1.75 for bulwark plates on the second tier deck and higher tiers.

9.4.2.2 Where the height of bulwark is 1.8 m and more, the thickness of bulwark plates shall fulfil the requirements for the superstructure side walls. For intermediate height of bulwark, the bulwark plate thickness may be determined by linear interpolation.

9.4.3 Stiffening and Bulwark Rails

9.4.3.1 Bulwark upper edge shall be finished with rail made of sufficiently firm section (angle bar, bulb bar or oval tube) having a thickness greater than that of the bulwark plating by at least 1 mm. The bulwark rail shall not have less than 75 mm in width.

9.4.3.2 Where the bulwark is not connected to the deck, the bulwark lower edge shall be reinforced with horizontal stiffener.

9.4.4 Arrangement of Stays

Bulwark shall be supported by stays spaced not more than 1.5 m. In the fore part of the ship – within $0.07L_0$ from FP – the spacing of stays shall not exceed double frame spacing. In ships having ratio $T/H > 0.95$ and where the flare is large, PRS may require application of stays at each frame.

9.4.5 Scantlings and Construction of Stays

9.4.5.1 Stay thickness shall be greater than the bulwark plating thickness by at least 1 mm.

9.4.5.2 The width of lower end of the stay of bulwark having 1 m in height shall not be less than that determined in accordance with the following formula:

$$b = (0.65L_0 + 150)\sqrt{s} \quad \text{[mm]} \qquad (9.4.5.2)$$

s – spacing of stays, [m].

In the fore part of ship within $0.07L$ from FP, s = 1.5 m shall be taken for the calculation of b.

Outside the fore part of ship, the value of b may be reduced by 20% if the bulwark has been welded to the sheer strake.

9.4.5.3 Where the bulwark height exceeds 1 m, width b shall be increased in proportion to the bulwark height.

9.4.5.4 The width of upper end of the bulwark stay shall be equal to that of the bulwark rail. Stays shall have either flanges or face plates. The width of flange (face plate) shall not be less than 60 mm. The lower end of flange (face plate) shall be bevelled and shall not be fixed to the deck plating.

9.4.5.5 If bulwark is interrupted to arrange gangways etc., the stays located at the segment ends shall have thickness greater than that of bulwark by at least 25%.

9.4.5.6 Additional strengthening of bulwark may be required in way of mooring pipes, fairleads and eyeplates for cargo gear.

9.4.5.7 Stays shall be fixed in the same planes as beams (terminating not further from the ship side than 30 mm), upper ends of frames welded to the deck and brackets, and the stays shall be welded to rail, bulwark and deck.

9.4.5.8 Width of the lightening holes in stays shall not exceed half the stay width in the relevant cross-section. In the lower part of stays, in way of the bulwark plating, adequate cuts shall be made for the deck water drainage.

9.5 Freeing Ports

9.5.1 Freeing ports in bulwarks shall be so arranged along the bulwark as to allow for quick and effective drainage of water from the entire deck. Lower edges of freeing ports shall be arranged as low as practicable. If the sheer strake extends above the deck, the construction of freeing ports shall not disturb the sheer strake, and the outline of the opening for the freeing port or drainage shall have lower corners in the shape of ellipse quarter with its edge situated at least 10 mm above the deck stringer plate.

9.5.2 Where bulwarks form sheltered areas on the exposed parts of deck, the minimum area of the freeing port – at each side of the ship in way of each of such sheltered areas – shall be determined taking account of the sheltered area length and bulwark height (see paragraphs 9.5.3 to 9.5.5).

9.5.3 For a bulwark of mean height not exceeding 1.2 m, the area of freeing ports on each of the ships sides shall not be less than the value obtained in accordance with the following formula:

– for $l \leq 20$ m: $A = 0.7 + 0.035l$, [m^2] (9.5.3-1)

– for $l > 20$ m: $A = 0.035l$, [m^2] (9.5.3-2)

l – bulwark length of the restricted space, however not more than 70% L_0,[m].

9.5.4 Where the mean height of bulwark is more than 1.2 m, the required area of freeing ports shall be increased by 0.004 m2 per each metre of the restricted space length and per each 100 mm of slope height.

9.5.5 Subject to PRS assessment that the deck sheer is insufficient to ensure effective deck water drainage, it may be required to increase the area of freeing ports.

9.5.6 Freeing ports of a height exceeding 300 mm shall be provided with bars arranged with a spacing not more than 230 mm and not less than 150 mm or other equivalent protection means shall be provided. If freeing port flaps are applied, their construction is subject to PRS approval in each particular case.

9.5.7 In ships intended to operate in the areas where icing occurs, freeing port flaps and other protective means shall be provided. The construction of such flaps or protective means shall allow for their easy dismantlement to reduce the ice accumulation. Dimensions of openings and the arrangements for their dismantlement are subject to PRS consent in each particular case.

9.5.8 Cockpits and recesses whose bottom is above the maximum draught waterline where water may accumulate shall be provided with effective means to discharge the water overboard.

10 STEM, STERNFRAME, PROPELLER SHAFT BRACKETS AND KEEL

10.1 General

10.1.1 The requirements specified in this Chapter apply to the construction, shape and scantlings of stem, sternframe, including fixed nozzle, and propeller shaft brackets.

10.1.2 Keel, stem and sternframe may be fabricated by fusion welding of plates or as steel casting, steel forging or made of rolled steel.

10.1.3 Welded structure or steel casting of the stem or sternframe shall be strengthened by transverse brackets (cast webs).

10.1.4 Butt welding is required as an essential assembly method for the particular components of stem, sternframe and propeller shaft brackets.

10.1.5 Plate (casting edge) thickness in way of the connection to the hull structure shall be reduced to the thickness of those components to which the stem or sternframe will be welded (smooth transition of the bevel not exceeding 1:3 is required).

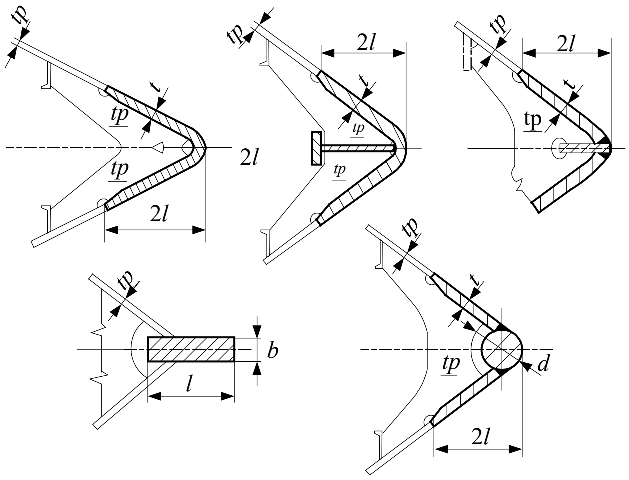
10.2 Stem

10.2.1 Structure

10.2.1.1 Stem steel plates shall be strengthened by transverse brackets fitted not more than 0.6 m apart below the summer load waterline and not more than 0.8 m apart above the summer load waterline. Vertical arrangement of the brackets shall, as far as practicable, correspond to that of the framing system structural members. Thickness brackets shall be equal to that of the shell plating they are connected to. The brackets shall extend beyond the connection of the stem with the shell plating to the nearest frames to which they shall also be connected (see Fig. 10.2.1.3).

10.2.1.2 If the bow is blunt or the bend radius of stem plates at the level of summer load waterline is more than 150 mm, then the stem web strengthened with face plate shall be applied at the centre plane from the keel to level 0.15T above the waterline (see Fig. 10.2.1.3). The web and face plate shall not have thickness less than thickness tp of shell plating connected to the stem.

10.2.1.3 Longitudinal reinforcement of stem plates may also have another construction approved by PRS.



l – length of bar stem section required in 10.2.2.1

Fig. 10.2.1.3 Fabricated stems and bar stems

10.2.1.4 Stem shall be connected to the bar keel or flat keel and, if practicable, to the bottom centre girder.

10.2.2 Scantlings

10.2.2.1 Dimensions of the bar stem with solid rectangular cross-section (see Fig. 10.2.2.1) from the keel to the summer load waterline shall not be less than those determined in accordance with the following formulae:

– length: $l = 1.2\ L_0 + 80$ [mm] (10.2.2.1-1)

– breadth: $b = 0.4\ L_0 + 12$ [mm] (10.2.2.1-2)

Above the summer load waterline, the cross-section area of the stem may be gradually tapered to 70% of the area obtained from the scantlings given above.

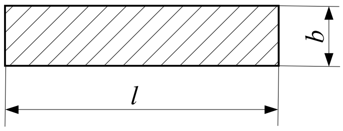


Fig. 10.2.2.1

10.2.2.2 Fabricated stems shall be made of steel plates, the thickness of which shall not be less than the value obtained in accordance with the following formula:

$$t = 0.1L_0 + 4 \text{ [mm]} \quad (10.2.2.2)$$

In no case shall the adopted thickness of plates be less than that of the bottom plating in way of their connection to the stem foot.

Above the summer load waterline, the plate thickness may be gradually tapered to the thickness of the shell plating at the ship ends.

It is recommended that the length of the cross-section of the fabricated stem be not less than twice that of the bar stem required in paragraph 10.2.2.1 (see Fig. 10.2.1.3).

10.3 Single-screw Ship Sternframe

10.3.1 Structure

10.3.1.1 Sternframe shall be of simple structure, it shall be strengthened with brackets and it shall have rounding radii as large as practicable. Lower part of the sternframe shall extend from the propeller post forwards by at least one frame spacing beyond the fore edge of the stern tube. Ribs of the sternframe lower part shall be connected to at least one floor.

Rudder post shall extend into the stern counter for the distance sufficient for its strong connection to the transom plate, however this distance shall not be less than triple length of the propeller post.

10.3.1.2 Transom plates mentioned in 10.3.1.1 shall generally extend to the nearest deck.

10.3.1.3 Sternframe without rudder post or with detachable rudder axle shall have the propeller post of the cross-section required in 10.3.2.1.

10.3.2 Scantlings

10.3.2.1 Propeller post with solid rectangular cross-section between the keel and stern counter shall not have dimensions less than the values obtained in accordance with the following formulae:

– length: $l = 1.30L_0 + 95$ [mm] (10.3.2.1-1)

– breadth: $b = 1.60L_0 + 20$ [mm] (10.3.2.1-2)

Length of the rudder post cross-section may be less than that of the propeller post by 10%.

Above the stern counter, the sternframe cross-section may be gradually reduced to 40% of the propeller post cross-section.

10.3.2.2 If the propeller post and rudder post form a single unit, the sole piece with the solid rectangular cross-section shall have the following dimensions:

– height greater than the propeller post length by at least 10%;

– breadth greater than that of the propeller post cross-section by at least 40%.

Sole piece unsupported length between the propeller post and rudder post shall be as little as practicable.

Sternframe lower part shall be constructed with smooth rise above the base plane.

10.3.2.3 Stern tube wall thickness after machining shall not be less than the greater of the following values:
–60% of the propeller post cross-section breadth,
–30% of the propeller shaft diameter.

10.3.2.4 Thickness of the transom plate (see 10.3.1.1) and the additional transom plate shall be greater than that required for after peak floors by at least 2 mm.

10.3.2.5 Any section modulus of the sole piece related to the vertical axis, W_z, shall not be less than the value obtained in accordance with the following formula:

$$W_z = \frac{R_2 l_x}{100k} \quad [\text{cm}^3] \qquad (10.3.2.5)$$

where:

l_x – distance between the relevant cross-section and the rudder axle, [m]; the value of l_x taken for calculations shall fulfil the condition: $0.5l_1 \le l_x \le l_1$; for l_1 – see Fig. 10.3.2.5;

R_2 – assumed reaction force acting in the rudder lower bearing or in the bearing located in the sole piece of sternframe, determined in accordance with the requirements specified in *Part III – Hull Equipment*, for the ship speed not less than that specified for ships without ice strengthening, [N]; in general, $R_2 = 0.7\,F$, [N] may be taken,

F – assumed force acting on the rudder blade, [N], determined in accordance with the requirements specified in *Part III – Hull Equipment.*

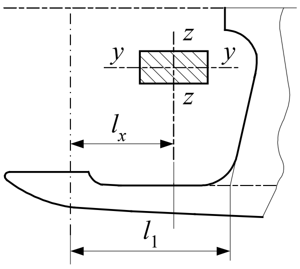


Fig. 10.3.2.5 Sternframe sole piece

10.3.2.6 In no cross-section, the sternframe sole piece sectional modulus, W_y, calculated for the horizontal neutral axis shall be less than that determined in accordance with the following formula:

$$W_y = 0.5W_z \quad [\text{cm}^3] \qquad (10.3.2.6)$$

where: W_z – determined in accordance with formula 10.3.2.5.

10.3.2.7 Any cross-section A of the sole piece shall be not less than either that determined in accordance with the requirements specified in paragraph 10.3.2.2 or that determined in accordance with the following formula:

$$A_s = \frac{R_2}{4800k} [\text{cm}^2] \qquad (10.3.2.7)$$

R_2 – see paragraph 10.3.2.5.

10.3.2.8 In no cross-section of the sole piece, shall the equivalent stress, σ_{zr}, exceed 115k, [MPa].

The stresses shall be determined in accordance with the following formulae:

$$\sigma_{zr} = \sqrt{\sigma^2 + 3\tau^2} \text{ [MPa]} \quad (10.3.2.8\text{-}1)$$

$$\sigma = \frac{R_2 l_x}{W_z} \text{ [MPa]} \quad (10.3.2.8\text{-}2)$$

$$\tau = \frac{R_2}{100 \cdot A_s} \text{ [MPa]} \quad (10.3.2.8\text{-}3)$$

σ_{zr} – equivalent stress, [MPa];
σ – normal stress, [MPa];
τ – shear stress, [MPa];
R_2, l_x, W_z – see paragraph 10.3.2.5;
A_s – see paragraph 10.3.2.7.

10.3.2.9 Dimensions of the cross-section of propeller post of the sternframe fitted with both upper and lower bearings shall be determined in accordance with Fig. 10.3.2.9-1 (for welded sternframe) or Fig. 10.3.2.9-2 (for steel cast sternframe) and with the following formulae:

– for welded sternframe:

$$t = 0.16L_0 + 6.4 \text{ [mm]} \quad (10.3.2.9\text{-}1)$$

$$l \geq 2.5L_0 + 160 \text{ [mm]}, \; b \geq 0.8\, l \quad (10.3.2.9\text{-}2)$$

$$t_w \geq 1.2\, t_p \text{ [mm]} \quad (10.3.2.9\text{-}3)$$

t_p – thickness of plating in way of sternframe;

– for steel cast sternframe:

$$t_1 = 0.15L_0 + 6.6 \text{ [mm]} \quad (10.3.2.9\text{-}4)$$

$$t_2 = 0.25L_0 + 11.0 \text{ [mm]} \quad (10.3.2.9\text{-}5)$$

$$t_3 = 0.35L_0 + 15.4 \text{ [mm]} \quad (10.3.2.9\text{-}6)$$

$$l \geq 1.9\, L_0 + 135 \text{ [mm]}, \; b \geq 0.8\, l \quad (10.3.2.9\text{-}7)$$

$$t_w \geq 1.2\, t_p \text{ [mm].} \quad (10.3.2.9\text{-}8)$$

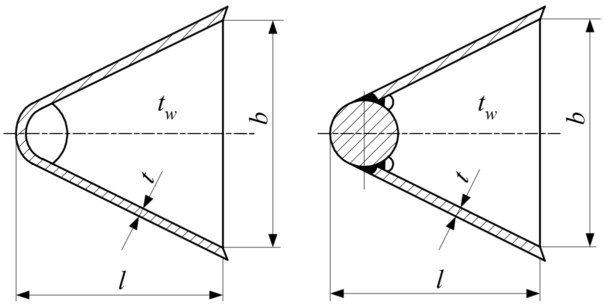


Fig. 10.3.2.9-1 Welded sternframe

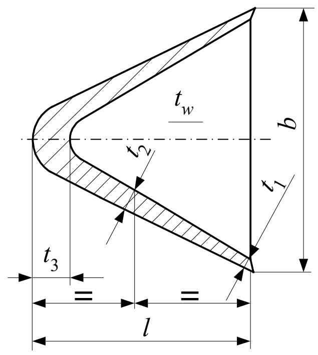


Fig. 10.3.2.9-2 Steel cast sternframe

10.3.2.10 Arrangement of strengthening brackets shall correspond to that of the framing system structural members. The brackets shall be applied with the spacing exceeding neither 0.6 m nor the frame spacing. Thickness of brackets shall exceed that of the plating in way of the sternframe by at least 20%.

10.3.2.11 Sternframe cross-section at the stern counter shall fulfil the requirements specified for welded sternframe.

10.4 Twin-screw Ship Sternframe

10.4.1 Structure

10.4.1.1 Sternframe structure and its connection to the ship hull shall fulfil the requirements specified in sub-chapter 10.3 to the extent corresponding to the specific considerations of the sternframe being dealt with in this sub-chapter.

10.4.1.2 Lower part of the sternframe shall extend forwards and its stiffener shall be connected to at least two floors.

10.4.1.3 Where two rudders situated aft of the screws and skeg situated in the centre plane are applied, the skeg side plating shall be welded to the flat bar – of a thickness not less than 1.5 times the plating thickness – situated in the centre plane (see Fig. 10.4.1.3).

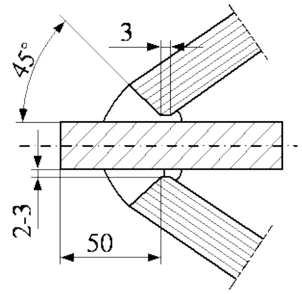


Fig. 10.4.1.3
Termination of skeg in the centre plane of twin-screw ship with two rudders

10.4.2 Scantlings

10.4.2.1 Rectangular sternframe cross-section shall not have dimensions less than the values obtained in accordance with the following formulae:

– length: $l = 1.00L_0 + 95$ [mm] (10.4.2.1-1)

– breadth: $b = 0.70L_0 + 9.0$ [mm] (10.4.2.1-2)

Sternframe cross-section in the stern counter may be gradually tapered to 50% of the above dimensions whereas the welded sternframe cross-section may be tapered to the dimensions required for the welded sternframe of single-screw ship.

10.4.2.2 Thickness of the transom plate shall be greater than that required for after peak floors by 2 mm.

10.4.2.3 Thicknesses of welded sternframe components shall not be less than the values determined in accordance with the following formulae (see Fig. 10.4.2.3):

$$t = 0.13L_0 + 5.5 \text{ [mm]} \quad (10.4.2.3\text{-}1)$$

$$t_1 \geq 1.15t \text{ [mm]} \quad (10.4.2.3\text{-}2)$$

Thickness t may be less by 15% than that required for the similar sternframe of single-screw ship with the spacing of transverse ribs not exceeding 0.75 m (see Fig. 10.4.2.3).

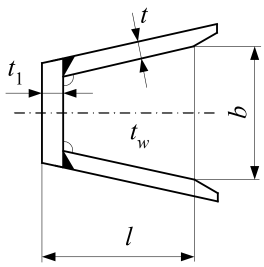


Fig. 10.4.2.3 Welded sternframe of twin-screw ship

10.4.2.4 Thicknesses of the components of steel cast sternframe in twin-screw ships may be less by 15% than that required for the similar sternframe of single-screw ship (see Fig. 10.3.2.9-2). The spacing of transverse ribs shall not exceed 1.0 m.

10.5 Propeller Shaft Brackets

10.5.1 Arms of two-armed shaft brackets shall be oriented at an angle around 90° to each other. Axes of their arms shall intersect on the propeller shaft axis.

10.5.2 Cross-section area of each arm of the shaft bracket shall not be less than 60% that of the propeller shaft in the bracket plane, the arm thickness – not less than 0.45 the shaft diameter, arm length – not less than 2.3 the shaft diameter, and the boss thickness – not less than 0.35 the shaft diameter.

The boss length shall be taken in accordance with the requirements specified in *Part VI – Machinery and Piping Systems*.

10.5.3 Cross-sectional area of a weld or rivets fixing each arm of the bracket shall not be less than 25% of the propeller shaft diameter.

Where bracket arms are fixed by flanges, the flange thickness shall not be less than 25% of the propeller shaft diameter.

10.5.4 Dimensions of fabricated shaft brackets and the arrangements fixing them to the hull shall not be less than those required in paragraphs 10.5.2 and 10.5.3.

Thickness of bracket plates, t_w, shall not be less than that determined in accordance with the following formula:

$$t_w = 0.15L_0 + 6 \text{ [mm]} \tag{10.5.4}$$

Construction of shaft brackets with their arms oriented an angle less than 80° or more than 100° and additional hull reinforcements in way of such brackets is subject to PRS consent in each particular case.

10.6 Keel

10.6.1 Dimensions of the bar keel cross-section shall not be less than the values obtained in accordance with the following formulae (see Fig. 10.6.1):

height: $h = 1.30L_0 + 95$ [mm] (10.6.1-1)

breadth: $b = 0.70L_0 + 7$ [mm] (10.6.1-2)

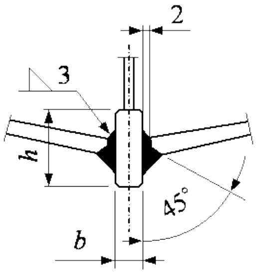


Fig. 10.6.1 Bar keel

Welds required for the connection of bottom plating to keel are shown in Fig. 10.6.1.

10.6.2 Flat keel breadth shall not be less than the values obtained in accordance with the following formula:

$$b = 600 + 5.0L_0 \text{ [mm]} \tag{10.6.2}$$

Flat keel thickness shall exceed – by at least 1 mm – the bottom plating thickness in the midship hull portion.

10.6.3 Box keel (see Fig. 10.6.3) is permitted unless its vertical wall thickness is less than 0.8 the bar keel breadth, b, determined in accordance with formula 10.6.1-2 and the lower plate thickness – less than bar keel breadth b. At every other frame space in the box keel, a membrane having thickness equal to that of floor shall be applied.

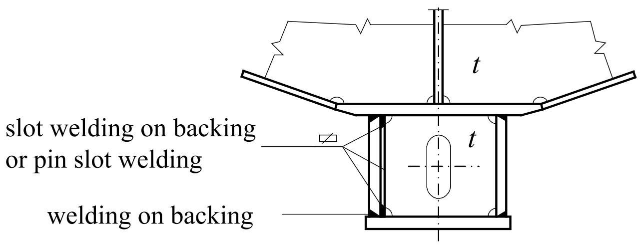


Fig. 10.6.3 Box keel

10.7 Distance between Screw and Hull

10.7.1 In single-screw ships, it is recommended that the distance from the screw blades and rudder to the hull be not less than those specified in Table 10.7.1 (see Fig. 10.7.1).

Values *a*, *b*, *c* and *e* specified in Table 10.7.1 also apply to ships with the underhung rudder.

Table 10.7.1
Minimum distance between the screw and single-screw ship hull

Dimension symbol	Distance between the screw blade and hull
a	0.10*D*
b	0.21*D*
c	0.18*D*
d	0.04*D*
e	200 ÷ 250 mm

D – screw diameter

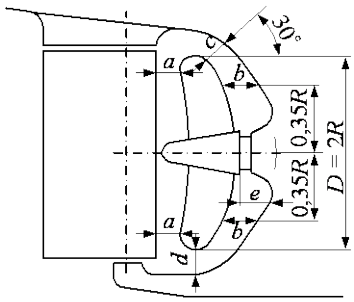


Fig. 10.7.1
Minimum distance from the screw blades and rudder to single-screw ship hull

10.7.2 In twin-screw ships, it is recommended that the distance from the propeller blade end to the hull and shaft bracket (see Fig. 10.7.2) be as long as practicable.

It is recommended that dimensions *f* and *g* (see Fig. 10.7.2) be not less than:

$$f = 0.20D \quad (10.7.2\text{-}1)$$

$$g = 0.20 \quad (10.7.2\text{-}2)$$

D – screw propeller diameter

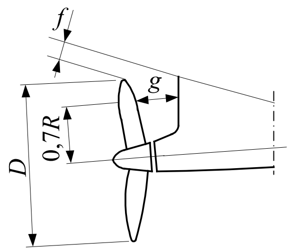


Fig. 10.7.2 Minimum distance between the screw and twin-screw ship hull

11 SEATINGS

11.1 General

11.1.1 The requirements specified in this Chapter apply to the construction of seatings for the main engines, boilers, and other heavy equipment located in the engine room as well as for deck, processing, cargo handling, auxiliary and other machinery.

11.1.2 Seatings of the main engine, gears and power generating sets shall have a robust and rigid structure attached to the structural members of the bottom, sides and decks so as to ensure the transmission of longitudinal and transverse – both static and dynamic – loads from such machinery to the hull structure (see also sub-chapter 5.4.6).

11.2 Structure and Scantlings of Structural Members

11.2.1 Seatings of Main Engines, Gears and Power Generating Sets

11.2.1.1 Seating shall consist, in general, of two longitudinal girders and horizontal bed plates for direct fixing of the engine, gear or generating set. Access to the seating structural members shall be provided for inspection and to prevent water from accumulation under the seating.

11.2.1.2 Where the single bottom side girder is also considered as the seating web, its thickness shall not be less than that required for the seating web or for the bottom centre girder. Reinforcements of the bottom floors required in way of a seating are specified in sub-chapter 5.4.6.

11.2.1.3 Thickness of the seating structural members shall not be less than the value determined in accordance with the following formulae:

– for low-speed engine, boiler or machinery component (specified in Table 11.2.1.3):

$$t = c_1 \sqrt[3]{M} + t_m \quad \text{[mm]} \qquad (11.2.1.3\text{-}1)$$

M – mass of engine, boiler or machinery component in operating condition, [t];
c_1 – factor to be determined in accordance with Table 11.2.1.3;
t_m = 4.0 mm – thickness allowance.

Table 11.2.1.3
Values of factor c_1

Machinery component	Foundation structure components		
	Horizontal plates (bed plates)	Web plates of longitudinal girders	Brackets, including console brackets [1)]
Main internal combustion engine	4.65	3.00	2.50
Electric main propulsion, generating set, electric propulsion motor	4.15	2.70	2.70
Boiler and other equipment of considerable mass	3.65	2.40	2.40

1) Console brackets – trapezoid brackets, three edges of which are attached to the seating structure members.

– for medium-speed engine:

$$t = c_2 \sqrt[3]{N} \quad \text{[mm]} \qquad (11.2.1.3\text{-}2)$$

c_2 = 2.3 for horizontal plate (bed plate);
c_2 = 1.6 for web plates of seating inner girders;
c_2 = 1.3 for web plates of girders, consoles and brackets;
N – engine rated power, [kW].

11.2.2 Deck Machinery Foundations

11.2.2.1 Foundation longitudinal girders welded to the deck or rounded sheer strake shall be positioned just over longitudinal deck girders. Construction of the foundation longitudinal girders shall provide for their smooth and continuous transition into the deck girders.

11.2.2.2 The method of connecting the foundation to the deck stringer upper surface is subject to PRS consent in each particular case.

11.2.2.3 Under the foundation, the deck plating shall be readily accessible for inspection. Foundation watertight construction having the enclosed space filled with an inert material of appropriate anti-corrosion characteristics may be applied subject to PRS consent in each particular case.

12 LOCAL STRENGTH AND STRUCTURE BUCKLING CONTROL

12.1 General

12.1.1 The requirements specified in this Chapter apply to the scantlings of plates, stiffeners, simple girders, pillars, supporting members, as well as to stiffener and girder brackets. These requirements, except those concerning the minimum scantlings, result from the local design loads on members in question.

12.1.2 Design load point – point at which the design pressure shall be determined.

The load point location shall be determined as follows:

– for horizontally stiffened plates: in the midpoint of non-stiffened field;
– for vertically stiffened plates: at the lower edge of the plate for unsupported edges (e.g. when the thickness is changed within the plate area), or in the distance equal to half of the stiffener spacing above the lower edge for supported edges;
– for stiffeners: in span midpoint; where the pressure distribution along the stiffener span is not linear, the design pressure shall be determined in the middle of the span and as the arithmetic mean of pressures at the stiffener ends, whichever is the greater;
– for girders: in the midpoint of the plating area supported by a girder.

12.2 Framing System

12.2.1 General

12.2.1.1 These provisions regard the transverse framing system of the bottom, sides and decks.

12.2.1.2 Longitudinal or combined framing system is subject to PRS consideration in each particular case.

12.2.2 Prescribed Spacing of Structural Members

12.2.2.1 Prescribed spacing of structural members, a_0, in the hull portion between the fore and after peaks is:

$$a_0 = 0.36 + 0.004\ L_0 \quad [\text{m}] \tag{12.2.2.1}$$

12.2.2.2 In the portion from the after peak to the section at $0.25L_0$ from *FP* (forwards), other spacing of structural members than prescribed spacing a_0 may be applied, the deviation, however shall not exceed 25%. Greater deviations are subject to PRS consideration in each particular case.

In the portion from the fore peak to the section at $0.25L_0$ from *FP* (aft) to the collision bulkhead, the spacing of structural members shall, generally, not exceed the prescribed value determined in 12.2.2.1. Application of greater spacing is subject to PRS consideration in each particular case.

12.2.2.3 Prescribed spacing of structural members in the fore and after peaks, a_{0s}, is as follows:

a_{0s} = 0.30 m for $L_0 < 15$ m;
a_{0s} = 0.33 m for $15 \text{ m} \le L_0 < 20$ m;

a_{0s} = 0.36 m for 20 m ≤ L_0 < 24 m.

12.2.2.4 In the fore and after peaks, other spacing of structural members than prescribed in 12.2.2.3, the deviation, however shall not exceed 10%. Greater deviations are subject to PRS consideration in each particular case.

12.3 Minimum Thicknesses

12.3.1 General

12.3.1.1 Minimum thicknesses determined in sub-chapter 12.3 apply to steel structural members and they take into account corrosion additions required in sub-chapter 2.5 for region B. Thicknesses of higher strength steel structural members are subject to PRS consideration in each particular case.

To determine minimum thicknesses of structural members within region A, the minimum thicknesses determined in accordance with the requirements specified in sub-chapter 12.3 shall be increased by the difference in the corrosion addition required in 2.5 for regions A and B.

If a ship is intended to be assigned additional mark **PAC** in the symbol of class (see 2.4.3), the minimum thicknesses of structural members determined in accordance with the requirements specified in sub-chapter 12.3 may be reduced by the corrosion addition value required in 2.5 for region B.

Unless minimum thicknesses of aluminium alloys structural members are clearly specified in the particular paragraphs of sub-chapter 12.3, they shall be determined in accordance with the requirements specified in 12.3.1.3.

12.3.1.2 Minimum thicknesses of the hull structural members contributing to the longitudinal strength, i.e. structural members of the bottom, decks and sides within $0.1H$ from the bottom and deck in the midship portion of the hull, shall not be less than the values determined in accordance with the following formulae:

– for steel: $t = 10.0\,a$ [mm] (12.3.1.2-1)
– for aluminium alloys: $t = 12.0\,a$ [mm] (12.3.1.2-2)
not less, however, than 3 mm unless otherwise specified elsewhere in *Part II*

a – stiffener spacing, [m].

If the stiffener spacing does not appear in the formulae for the minimum thickness specified in sub-chapter 12.3 and the applied stiffener spacing is different from that prescribed, a_0 or a_{0s}, then the minimum thickness of structural members shall be increased (or reduced) respectively by the value of Δt determined in accordance with the following formulae:

– between the fore and after peaks:

$$\Delta t = 5(a - a_0) \quad \text{[mm]} \qquad (12.3.1.2\text{-}3)$$

where:
a – stiffener spacing, [m];
a_0 – prescribed spacing determined in accordance with formula 12.2.2.1;

– in the fore and after peaks:

$$\Delta t = 5(a - a_{0s}) \quad \text{[mm]} \qquad (12.3.1.2\text{-}4)$$

where:
a_{0s} – prescribed spacing determined in accordance with the formulae specified in 12.2.2.3.

If $a < a_0$ and/or $a < a_{0s}$, the forebody plating thickness shall not be reduced within $0.2L_0$ from FP and (or) in way of the after peak.

12.3.1.3 Minimum thicknesses of aluminium alloy structural members shall be determined based on the minimum thicknesses of steel structural members obtained in accordance with the requirements specified in sub-chapters from 12.3.2 to 12.3.6 in accordance with the following formula:

$$t_{al} = \frac{t - t_k}{\sqrt{k_{al}}} \text{ [mm]} \qquad (12.3.1.3)$$

where:

t – minimum thickness of a structural member of normal strength structural steel NS, [mm],
t_{al} – required minimum thickness of aluminium alloy structural member, [mm],
k_{al} – material factor for aluminium alloy determined in accordance with formula 2.3.1.3,
t_k – corrosion addition, as required in sub-chapter 2.5 for region B, [mm].

12.3.2 Bottom Plating

Minimum thickness of the bottom plating:

– in the forebody, within $0.25L_0$ from FP:

$$t = 0.13L_0 + 2.5 \text{ [mm]} \qquad (12.3.2\text{-}1)$$

– elsewhere:

$$t = 0.10L_0 + 2.3 \text{ [mm]} \qquad (12.3.2\text{-}2)$$

12.3.3 Sideshell Plating

Minimum thickness of the sideshell plating:

$$t = 0.12L_0 + 2.3 \text{ [mm]} \qquad (12.3.3)$$

12.3.4 Deck Plating

Minimum thickness of the strength deck plating:

– between the ship side and the line of large openings and in the forebody:

$$t = 0.065L_0 + 3.2 \text{ [mm]} \qquad (12.3.4\text{-}1)$$

– in the line of large openings and in the afterbody:

$$t = 0.065L_0 + 2.7 \text{ [mm]} \qquad (12.3.4\text{-}2)$$

Minimum thicknesses of the second tier deck and platforms:

$$t = 0.05L_0 + 2.8 \text{ [mm]} \qquad (12.3.4\text{-}3)$$

12.3.5 Bulkhead Plating

Minimum thicknesses of:

– watertight bulkheads and lubrication oil tank bulkheads:

$$t = 0.05L_0 + 5a + 1.25 \text{ [mm]} \qquad (12.3.5\text{-}1)$$

not less, however, than:
t = 3.0 mm, for $L_0 < 20.0$ m,
t = 4.0 mm, for $20.0 \text{ m} \le L_0 < 24.0$ m,

– bulkheads of tanks other than lubrication oil tanks:

$$t = 0.05L_0 + 6.7a + 1.5 \text{ [mm]} \qquad (12.3.5\text{-}2)$$

not less, however, than 4.5 mm;

– non-watertight bulkheads:

$$t = 6.7a \text{ [mm]} \qquad (12.3.5\text{-}3)$$

not less, however, than 3.0 mm;

a – stiffener spacing, [m]; $a \le a_0$ to be taken for calculations;
a_0 – prescribed spacing of structural members, determined in accordance with formula 12.2.2.1.

12.3.6 Plating of Decks and Superstructure Walls

Minimum plating thicknesses of the side walls, end walls and decks of superstructures for:

– lower tier:
  – forward walls: $t = 0.02L_0 + 3.8$ [mm] (12.3.6-1)
  – other walls: $t = 0.02L_0 + 3.0$ [mm] (12.3.6-2)
– higher tiers:

$$t = 0.015L_0 + 2.6 \text{ [mm]} \quad (12.3.6\text{-}3)$$

– poop open deck, bridge open deck, forecastle open deck:

$$t = 0.04L_0 + 3.0 \text{ [mm]} \quad (12.3.6\text{-}4)$$

– other decks:

$$t = 0.03L_0 + 2.8 \text{ [mm]} \quad (12.3.6\text{-}5)$$

Subject to PRS consent, the minimum plating thickness of superstructure decks and wall may be reduced by:
up to 4 mm – for 20.0 m < $L_0 \le 24$ m,
up to 3 mm – for $L_0 \le 20$ m,
which does not apply to the fore walls of the lower tier and exposed poop deck in ships of $L_0 \ge$ 20.0 m.

12.3.7 Plating Adjoining Structural Members

Thickness of structural members adjoining the plating in way of the structures mentioned in sub-chapters from 12.3.2 to 12.3.6 shall not be less than the minimum plating thickness required in those regions, however not less than 4.0 mm.

12.4 Buckling Control of Structural Elements

12.4.1 Application

The requirements specified in sub-chapter 12.4 apply to the structural elements subjected to axial compressive stress (see sub-chapter 12.8).

12.4.2 Buckling Stress Criteria

Compressive stress shall not exceed critical stress, σ_c, determined in accordance with the following formulae:

$$\sigma_c = \sigma_E \text{ [MPa] for } \sigma_E \le \frac{R_e}{2} \quad (12.4.2\text{-}1)$$

$$\sigma_C = R_e\left(1 - \frac{R_e}{4\sigma_E}\right) \text{ [MPa] for } \sigma_E > \frac{R_e}{2} \quad (12.4.2\text{-}2)$$

where:
σ_E – ideal elastic compressive buckling stress, determined in accordance with the following formula:

$$\sigma_E = n0.001E\frac{I_\alpha}{Al^2} \text{ [MPa]} \quad (12.4.2\text{-}3)$$

$n = 1$ – where both ends are simply supported,
$n = 2$ – where one end is simply supported and the other one is fixed,
$n = 4$ – where both ends are fixed;

l – span of support, cross-tie or panting beam, [m];
I_α – moment of inertia of the compressed pillar, without the corrosion addition, about the axis perpendicular to the expected direction of buckling; for a support being a bulkhead component this is a moment of inertia about the axis parallel with such a bulkhead; for pillars not being connected to any plating this is the minimum moment of inertia of the pillar section (i.e. the principal central moment of inertia), [cm^4];
R_e – pillar material yield point, [MPa];
A – stiffener cross-sectional area, [cm].

12.5 Hull Plating

12.5.1 Application

The requirements specified in sub-chapter 12.5 shall be applied to determine scantlings of the plating panels subjected to pressure, unless other requirements are specified in chapters from 5 to 9.

12.5.2 Plating Thickness

Thickness of the plating subjected to lateral pressure shall be determined in accordance with the following formula:

$$t = 15.8a\sqrt{\frac{p}{\sigma}} + t_k \text{ [mm]} \qquad (12.5.2)$$

where:
a – stiffener spacing, [m];
p – design pressure acting on the plate in question, [kPa], to be determined in accordance with the recommendations specified in Chapter 14, [kPa];
σ – allowable stress, determined in accordance with the recommendations specified in 12.5.3, [MPa];
t_k – corrosion addition, determined in accordance with the recommendations specified in 2.5, [mm].

12.5.3 Allowable Stress

12.5.3.1 Allowable stress used in formula 12.5.2 shall be taken in accordance with Table 12.5.3.1. The values of σ in that table apply to the transverse framing system. For longitudinal framing system, the values of σ are subject to PRS agreement in each particular case.

Table 12.5.3.1
Allowable stress for plating panels

Item	Plating in way of:		σ [MPa]
1.	outer bottom 3):	– in the midship portion	110 k
		– in the fore and after peaks	160 k
2.	side shell 1), 2), 3):	– in the midship portion	130 k
		– in the fore and after peaks	160 k
3.	transverse watertight bulkheads 4)		
3.1	collision bulkhead plating		160 k
3.2	plating of other bulkheads		190 k
4.	longitudinal watertight bulkheads 1), 2)		140 k
5.	tank bulkheads		
5.1	ballast tank bulkhead plating		140 k
5.2	plating of other than ballast tanks		140 k

Item	Plating in way of:	σ [MPa]
6.	strength deck plating [3]: – in the midship portion – in the fore and after peaks	100 k 160 k
7.	superstructure decks, 'tween deck and platforms	140 k

1) Values of σ in way of the neutral axis of the hull cross-section are given. Above and below the neutral axis, the σ shall be linearly reduced (if the material factor is constant) to the values for the deck and bottom plating assuming the same stiffening direction and the material factor as for the plating in question.

2) If a bulkhead or side forms the boundary of tank for which design pressure p has been determined in accordance with 14.3.2.2 as p_2, than the allowable stress may be increased to σ = 160 k, [MPa].

3) The values of allowable stress for the regions between the midship portion and peaks shall be determined by linear interpolation.

4) Design pressures shall be determined in accordance with 14.3.2.1.

12.6 Stiffeners

12.6.1 Sectional Modulus

Unless otherwise provided in chapters from 5 to 9, sectional modulus of the stiffeners of the plating of decks and bulkheads, together with the effective strake of plating determined in accordance with the requirements specified in sub-chapter 3.2.2 shall not be les than that determined in accordance with the following formula:

$$W = \frac{1000apl^2}{m\sigma} w_k \quad [\text{cm}^3] \qquad (12.6.1\text{-}1)$$

however not less than 5 cm^3;

a – stiffener spacing, [m];

p – design pressure determined in accordance with the requirements specified in Chapter 14 (see also 12.1.2), [kPa];

l – stiffener span determined in accordance with the requirements specified in sub-chapter 3.2.1, [m];

m – bending moment factor, each time determined in the chapters regarding construction of the relevant regions of the ship hull;

σ – allowable stress of the values taken in accordance with Table 12.6.2.1 or specified in chapters from 5 to 9;

w_k – corrosion addition factor.

The value of factor w_k for rolled section stiffeners shall be taken as follows:

– for angle bars, T-bars, I-bars and channel bars:

$$w_k = 1 + 0.1t_k \qquad (12.6.1\text{-}2)$$

– for bulb bars:

$$w_k = 1 + 0.06t_k \qquad (12.6.1\text{-}3)$$

t_k – corrosion addition, see sub-chapter 2.5 or 2.6.

Where corrosion addition is not required, w_k = 1 (see sub-chapter 2.5 and 2.6).

Where flat bars or fabricated sections are used as stiffeners, the required value of sectional modulus shall be determined in accordance with formula 12.6.1-1 for w_k = 1, and then the stiffener wall thickness shall be increased by corrosion addition required in sub-chapter 2.5.

12.6.2 Allowable Stress

12.6.2.1 Allowable stress of stiffeners shall be taken in accordance with Table 12.6.2.1 – for stiffeners of hulls with transverse system of stiffeners. For longitudinal system of stiffeners, the values of σ are subject to PRS agreement in each particular case.

Table 12.6.2.1
Allowable stress for stiffeners

Item	Region of stiffeners and load type	σ [MPa]
1.	Frames	
1.1	Main frames – load induced by outside pressure	185 k
1.2	Main frames – load induced by stores and ballast	140 k
1.3	Main frames – load induced by hydrostatic pressure at $T = T_{max}$	120 k
1.4	Frames on ‘tween deck – load induced by outside pressure	185 k
1.5	Frames on ‘tween deck – load induced by stores and ballast	140 k
1.6	Frames in superstructures	160 k
2.	Transverse watertight bulkheads – load induced by ballast, liquid cargo or in damaged condition	
2.1	Collision bulkhead stiffeners – load induced by ballast or liquid cargo	160 k
2.2	Collision bulkhead stiffeners – in damaged condition	160 k
2.3	Stiffeners of other bulkheads – load induced by ballast or liquid cargo	160 k
2.4	Stiffeners of other bulkheads – in damaged condition [1)]	190 k
3.	Stiffeners of longitudinal bulkheads stiffened transversely – load induced by ballast, liquid cargo or in damaged condition [1)]	140 k
4.	Deep tank bulkheads	
4.1	Vertical stiffeners	140 k
4.2	Tank top horizontal stiffeners	140 k
5.	Strength deck beams and ‘tween deck beams [2)]:	
5.1	– in the midship portion	140 k
5.2	– in the fore and after peaks	160 k
6.	Superstructure deck beams	160 k

[1)] Design pressures shall be determined in accordance with the requirements specified in 14.3.2.1.
[2)] Allowable stress values between the midship portion and peaks shall be determined by linear interpolation.

12.6.2.2 Stiffeners and plating shall generally be of steel with the same yield stress. If the stiffener is of a greater value of yield stress than that of the plating, then the value of σ corresponding to the plate material shall be applied. If the calculated stress in the plating is less than the applicable limit, the value of σ for the stiffener may be multiplied by a factor determined in accordance with the following formula:

$$f_k = \frac{k_u}{k_p} \tag{12.6.2.2}$$

where:
k_u – stiffener material factor;
k_p – plating material factor.

12.6.3 Buckling Strength of Stiffeners

Proportions of the scantlings of stiffener webs and flanges shall fulfil the following conditions to make their buckling strength acceptable:

– for steel:

webs:
$$\frac{h_s}{t_s} \leq \frac{60}{\sqrt{k}} \tag{12.6.3-1}$$

flanges:
$$\frac{b_m}{t_m} \leq \frac{15}{\sqrt{k}} \tag{12.6.3-2}$$

– for aluminium alloys:

webs
$$\frac{h_s}{t_s} \leq \frac{50}{\sqrt{k_{al}}} \tag{12.6.3-3}$$

flanges $$\frac{b_m}{t_m} \leq \frac{12}{\sqrt{k_{al}}} \qquad (12.6.3\text{-}4)$$

where:
h_s, t_s – web net height and thickness, [mm];
t_m – net thickness of flange, flat bar, angle bar flange etc., [mm];
b_m – part of flange width (angle bar flange etc.) extending beyond the web on the one side (for asymmetrical web this is the greater dimension of the extending parts), [mm].

For flat bars used as stiffeners, the criteria for stiffener webs apply.

12.7 Girders

12.7.1 Strength of Girders

12.7.1.1 The requirements regarding the strength and construction of simple girders (e.g. web frames, deck stringers, hatch end beams, etc.) are specified in chapters from 5 to 7.

In the cases not covered by the provisions of chapters from 5 to 7 or for the structures considered by PRS as atypical, scantlings of girders shall be determined by direct calculations.

12.7.1.2 Allowable stress values for service loads as specified in Chapter 14 for net scantlings of girders and effective strakes of plating (i.e. exclusive of the corrosion additions required in sub-chapter 2.5) determined by direct calculations are as follows:
– bending stress: σ = 160 k, [MPa];
– mean shear stress in web (for the effective cross-sectional area determined in accordance with 3.2.3): τ = 90 k, [MPa];
– equivalent stress: σ_{zr} = 180 k, [MPa].

Equivalent stress shall be determined in accordance with the following formula:

$$\sigma_{zr} = \sqrt{\sigma^2 + 3\tau^2} \qquad (12.7.1.2)$$

where:
σ – normal stress, [MPa];
τ – mean shear stress in web, [MPa].

12.7.1.3 For longitudinal girders, PRS may require reduction of allowable stress values σ specified in 12.7.1.2 to take the stress due to hull girder bending into account.

12.7.1.4 Net thicknesses of girder webs and girder flanges shall be increased by corrosion additions in accordance with the requirements specified in 2.5.

12.7.2 Buckling Strength of Girders

Proportions of the scantlings of girder webs and flanges shall fulfil the following conditions to make their buckling strength acceptable:
– for steel:

webs: $$\frac{h_s}{t_s} \leq \frac{60}{\sqrt{k}} \qquad (12.7.2\text{-}1)$$

flanges: $$\frac{b_m}{t_m} \leq \frac{15}{\sqrt{k}} \qquad (12.7.2\text{-}2)$$

– for aluminium alloys

webs: $$\frac{h_s}{t_s} \leq \frac{50}{\sqrt{k_{al}}} \qquad (12.7.2\text{-}3)$$

flanges: $$\frac{b_m}{t_m} \leq \frac{12}{\sqrt{k_{al}}} \qquad (12.7.2\text{-}4)$$

where:

h_s, t_s, – web net height and thickness, [mm];

t_m – flange net thickness, [mm];

b_m – part of flange width extending beyond the web on the one side (for asymmetrical web this is the greater dimension of the extending parts), [mm].

12.8 Pillars and Supporting Members

12.8.1 Application

The requirements specified in sub-chapter 12.8 apply to members subjected to compressive axial stresses: deck pillars, vertical stiffeners and bulkhead girders supporting deck structures, panting beams in peaks and cross-ties in tanks.

12.8.2 General Requirements

12.8.2.1 Deck stringers and web frames shall be strengthened with brackets in way of their connection to pillars.

12.8.2.2 Pillars shall be arranged on bottom floors, bottom girders or on their intercrossings.

12.8.2.3 In addition to pillars supporting deck girders, additional pillars may be required under deckhouses, windlasses, etc.

12.8.3 Pillars and Supporting Stiffeners

12.8.3.1 Compressive stress σ in pillars, cross-ties and supporting stiffeners to be determined in accordance with the following formula:

$$\sigma = \frac{10P}{Ak_1} \text{ [MPa]} \qquad (12.8.3.1\text{-}1)$$

shall not exceed the critical buckling stress σ_c determined in accordance with the requirements specified in 12.4.2, where:

A – pillar cross-sectional area [cm²];

$$k_1 = \frac{k_2}{1+\frac{l}{i}}, \text{ however not less than 0.3;} \qquad (12.8.3.1\text{-}2)$$

$k_2 = 0.5$ – for supporting members of weather deck within $x \geq 0.4\ L_0$, as well as for cross-ties and panting beams in side tanks and peaks,

$k_2 = 0.6$ – for supporting members of weather deck when sea loads are applied,

$k_2 = 0.7$ – in other cases;

$i = \sqrt{\frac{I_\alpha}{A}}$ – radius of gyration of the supporting member net cross-section, [cm];

I_α – moment of inertia, without corrosion allowance, about the axis perpendicular to the expected direction of buckling, i.e. perpendicular to the plating, [cm⁴];

l – span of a pillar, cross-tie or panting beam, [m];

P – design axial force in pillar determined in accordance with the following formula:

$$P = b\, l_1\, p + \textstyle\sum_i (b\, l_1\, p)_i \text{ [kN]} \qquad (12.8.3.1\text{-}3)$$

p – design pressure on decks determined in accordance with 14.2.2.3 or 14.4, [kPa];

$\sum_i (b\, l_1\, p)_i$ – the sum of loads induced by the pillars located above which may transmit the load on the pillar in question;

l_1 – distance measured on deck stringers between their mid-span points, [m];

b – average breadth of deck portion supported by the pillars, taking account of the cargo hatches in the relevant hull portion, [m].

12.8.3.2 Wall thickness of tubular pillars shall not be less than that determined in accordance with the following formula:

$$t = \frac{D}{50} + 3.0 \quad \text{[mm]} \qquad (12.8.3.2)$$

D – pillar outside diameter, [mm].

12.8.3.3 Web thickness of pillars made of sections (box sections, channel sections, I-sections, etc.) shall not be less than that determined in accordance with the following formula:

$$t = \frac{b}{50} \ \text{[mm]} \qquad (12.8.3.3)$$

b – pillar web height, [mm].

12.8.3.4 Pillar wall thickness shall not, in general, be less than 4.5 mm, however the required cross-sectional area of the pillar shall be maintained.

12.8.4 Bulkhead Pillars

Stiffeners of bulkheads supporting decks shall be considered as pillars which are subject to the requirements specified in 12.8.3.1 and the radius of gyration of the stiffener cross-section shall be determined taking into account the effective strake of plating having 20t in width on each side of the stiffener, where t represents the bulkhead plating thickness, [mm]. The requirements specified in 12.8.3.3 shall also be fulfilled.

12.8.5 Pillars in Tanks

12.8.5.1 If hydrostatic load may induce tensile stress in the pillar, cross-sectional area, A_p, of such a pillar shall not be less than the value determined in accordance with the following formula:

$$A_p = 0.07 F_p p_p \ [\text{cm}^2] \qquad (12.8.5.1)$$

F_p – pillar-supported area, [m^2];
p_p – design pressure inducing tensile stress in pillar, [kPa].

12.8.5.2 Pillars in tanks shall be constructed of bars, plates or open sections.

12.8.5.3 Pillars shall be fixed with brackets at their both lower and upper ends.

12.9 Brackets

12.9.1 Application

The requirements specified in sub-chapter 12.9 apply to brackets connecting stiffener and girder ends to other structures.

12.9.2 Bracket Ends of Stiffeners

12.9.2.1 All types of stiffeners shall, in general, be connected at their ends with brackets (see Fig. 12.9.2.1). In special cases, bracketless connections may be allowed, e.g.:

- stiffener end joint is welded with full penetration or an increased fillet weld is made;
- stiffener lower end is fixed with continuous flat bar welded to the stiffener face plates and to the plate on which the stiffener terminates;
- stiffener ends are snipped (see 12.9.2.2).

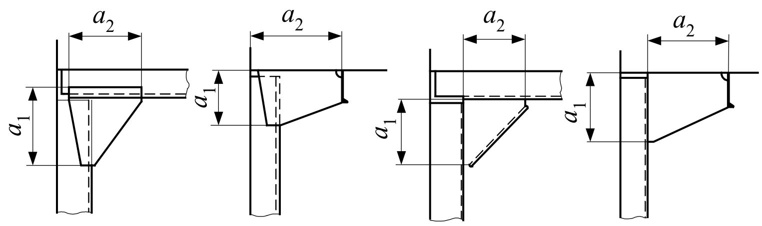


Fig. 12.9.2.1 Bracket ends of stiffeners

12.9.2.2 Stiffeners with snipped ends may be used in the areas where low dynamic loads may be expected and where vibration is insignificant. The condition is that the supported plating thickness be not less than that determined in accordance with the following formula:

$$t = 1.25\sqrt{\frac{(l-0.5a)ap}{k}} + t_k \text{ [mm]} \qquad (12.9.2.2)$$

where:
l – stiffener span, [m];
a – stiffener spacing, [m];
p – design pressure acting on the plating supported by the relevant stiffener, [kPa].

12.9.2.3 Sectional modulus of the stiffener defined in 12.9.2.2 shall be determined in accordance with formula in 12.6.1-1 taking m =7.5 and σ = 140k, [MPa].

12.9.2.4 Bracketless connections may be used for stiffeners which are continuous through structural members (web frames, deck girders, bulkheads) provided that adequate welded joints are applied.

12.9.2.5 It is recommended that brackets be made of a material having the same yield point as the material of the attached structural members.

12.9.2.6 Bracket thickness, t_w, shall not be less than that determined in accordance with the following formula:

$$t_w = \frac{3+k_1\sqrt{W}}{\sqrt{\frac{k_w}{k_u}}} + t_k \quad \text{[mm]} \qquad (12.9.2.6)$$

where:
W – prescribed sectional modulus of the smaller stiffener, [cm^3];
k_1 = 0.2 for brackets with flange or face plate on the free edge,
k_1 = 0.3 for brackets without flanges or face plates;
k_w – bracket material factor (see 2.2 and 2.3);
k_u – stiffener material factor (as above);
t_k – corrosion addition, determined in accordance with sub-chapter 2.5 or 2.6.

The applied bracket thickness, t_w, shall not be less than that of the connected stiffeners' webs, however not less than 5 mm unless provided otherwise elsewhere in the *Rules*.

12.9.2.7 Characteristic bracket arm length a_w determining the required values of a_1 and a_2 as shown in Fig. 12.9.2.1 shall not be less than that calculated in accordance with the following formula:

$$a_w = c\sqrt{\frac{W}{t_w}} \quad \text{[mm]} \qquad (12.9.2.7)$$

where:
W, t_w – see 12.9.2.6;
c = 70, for brackets with flange or face plate on the free edge,

c = 75, for brackets without flanges or face plates.

Arm length, a_w, of the brackets connecting structural members shall not be less than 1.5 times the depth of the stiffener web connected. If the bracket arms have different lengths a_1 and a_2 , their sum shall not be less than $2a_w$ and the length of the shorter arm shall not be less than $0.75a_w$.

Height of the bracket triangle shall not be less than $0.75a_w$ or the length of its one or both arms shall be increased. If structural members are interconnected by welded joints and brackets have face plates or flanges (see patterns b) and c) in Fig. 12.9.2.7), the bracket arms may be reduced by 25%.

In areas where increased vibration of stiffener connection – e.g. of the shell plating and deck plating – may be expected, such connections shall be arranged in accordance with patterns a), b) or c) shown in Fig. 12.9.2.7. In pattern as shown in Fig. 12.9.2.7 c) where one stiffener's end is welded to the plating and to the other stiffener, face plates of stiffeners having a form of an angle bar or T-bar shall have snipped ends in way of the connection.

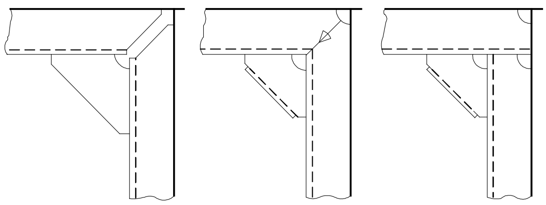


Fig. 12.9.2.7
Recommended patterns of stiffener connections in areas where increased vibration may be expected

12.9.2.8 Where the bracket free edge length is more than $50t_w$ (t_w – bracket thickness), such an edge shall have a flange or face plate of the width not less than that determined in accordance with the following formula:

$$b = 40(1 + \frac{W}{1000}) \text{ [mm]} \quad (12.9.2.8)$$

not less, however, than 50 mm; for W – see 12.9.2.6.

12.9.2.9 Free ends of bracket asymmetrical face plates or flanges shall be snipped to the width not greater than 15 mm. The length of the snipped part shall be approximately the same as the width of face plate. Free ends of bracket symmetrical face plates shall be snipped on both sides at the angle of 30°, and the snipped part height shall not exceed $3t_w$.

12.9.3 End Connections of Girders

12.9.3.1 Ends of girders or connections between girders forming frame systems shall be provided with brackets. Bracketless connections may be applied, provided adequate support of adjoining face plates is arranged.

12.9.3.2 Thickness of the girder brackets shall not be less than that of the girder web plate.

12.9.3.3 Girder brackets shall have along their free edges the face plates with cross-sectional area not less than:

$$A_{mw} = l_w t_w \text{ [cm}^2\text{]} \quad (12.9.3.3)$$

where:
l_w – bracket free edge length, [m];
t_w – bracket thickness, [mm].

12.9.3.4 Bracket arm length, increased by the girder depth, shall be determined in accordance with formula 12.9.2.7, taking into account the following:
W – required section modulus of the girder connected with bracket, [cm³];
t_w – bracket thickness, [mm];
c = 63 for bracket of bottom and deck girders,
c = 88 in other cases.

13 LONGITUDINAL STRENGTH

13.1 General

For steel ships of typical main dimensions' ratios and intended service (see 1.1.2), the minimum level of longitudinal strength is ensured by structural members whose scantlings are determined in accordance with the local strength criteria and the criteria for minimum thickness of those structural members. For such steel ships, calculation of hull longitudinal strength.

Where such ratios as L:H or B:H are beyond the limits defined in 1.1.2, the requirements specified in sub-chapters from 13.2 to 13.4 are to be complied with.

Where the hull loads are found by PRS to be extraordinary, the hull longitudinal strength is subject to PRS consideration in each particular case.

13.2 Hull Section Modulus

Hull section modulus in the midship portion of the ship determined in accordance with sub-chapter 13.5 related to the strength deck and keel shall not be less than that determined in accordance with the following formula:

$$W_0 = \frac{C_1 C_{RP}}{k} L_0^2 B(\delta + 0.7)\ [\text{cm}^3] \qquad (13.2\text{-}1)$$

C_1 – coefficient determined in accordance with the following formula:

$$C_1 = 34{,}3 - [665 - (33 - L_0)^2]^{0{,}5} \qquad (13.2\text{-}2)$$

C_{RP} – intended operating area coefficient taking the following values:
- operating area **I** C_{RP} = 0.95,
- operating area **II** C_{RP} = 0.90,
- operating area **III** C_{RP} = 0.85;

δ – block coefficient, to be taken as $\delta \geq 0.6$.

The required sectional modulus minimum value shall be maintained within $-0.2L_0 \leq x \leq 0.2L_0$. The value may be reduced gradually from the midship portion of the ship both aftwards and forwards to the values resulting from the local strength criteria.

13.3 Moment of Inertia of Hull Cross-section

Moment of inertia of the hull cross-section shall not be less than:

$$I_n = 3W_0 L_0\ [\text{cm}^4] \qquad (13.3)$$

where:
W_0 – see 13.2.

13.4 Strength Deck Cross-sectional Area

Strength deck cross-sectional area in the midship portion of the ship shall not be less than:

$$A = \frac{0.114 L_0^2 B}{H}\ [\text{cm}^2] \qquad (13.4)$$

A represents the total cross-sectional area of the strength deck plating together with the continuous longitudinal structural members between hatch openings and ship sides.

13.5 Geometrical Data on Hull Cross-section as Built

13.5.1 Section Modulus and Moment of Inertia of Hull Section

For ships with continuous longitudinal hatch coamings or other continuous structural members above the strength deck, the prescribed hull sectional modulus determined for the gross thickness of structural members (i.e. taking account of the corrosion additions) shall be related to the line situated above the neutral axis at the distance calculated in accordance with the following formula:

$$z_t = (z_n + z_a)(0.9 + 0.2\frac{y_a}{B}) \text{ [m]} \quad (13.5.1)$$

not less, however, than z_n, where:
z_n – distance between the hull neutral axis and strength deck, [m];
z_a – vertical distance between the relevant member and strength deck, [m];
y_a – horizontal distance between the relevant member and centre plane, [m].

Coordinates y_a and z_a of the point shall be so selected that the obtained value of z_t reach its maximum.

13.5.2 Determining Influence of Openings on Effective Cross-Sectional Area of Hull

13.5.2.1 Smaller openings (manholes, lightening holes), as well as ineffective sections of cross-sectional area of longitudinal structural members (situated within an ineffective area of plating defined in 13.5.2.3, in way of stiffener ends or longitudinal member ends, holes in their webs, etc.) need not be deducted when calculating the cross-sectional area of these members, provided that the sum of their breadths in one transverse section does not reduce the section modulus at deck or bottom by more than 3%. The height of these openings in longitudinals and longitudinal girders shall not exceed 25% of the web depth (75 mm for scallops), and the distance between single openings or groups of openings along the stiffener (girder) shall not be less than 10 times the height of opening.

The sum of breadths of smaller openings in one transverse section of bottom or deck, equal to $0.06(B - \Sigma b_i)$ (Σb_i – the sum of breadth of openings), may be considered as equivalent to the above reduction in section modulus.

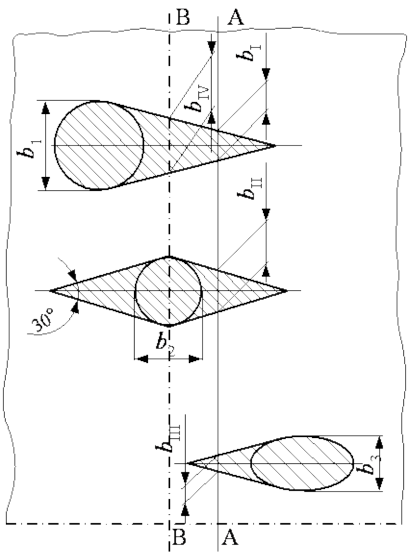


Fig. 13.5.2.1 Examples of determining the influence of openings on the effective sectional area

13.5.2.2 When calculating the total breadth of openings in one cross-section, the openings are assumed to have longitudinal extension as shown by the shaded areas in Fig. 13.5.2.1, inside tangents at angle 30° to each other, and symmetric about the longitudinal axis.

For instance, the total design breadth of openings in section A–A is: $b_{AA} = b_{\mathrm{I}} + b_{\mathrm{II}} + b_{\mathrm{III}}$, and in section *B–B*: $b_{BB} = b_2 + b_{\mathrm{IV}}$.

13.5.2.3 Cross-section area of openings which are subject to deduction may be compensated by increased plate thickness, additional longitudinal stiffeners or increase of sectional area of existing longitudinals or girders in way of the opening so that the sectional modulus related to the bottom or deck be not less than the required value by more than 3%. Compensation shall be extended respectively beyond the opening edge.

14 LOCAL LOADS OF STRUCTURE

14.1 Application

In this Chapter, the method of determining the design values of local loads applicable for scantling of the plating, plating stiffeners, structural members and pillars in the hull structure is presented. These are external pressures acting on the ship hull, internal pressures induced by liquids (water ballast, stores, liquid cargo), as well as loads induced by general cargo and heavy units.

For ships with speed in still water not less than 7.19 $\nabla^{0.1667}$, [knots], the loads determined in Chapter 20 shall be taken into account.

∇ represents the ship displacement corresponding to the moulded waterline, [m^3].

14.2 Sea Pressure

14.2.1 General Requirements

14.2.1.1 Loads may be exerted from both sides on the plating under consideration and the structural members supporting such plating. The loads shall be determined independently and higher values shall be taken as design loads. In special cases, the design load can be taken as the difference between the loads imposed on both sides of the plating if both of them are imposed simultaneously.

14.2.1.2 Tanks for crude oil or diesel oil shall be designed for liquids of density equal to that of sea water:

$$\rho = 1.025 \ \mathrm{t/m^3}.$$

14.2.1.3 The structure of tanks for heavier liquids is subject to PRS consideration in each particular case. In such cases, the density applied as the basis for approval is entered by PRS in the *Certificate of Class*.

14.2.1.4 Sea pressures or coefficients taking into account, in the formulae, local dynamic loads on structures may be reduced for restricted service ships as follows, unless otherwise specified elsewhere in the *Rules*:
– for operating area **II** – by 10%,
– for operating area **III** – by 15%,
– for passeneger ships assigned mark **Pass C** – by 20%,
– for passeneger ships assigned mark **Pass D** – by 30%.

14.2.2 External Pressure Acting on Ship Hull

14.2.2.1 Sea Pressure in Midship Portion Acting on Ship Bottom and Ship Side

Sea pressure in midship portion acting on the bottom and side shell plating shall be determined in accordance with Fig. 14.2.2.1.

For single deck ships (Fig. 14.2.2.1-*a*):

$$p = \rho g(H_{1p} - z) + p_{d1} \text{ [kPa]} \qquad (14.2.2.1\text{-}1)$$

H_{1p} – moulded depth, [m];
z – vertical coordinate of the point where pressure is being determined, [m] (see Fig. 1.2.2.1);
p_{d1} – design pressure on open deck, to be determined in accordance with formula 14.2.2.3.

For double deck ship (Fig. 14.2.2.1-*b*):
– for $z \le H_0$ $p = \rho g\,(H_0 - z) + p_{d1}$ [kPa] (14.2.2.1-2)
– for $z > H_0$ $p = p_{d1} + \frac{z - H_0}{H_{2p} - H_0}(p_{d2} - p_{d1})$ [kPa] (14.2.2.1-3)
where:
H_0 – design height taken as the greater value out of the following, [m]:

$$H_0 = 0.65H_{2p} \qquad (14.2.2.1\text{-}4)$$

$$H_0 = 1.3T \qquad (14.2.2.1\text{-}5)$$

H_{2p} – moulded depth, [m];
p_{d1} – pressure acting on the ship side at height H_0, equal to the design pressure on open deck determined in accordance with formula 14.2.2.3 for $H = H_0$ [kPa];
p_{d2} – design pressure on open deck determined for in accordance with formula 14.2.2.3 for $H = H_{2p}$ [kPa];
ρ = 1.025 [t/m^3] – sea water mass density.

The values of p_{d1} and p_{d2} for restricted service ships may be reduced in accordance with the requirements specified in 14.2.1.4. For high-speed ships, the requirements specified in 20.3.1 shall be taken into account.

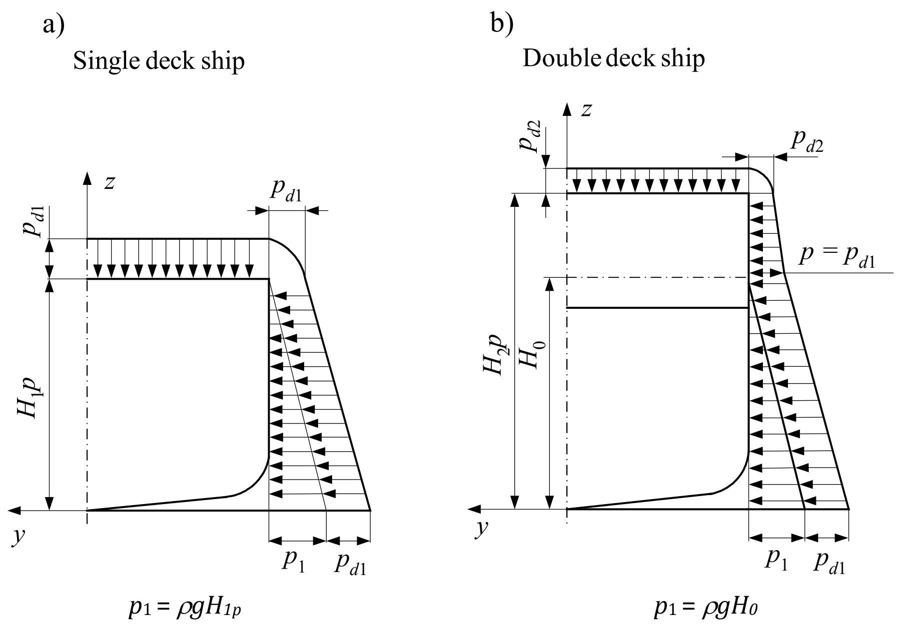


Fig.14.2.2.1 Sea pressure distribution in the midship portion

14.2.2.2 Sea Pressure in Afterbody and Forebody

Sea pressure in the afterbody and forebody shall be determined like in the midship portion of the ship, however it shall be increased by Δp, to be calculated in accordance with the following formula:

$$\Delta p = \rho g k_f L_0 \quad \text{[kPa]} \qquad (14.2.2.2)$$

where:

ρ = 1.025 [t/m²] – sea water mass density;

k_f – coefficient to be determined in accordance with the diagram in Fig. 14.2.2.2, in relation to x/L ratio.

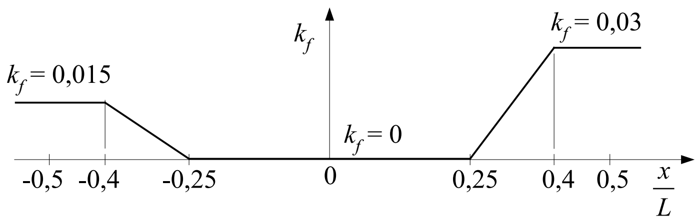


Fig.14.2.2.2 Sea pressure distribution ratio in the afterbody and forebody

14.2.2.3 Open Deck Design Load

Design load of open decks shall be determined in accordance with the following formula:

$$p = u_0(0.08L_0 + 13\frac{T}{H} - 5) \quad \text{[kPa]} \qquad (14.2.2.3)$$

where:

u_0 – coefficient to be determined in accordance with Table 14.2.2.3.

For ships with length L_0 < 15 m, the value of p shall be determined like for those of 15 m in length.

The value of $\frac{T}{H}$ taken for calculations in accordance with formula 14.2.2.3 shall not be less than 0.65, however it need not exceed 0.80.

Table 14.2.2.3
Coefficient u_0

Item	Open deck type	u_0
1.	Upper deck and forecastle deck within $0.2L_0$ from *FP*	1.15
2.	Upper deck at distance more than $0.2L_0$ from *FP* afterwards	1.00
3.	Midship superstructure deck of more than $0.15L_0$ in length, and poop deck covering machinery space	0.90
4.	Poop deck	0.80
5.	Midship superstructure deck of less than $0.15L_0$ in length	0.75
6.	Deckhead of the first tier deckhouse and deckhead of the second tier superstructure	0.60
7.	Deckhead of the second tier deckhouse	0.45
8.	Deckhead of the third and higher tiers' deckhouse	0.30

For single deck ships without the forecastle with the forward sheer, pressure p calculated for u_0 in accordance with item 1 in Table 14.2.2.3 shall be increased by 3 kPa.

Design load of upper open decks in restricted service ships determined in accordance with formula 14.2.2.3 may be reduced in accordance with the requirements specified in 14.2.1.4.

14.2.3 Loads of Sheltered Decks not Intended for Cargo Carriage

For sheltered decks not intended for the carriage of cargo (decks in enclosed spaces) the design pressure shall be taken equal to 0.35 t/m^2.

PRS may agree that the above mentioned load be reduced to 0.25 t/m^2 after an analysis of the particular spaces.

14.2.4 External Pressure on Outer Boundaries of Superstructures

The design pressure shall be determined in accordance with the following formulae:

– for the forward boundary: $p = 17.0 + 0.07L_0$ [kPa] (14.2.4-1)

– for other boundaries: $p = 8.5 + 0.07L_0$ [kPa] (14.2.4-2)

14.3 Pressure of Liquids in Tanks

14.3.1 If tanks intended for the carriage of liquids may be either filled or empty, then the design pressures acting on their particular boundary structures shall be determined in accordance with 14.3.2. The boundary structures are the structures of: inner and outer bottom, ship sides, bilge, platform decks, watertight walls (bulkheads) of any location in the ship hull. These structures may form common boundaries of adjacent tanks and in that case such boundaries shall be considered as a separate boundary of each tank.

14.3.2 Design Pressure for Watertight Bulkheads and Tank Bulkheads

14.3.2.1 Design pressure for watertight bulkheads shall be determined in accordance with the following formula:

$$p = \rho g h \quad \text{[kPa]} \tag{14.3.2.1}$$

where:

ρ = 1.025 t/m^3;

h – vertical distance measured from the load application point to the bulkhead top, [m].

The pressure value taken for scantling of the bulkhead stiffeners and members shall not be less than 15 kPa.

14.3.2.2 Design pressure for tank bulkheads shall be taken as the maximum of the values determined in accordance with the following formulae:

$$p_1 = \rho(g + 0.5a_v)h_a \quad \text{[kPa]} \tag{14.3.2.2-1}$$

$$p_2 = 0.67\rho g h_p \quad \text{[kPa]} \tag{14.3.2.2-2}$$

$$p_3 = \rho g h_a + p_0 \quad \text{[kPa]} \tag{14.3.2.2-3}$$

where:

ρ – mass density of liquid, [t/m^3]; to be taken as $\rho \ge 1.025$ t/m^3;

a_v – vertical acceleration, to be determined in accordance with the requirements specified in 15.3, [m/s^2];

h_a – vertical distance measured from the load application point to the top of tank, [m];

h_p – vertical distance measured from the load application point to the vent pipe top end, [m];

p_0 – safety valve activating pressure, [kPa], to be taken not less than 15 kPa.

14.4 Solid Cargo Loads

14.4.1 General Cargo Loads

Pressure acting on cargo decks and ship bottom due to the general cargo or equipment shall be determined in accordance with the following formula:

$$p = (g + 0.5a_v)q \text{ [kPa]} \tag{14.4.1}$$

a_v – vertical acceleration, to be determined in accordance with the requirements specified in 15.3, [m/s^2];

q = ρh – cargo or equipment mass, [t], related to 1 m^2 of loaded surface;
ρ – mass density of cargo acting on the relevant surface, [t/m^3].

Unless there are other indications, ρ = 0.7 t/m^3 shall be taken for general cargo. Where, as a result of the application of ρ = 0.7 t/m^3 for all cargo areas designed for the carriage of general cargoes, the ship's deadweight is exceeded, the assumed value of ρ may be reduced subject to PRS consent in each particular case. If the mass of deck exceeds 10% of the cargo mass assumed for this deck, then, when determining the value q for this deck, account shall be taken of the mass of deck and the mass of cargo carried on the deck;

h – height of cargo tier loading acting on the relevant structure, [m].

For cargo hold bottom structures, as well as the structures of sheltered decks designed for the carriage of general cargo, height h shall be measured vertically from the load point to the deck above and in way of hatchways – to the top of the coaming.

14.4.2 Bulk Cargo Loads

If a ship is capable of carrying bulk cargoes, strength of the hull structure within cargo spaces shall be checked taking design pressures determined in accordance with the following formula:

$$p = \rho h_a (g + 0{,}5a_v)K \quad \text{[kPa]} \tag{14.4.2-1}$$

where:

ρ – cargo mass density determined in accordance with formula 14.4.2-3, [t/m^3];
h_a – vertical distance measured from the load application point to the hatch coaming, [m];
a_v – vertical acceleration determined in accordance with the requirements specified in 15.3, [m/s^2];

$$K = \sin^2\alpha \cdot \text{tg}^2(45 - 0{,}5\,\gamma) + \cos^2\alpha \tag{14.4.2-2}$$

α – angle between the relevant panel and horizontal plane, [degrees];
γ – cargo repose angle [degrees], to be taken as follows:
$\gamma \le 20°$ – for light bulk cargo (coal, grain, etc.),
$\gamma \le 25°$ – for cement,
$\gamma \le 35°$ – for heavy bulk cargo (ores).

The value of ρ shall be determined in accordance with the following formula:

$$\rho = \frac{M_c}{V_h} \text{ [t/m}^3\text{]} \tag{14.4.2-3}$$

M_c – the maximum total mass of cargo aboard, [t];
V_h – total volume of cargo holds, [m^3].

The value of ρ >0.7 t/m^3 shall be taken for calculations.

15 SHIP ACCELERATIONS

15.1 Application

The formula specified in this Chapter allow for calculation of the design vertical accelerations of ship hull used in sub-chapters 14.3 and 14.4 to determine design loads due to liquid and solid cargoes.

15.2 Determining Coefficients C_w and C_v

15.2.1 Wave coefficient, C_w, shall be determined in accordance with the following formula:

$$C_w = 0.0792L_0 \quad (15.2.1)$$

For restricted service ships, wave coefficient C_w may be reduced as follows:
– for operating area **II** by 10%,
– for operating area **III** by 30%.

15.2.2 Coefficient C_v shall be determined in accordance with the following formula:

$$C_v = 0.02\sqrt{L_0} \quad (15.2.2)$$

15.3 Resultant Vertical Acceleration

Resultant vertical acceleration, a_v, shall be determined in accordance with the following formula:

$$a_v = \frac{k_v g a_0}{\delta} \text{ [m/s}^2\text{]} \quad (15.3\text{-}1)$$

where:
k_v – coefficient taking the following values:
k_v = 1.3 for $x \le -0{,}5L_0$;
k_v = 0.7 for $-0{,}3L_0 \le x \le 0{,}2L_0$;
k_v = 1.5 for $x \ge 0{,}5L_0$
in the intermediate portions of the ship hull $-0.5L_0 \le x \le -0.3L_0$, and $0.2L_0 \le x \le 0.5L_0$, the value of k_v varies linearly (see Fig. 15.3);

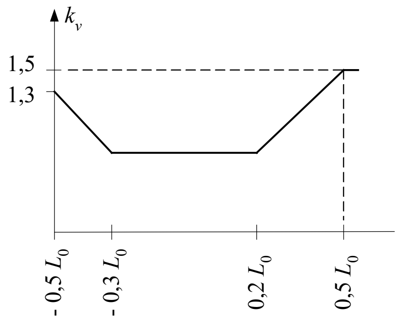


Fig. 15.3 Diagram of coefficient k_v

a_0 – general parameter of acceleration, [m/s²], to be determined in accordance with the following formula:

$$a_0 = \frac{3C_w}{L_0} + \frac{C_v v}{\sqrt{L_0}} \text{ [m/s}^2\text{]} \quad (15.3\text{-}2)$$

C_w – wave coefficient, to be determined in accordance with formula 15.2.1;
C_v – coefficient determined in accordance with formula 15.2.2.

16 PASSENGER SHIPS

16.1 Application

The requirements specified in this Chapter apply to passenger ships intended to be assigned additional mark **pas A**, **pas B**, **pas C** or **pas D** in the symbol of class.

16.2 General

16.2.1 Ship intended to be assigned additional mark **pas A, pas B, pas C** or **pas D** in the symbol of class shall fulfil the requirements of chapters from 2 to 15 specified for operating area **III**.

Ships intended for service in ice conditions shall fulfil additional requirements specified in Chapter 21.

The ship hull, structural bulkheads, decks, and superstructures as well as oil fuel tanks shall be constructed of steel or equivalent materials.

The requirements of the UE Parliament and Council Directive 2009/45/EC regarding the ship subdivision into watertight compartments shall be fulfilled.

Additionally ships should comply with the requirements of 3 Chapter II-1, parts A-1 and B of *Publication 100/P as far as practicable and reasonable.*

16.2.2 In the fore peak and after peak transverse bulkheads as well as bulkheads forming boundaries of machinery spaces, no doors, manholes or access openings shall be arranged.

16.2.3 Design load for decks in passenger spaces shall not be less than 4.5 kPa.

16.2.4 Ship sides shall be protected with fenders. Exemplary construction patterns of fenders are shown in Fig. 16.2.4.

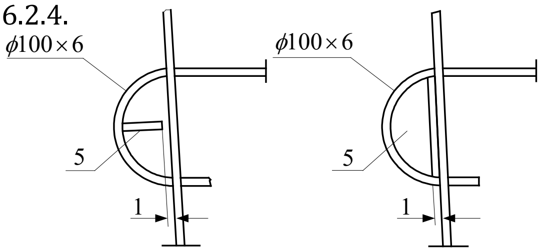


Fig. 16.2.4 Fenders

17 FISHING VESSELS

17.1 Application

The requirements specified in Chapter 17 apply to fishing vessels with steel or aluminium hulls intended to be assigned additional mark **sr** in the symbol of class.

17.2 General

Structural elements not covered in Chapter 17 shall fulfil the requirements specified in chapters from 2 to 15.

17.3 Structure and Scantlings of Structural Members

17.3.1 General

Scantlings of structural members shall not be less than the respective scantlings specified in chapters from 4 to 11.

17.3.2 Height of Bow and Stern

17.3.2.1 In fishing vessels, bow and stern height shall be determined in accordance with the requirements of *Part IV – Stability and Freeboard*.

17.3.2.2 Forecastle length shall not be less than 1.5 m.

17.3.2.3 Forecastle shall be enclosed if its length is more than $0.075L_0$. The forecastle portion extending beyond its fore part of the length of $0.075L_0$ may be open if freeing ports are arranged in accordance with the requirements specified in 9.5.

17.3.3 Keel, Stem, Sternframe

17.3.3.1 It is recommended that the bar keel be arranged in accordance with the requirements specified in 10.6.1, and if the design length of vessel is less than 12 m, L_0 = 12 m shall be taken for calculations. The stem scantlings so determined shall be maintained throughout the length of vessel.

It is recommended that the bar stem be arranged in accordance with the requirements specified in 10.2.2.1, and if the design length of vessel is less than 12 m, L_0 = 12 m shall be taken for calculations.

17.3.3.2 Dimensions of the propeller post with rectangular cross-section shall be determined in accordance with the requirements specified in 10.3.2.1, and if the design length of vessel is less than 12 m, L_0 = 12 m shall be taken for calculations.

17.3.4 Bulkheads

In ships of a length $L_0 \leq 12$ m, access to the chain locker may be arranged in the forward collision bulkhead by means of a manhole provided with the watertight closing appliance. The manhole shall be situated above the waterline. The manhole construction and its closing appliance are subject to PRS approval in each particular case.

17.3.5 Cargo Holds

17.3.5.1 In cargo holds of ships having a length L0 ≤ 12 m, face plates or flanges need not be used on the upper edge of floors required in 5.3.2.3 if the cargo hold bottom is covered with concrete up to the upper edge of such floors.

17.3.5.2 If cargo holds intended for the storage of salted fish or salt in bulk are not tightly lined with metal sheets, then the thickness of the inner bottom plating, and bottom plates of the transverse watertight bulkheads forming the hold boundaries, the thickness of the web and face plate/flange of the bottom centre girder web as well as side girders and floors shall be greater by 1 mm than the values required in 5.3.

17.3.5.3 Where tight lining of cargo hold interior is made with stainless steel plates (e.g. AISI 316L – EN X2CrNiMo17-12-2 or similar), all the enclosed spaces shall be filled with an inert material of appropriate anti-corrosion characteristics. If the cargo hold is to be heat-insulated, polyurethane foam may be used to fill such spaces. Drain plugs shall be provided to enable tightness tests and subsequent filling the enclosed spaces with foam.

Tight lining of the cargo holds is understood as overlapping plates welded to the structure of the bottom, ships side, bulkhead, deck as well as additional support structure welded to them.

17.3.6 Processing Spaces

17.3.6.1 In processing spaces where the deck plating is subjected to the effect of refuse of processed fish and sea water, the plating thickness shall be greater by 1 mm than that required in 12.3 and 12.5.

17.3.6.2 Plating thickness shall be greater by 1 mm than that required in 12.3 and 12.5 in the spaces where salted fish or salt in bulk is stored. In way of decks, the plating of transverse bulkheads forming boundaries of the processing spaces shall be increased in thickness by 1 mm to a height of at least 500 mm above the deck plating.

17.3.6.3 Sectional modulus of beams and longitudinals of the deck, on which the processing gear is located, shall be determined for design load taken in accordance with Chapter 14, not less, however, than that determined in accordance with the following formula:

$$p = 15\frac{M}{F} \quad \text{[kPa]} \qquad (17.3.6.3)$$

M – mass of processing gear, [t];
F – deck area in way of the processing gear, [m^2].

17.3.7 Bulwark Stays

On fishing vessels bulwark stays shall be applied at least at every other frame.

17.4 Stern Trawlers

17.4.1 Stern Ramp Structure

17.4.1.1 Stern after part shall be strengthened by additional longitudinal and transverse members (frameworks, beams, divisions, etc.).

17.4.1.2 Ramp side walls in their after parts shall be extended downwards as far as practicable to the shell plating whereas in their upper and fore parts the ramp side walls shall be connected to the after peak bulkhead. The walls and longitudinal members of the ramp shall pass smoothly into the deck structural members.

17.4.1.3 If fish is intended to be pulled on deck by trawl, longitudinal framing system is recommended under the ramp plating. In that case, web frames supporting the deck longitudinals under the ramp plating shall be arranged with the spacing not exceeding 4 times the frame spacing. The spacing of ramp longitudinal stiffeners shall not exceed 600 mm.

17.4.1.4 Where there is a ramp, a flat form of the lower part of the stern counter shall be avoided. The connection of the side walls of the ramp with transom plating, deck plating and bottom part of stern counter plating shall be rounded with a radius not less than 100 mm. The connection by means of a round rod of not less than 20 mm in diameter is permitted. It is recommended that vertical protective belts in the form of semicircular steel bars be fixed in way of the rounded walls. In way of transition of the ramp plating into deck plating, a horizontal roll may be applied.

17.4.2 Ramp Plating

Ramp plating thickness shall be greater than that required in 12.3 and 12.5 for the shell plating in peaks. The plating thickness shall be increased by at least 5 mm at the ramp rounding in the transom lower portion and the transom upper portion in way of the working deck and by at least 3 mm in its middle portion.

In no case the ramp plating thickness shall be less than 8 mm.

17.4.3 Ramp Deck Framing

Sectional moduli of deck beams and deck longitudinals under the ramp plating shall be determined in accordance with the requirements specified 12.6.1 taking the greater value of the following two ones:

$$p = 6.5b \text{ [kPa]} \quad (17.4.3\text{-}1)$$

$$p = 25 \text{ [kPa]} \quad (17.4.3\text{-}2)$$

where:

b – ramp width, [m]. If the width of the ramp is changed within its length, the least width shall be taken for calculations.

The following values of coefficient m shall be taken for calculations:
10.0 – for deck beams and deck transverse girders,
9.0 – for deck longitudinals.

The allowable stress σ is 175k, [MPa].

17.4.4 Ramp Wall Plating

Ramp wall plating thickness below the working deck shall not be less than that required for the shell plating in ship ends.

If the pulling device construction or ramp construction prevents wear and tear of plating or side walls while pulling the nets, thickness allowances required in 17.4.2 need not be applied.

17.4.5 Framing of Ramp Walls

Sectional modulus of the ramp side wall stiffeners shall be determined in accordance with the requirements specified in 12.6.1, taking load p in accordance with the requirements specified in 17.4.3, σ = 160k, [MPa] and m = 12.0. The applied value of l shall not be less than 2.0 m.

Stiffener ends shall be fixed with brackets. Bracket dimensions shall be determined in accordance with the requirements specified in 12.9.2.

17.4.6 After End Strengthenings

Thickness of the transom plating shall be by at least 1 mm greater than that required in 5.3.1 and 6.3.1 for the shell plating at ship ends.

The transom plating shall be protected against wear and tear by means of diagonally welded halfround steel rods.

17.5 Side Trawlers

17.5.1 In way of each gallow (see 17.5.2) the following strengthenings shall be provided:

.1 intermediate frames extending from the upper deck to the level not less than 0.5 m below the ballast waterline, having the section modulus not less than 75% of that required by 6.3.3 for 'tween deck frames (or main frames – where lower deck is not arranged). Upper and lower ends of intermediate frames shall be attached to longitudinal intercostal members fitted between the main frames. These members shall be fitted in a straight line. The upper intercostal members shall be fitted at a distance not exceeding 250 mm;

.2 bulwark stays fitted at every frame;

.3 structural member thickness shall be increased as follows:
– sheer strake – by at least 2 mm greater than that required in 6.3.1.1;

– deck stringer – by at least 3 mm greater than that required in 7.7;
– bulwark – by at least 2 mm greater than that required in 9.4.2;

.4 steel bars of semicircular section welded diagonally to side plating (above the ballast waterline level), sheer strake and bulwark.

17.5.2 The gallow ship portion is considered as the area of deck, side and bulwark extending between the sections located beyond the gallow end by 3 frame spacings fore and aft.

17.6 Wet Fish Well Construction

If a wet fish well is provided on board the ship, then the deck structure shall be strengthened respectively.

17.7 Freeing Ports

Fish ponds and other means of storage and handling the fishing gear shall be so arranged as not to damage freeing ports, not to retain water and not to obstruct free influx of water to the freeing ports (see also 9.5).

18 TUGS

18.1 Application

18.1.1 The requirements specified in Chapter 18 apply to ships intended to be assigned additional mark hol in the symbol of class.

18.1.2 Unless otherwise specified in this Chapter, the requirements specified in chapters from 1 to 15 apply, however, draught $T = 0.9H$ shall be assumed while scantling the structural members.

18.2 Structural Arrangement

18.2.1 Sternframe

Dimensions of the propeller post with rectangular cross-section required in 10.3 shall be increased by at least 20%. For the propeller post with another cross-section, its sectional modulus shall be equal to that required for the rectangular cross-section specified above.

18.2.2 Side Fenders

Fenders of adequate strength made of steel or rubber sections shall be fitted at deck level throughout the ship (if the upper part of the ship side is additionally stiffened). It is recommended that the design of sides in tug provide for the pressure caused by external objects being distributed over the largest possible area.

18.2.3 Machinery Casings

18.2.3.1 Machinery casings not protected by superstructures or deckhouses shall extend above the deck by at least 900 mm to be measured from the upper edge of deck or cover, if applied.

18.2.3.2 Scantlings of skylight coamings shall be as in exposed casings.

18.2.3.3 Where the length of casing is greater than the ship breadth, it is recommended that a continuous transverse deck girder be fitted in the mid-length of the casing. Unless such a deck girder is applied, the construction of casing and deck strengthening in way of the coaming is subject to PRS consideration in each particular case.

18.2.4 Superstructures and Bulwarks

All superstructures, deckhouses and companionways located on the deck shall be provided with weathertight closing appliances.

Superstructures, bulwarks and other arrangements on the deck shall be so retracted from the ship side that they do not protrude beyond the deck outline at the heel of:
10° – for tugs with operating area **I**, **II** or **III**;
15° – for harbour-and-roadstead service tugs.

18.2.5 Companionway Coamings, Sidescuttles

18.2.5.1 Companionways from the open deck to spaces located below shall have coamings not less than 600 mm in height, to be measured from the upper edge of deck or cover, if applied.

18.2.5.2 Tugs intended for harbour-and-roadstead service shall not have sidescuttles.

18.2.6 Strengthening in Way of Towing Arrangements

18.2.6.1 Foundations in way of the towing hook, towing winch and towing bollards shall be properly connected to the structure of ship hull or superstructures, particularly with girders.

18.2.6.2 Plating thickness in way of the foundations of the above mentioned arrangements shall be greater by at least 60% than the values required in 12.3, 7.3.1 or 9.3.1.

18.3 Scantlings of Structural Members

18.3.1 Plating

18.3.1.1 Deck plating thickness shall fulfil the requirements specified in 12.3 for the minimum thicknesses. If, however, the width of opening in the strength deck for machinery casing exceeds $0.6B_1$, then the deck cross-sectional area in the midship portion of the hull required in 13.4 shall be provided.

B_1 represents the minimum breadth of ship along the opening for machinery casing.

18.3.1.2 Plating thickness and sectional modulus of stiffeners of machinery casings not protected by deckhouses shall be greater by at least 20% than the values required for both the thickness and modulus of the deckhouse walls.

19 RESCUE SHIPS

19.1 Application

19.1.1 The requirements specified in Chapter 18 apply to ships intended to be assigned additional mark rat in the symbol of class.

19.1.2 Unless otherwise specified in this Chapter, the requirements specified in chapters from 1 to 15 apply.

19.2 Structural Arrangement

19.2.1 Bow Height

Rescue ships shall have the height of bow and stern determined in accordance with the requirements of *Part IV – Stability and Freeboard*.

19.2.2 Superstructures

19.2.2.1 In superstructures, the fore bulkhead and side wall of the first tier shall be of robust construction and fulfil the requirements specified in Chapter 9, and the number and size of window openings shall be as small as possible.

19.2.2.2 Brackets at the ends of stiffeners of the fore and after bulkheads shall be connected to the nearest deck beams.

19.2.2.3 If the wheelhouse front bulkhead is inclined forwards in relation to the line perpendicular to the waterline, the sectional modulus of stiffeners and plating thickness shall be greater by at least 20% than the values required in Chapter 9.

19.2.3 Manhole Means of Closing

19.2.3.1 Vertical communication route covering the wheelhouse shall have weathertight means of closing at the upper deck level and companionways providing access to the compartments located under the upper deck. They shall be capable of being open and closed from both sides.

19.2.3.2 Exits from the wheelhouse to the port side and starboard side as well as to the navigation deck shall have weathertight means of closing.

19.2.3.3 All closing appliances of openings in the hull, superstructures and deckhouses shall fulfil the requirements specified in *Part III – Hull Equipment*.

19.2.4 Fender

19.2.4.1 Ship sides shall be protected with fenders. Recommended construction patterns of fenders are shown in 16.2.4 and 18.2.2.

19.2.4.2 Rubbing strakes or rolls shall be provided in the areas exposed to the hull increased wear and tear due to the friction of ropes, movements of rescue boat or contact with another ship.

19.2.5 Additional Equipment

If a ship is fitted with towing arrangements, they shall fulfil the requirements specified in 18.2.6.

20 HIGH SPEED CRAFT

20.1 Application

The requirements specified in Chapter 20 apply to ships whose speed fulfils the following condition:

$$2.7\sqrt{L_W} \leq v \leq 4{,}5\sqrt{L_W} \qquad (20.1.1\text{-}1)$$

and is not less than:

$$v = 7.19 \cdot \nabla^{\,0{,}1667} \qquad (20.1.1\text{-}2)$$

v – ship speed in still water, [knots];
L_W – see 1.2.2;
∇ – ship displacement corresponding to the moulded waterline, [m³].

If the ship speed $v < 2.7\sqrt{L_W}$, and the rise of floors is less than 12°, or if $v > 4.5\sqrt{L_W}$ – then the loads of bottom and sides are subject to PRS consideration in each particular case.

20.2 Structural Arrangement

20.2.1 Deck

For ships with the deck transverse framing system where $\frac{v}{\sqrt{L_W}} > 3.1$, PRS may require additional strengthening of the deck.

20.3 Loads

20.3.1 In the formulae for determining the bottom and side shell plating thickness as well as sectional moduli of the bottom framing and side framing, the values of design pressure *p* determined in accordance with the following formulae shall be used rather than those determined in accordance with the requirements specified in 14.2.2:
– pressure acting on the ship bottom:

$$p = 9.81 k_V k_d (0.007 v^2 + 0.008 v \sqrt{L_W} + 0.2162 L_W) \quad \text{[kPa]} \qquad (20.3.1\text{-}1)$$

where:
k_d – coefficient depending on coordinate *x* (see Fig. 20.3.1-1);

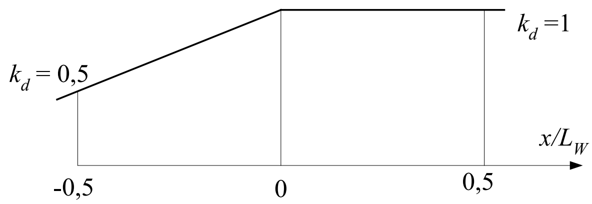


Fig. 20.3.1-1 Coefficient k_d for the bottom

k_v – coefficient depending on the ship speed:
– for $2.7\sqrt{L_W} < v < 3.1\sqrt{L_W}$: $k_v = \left[2.5\frac{V}{\sqrt{L_W}} - 6.75\right]$; (20.3.1-2)
– for $3.1\sqrt{L_W} \le v < 4.5\sqrt{L_W}$: $k_v = 1$; (20.3.1-3)
v – see 20.1.1;

– pressure acting on the ship sides:

$$p = 7.85 k_v k_d (0.007 v^2 + 0.008 v \sqrt{L_W} + 0.2162 L_W) \quad \text{[kPa]} \qquad (20.3.1\text{-}4)$$

k_d – coefficient depending on coordinate *x* (see Fig. 20.3.1-2);

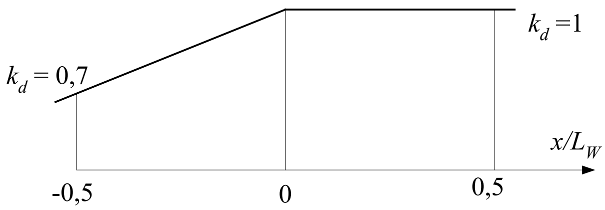


Fig. 20.3.1-2 Coefficient k_d for the sides

k_v – as above.

20.3.2 In formula 5.3.2.3.5 for determining the sectional modulus of floors, the value of T_1 shall be increased by ΔT to be determined in accordance with the following formula:

$$\Delta T = k_v k_d 0{,}008 v \sqrt{L_W} \quad \text{[m]} \qquad (20.3.2)$$

where:
k_v, v – see 20.3.1;
k_d – coefficient for the ship bottom, see Fig. 20.3.1.-1.

21 ICE AND SPECIAL STRENGTHENING

21.1 General

21.1.1 Application

The requirements specified in Chapter 21 apply to ships with ice strengthening intended to be assigned additional mark **Lm1** or **Lm2** in the symbol of class.

Application of strengthening which enables the ship navigation in worse ice conditions than those allowable for marks **Lm1** and **Lm2** is permitted. In that case PRS specifies requirements relevant to such strengthening and the respective additional mark is included in the symbol of class.

21.1.2 Definitions and Symbols

For the purpose of Chapter 21, the following additional definitions and symbols have been introduced:

Ice belt – the part of the shell plating to be reinforced.

Ice strengthening forward region – region extending aft of the stem for the distance ($b + a$), [m], where:

b – distance from *FP* to the forward borderline of the part of the hull where the waterlines run parallel to the centre plane or to the line of the maximum waterline breadth at the level 0.5 m above the load waterline if the ship has no cylindrical insert;

a – frame spacing in the midship portion of the ship, [m].

LWL – *load waterline* – line on the side shell plating determined by the maximum draught at the stern, amidships and bow (this may be a broken line);

BWL – *ballast waterline* – line on the side shell plating determined by the minimum draught at the stern and bow.

21.2 Construction and Scantlings of Ice Strengthening Marked with Lm1

21.2.1 Ice Belt

21.2.1.1 Ice belt shall extend vertically from 0.5 m above LWL to 0.5 m below BWL and longitudinally – it covers the whole ice strengthening forward region, as defined in 21.1.1.

21.2.1.2 If any portion of the ship bottom is closer than 0.5 m from *BWL*, the bottom plating thickness in such a portion shall be the same as the ice belt thickness, and the lower ends of frames shall extend as close as practicable to the keel.

The ice belt thickness shall be greater than the side shell plating determined in accordance with the requirements specified in 6.3.1.1 by at least 25%, however, not less than by 1.5 mm.

21.2.2 Frames

21.2.2.1 Frame sectional modulus and fixing of frame ends shall be in accordance with the requirements specified in 6.3.3 and 6.2.2.

21.2.2.2 Frame sectional modulus in the fore and after peaks shall be greater by at least 20 % than that required in 6.3.3.

21.2.3 Intermediate Frames

21.2.3.1 Within the ice belt defined in 21.2.1, intermediate frames shall be fitted in accordance with the following requirements:
- aft of the collision bulkhead their sectional modulus shall not be less than 75% of that of the frames in the respective portion of the ship,
- in the fore peak, forward of the collision bulkhead the intermediate frames shall have the same sectional modulus as the frames in the respective portion of the ship.

21.2.3.2 Lower ends of the intermediate frames in the fore peak shall extend as close to the keel as practicable.

21.2.3.3 Intermediate frames shall intersect the line passing at the level of floor face plates and extend to the bilge strake lower edge.

21.2.3.4 Intermediate frame upper ends shall extend at least to the level 650 mm above *LWL* and be connected to the longitudinal intercostal members fitted between the main frames. These members shall be located in a straight line.

3.5.2.5 Intermediate frames terminating at the deck need not be welded to such deck.

21.2.4 Side Stringer

In the forward portion of the ship, within (b + 4a) from *FP*, side stringer shall be applied at the level between 200 and 300 mm below *LWL* (b, a – see 21.1.3). In the region from the collision bulkhead to the section located at the distance of (b + 4a) from *FP*, the side stringer may be intercostal, and its depth shall be equal to that of the frames.

The side stringer need not be applied if other longitudinal stiffener of the ship side has been used (e.g. a platform).

21.2.5 Stem

Stem, made of bent plates, shall have thickness greater by at least 20% than that of the ice belt up to the level 0.6 m above *LWL*. Above that level, the stem thickness may be reduced gradually to the shell plating thickness at the deck.

21.3 Construction and Scantlings of Ice Strengthening Mark Lm2

21.3.1 Ice Belt

Ships shall have an ice belt of the extent and thickness specified in 21.2.1 – for ice strengthening mark **Lm1**.

21.3.2 Frames and Intermediate Frames

21.3.2.1 Ships may have ice strengthening without intermediate frames (the requirements relevant to that case are specified in 21.3.2.2) or with intermediate frames (see 21.3.2.3).

21.3.2.2 Frame spacing within 0.075 L_0 from *FP* shall not exceed the prescribed spacing of structural members in fore and after peaks specified in 12.2.2.3.

Sectional modulus of frames shall be determined in accordance with 6.3.3 taking the prescribed spacing of structural members specified in 12.2.2.1 for the region between fore and after peaks.

21.3.2.3 Within 0.075 L_0 from *FP*, frames with scantlings determined in accordance with the requirements specified in 6.3.3 may be applied together with intermediate frames.

Lower ends of intermediate frames shall extend to the level at least 600 mm below *BWL*, whereas the upper ends – to the level at least 600 mm above *LWL*.

Upper ends shall be fixed to the longitudinal intercostal members applied between frames.

Intercostal frames shall have a sectional modulus not less than 75% of the value required for the fore peak frames.

21.3.3 Side Stringer

Side stringer of the extent and construction specified in 21.2.4 for ice strengthening **Lm1** shall be applied.

22 GLASS-REINFORCED PLASTIC SHIP HULLS

22.1 General

22.1.1 Application

The requirements specified in Chapter 22 apply to ships with hull made of glass reinforced plastic. Construction of ship hulls made of other plastics is subject to PRS consideration in each particular case.

22.1.2 Definitions and Symbols

For the purpose of Chapter 22, the following additional definitions and symbols have been introduced:

grp – glass reinforced plastic;

T – *moulded draught,*[m] – for glass reinforced plastic ship hulls, the following value shall be taken for calculation:

$$T \geq 0.66H.$$

Effective strake – the strake of plating to be taken for determining the values of sectional moduli and moments of inertia of the cross sections of structural members. Its breadth equals to 1/2 of the distance between the nearest structural members located on both sides of the structural member in question or has the value determined in accordance with formula 22.1.2-1 – whichever is lesser (see Fig. 22.1.2).

$$b = 18\,t + e \text{ [cm]} \tag{22.1.2-1}$$

t – plating thickness, [cm];
e – width of stiffener at the plating, [cm].

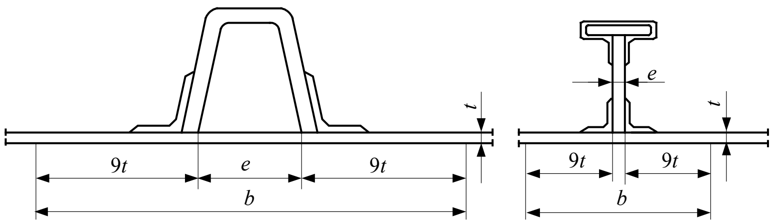


Fig. 22.1.2 Breadth of effective strake of plating

For a stiffener located at the edge of plating, it shall be taken as:

$$b = 9\,t + e \text{ [cm]} \tag{22.1.2-2}$$

For plating made of sandwich laminate with the core ineffective for bending, thickness t shall be taken in the above formulae like for monolithic plating having the same bending stiffness (E_gI) as sandwich laminate plating.

In this Chapter the following symbols have also been adopted:
M_z – prescribed mass of glass reinforcement, [g/m^2];
Z – glass reinforcement mass content in the laminate, [%];
W – stiffener sectional modulus, [cm^3];
I – stiffener cross section moment of inertia, [cm^4].

22.2 General Requirements for Hull Structural Members

22.2.1 The requirements specified in sub-chapter 22.2 regarding the plating are related to rectangular parts of the plating which are stiffened at their boundaries, flat or of gentle curvature. Other shapes are subject to PRS consideration in each particular case.

22.2.2 Basic dimensions of plate (width a and length b) are measured to the nearest stiffener edges (Fig. 22.2.2 a). It is assumed that $b \geq a$. If a plate is not rectangular, dimensions a and b shall be determined in accordance with Fig. 22.2.2 b.

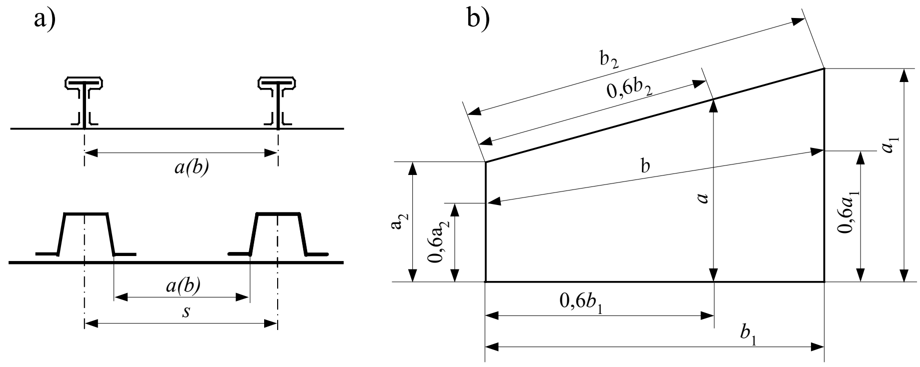


Fig. 22.2.2 Basic dimensions of plate

22.2.3 While determining the plating panel reinforcement mass in accordance with the requirements specified in 22.6 the following coefficient shall be used:

$$k_k = -0.2\left(\frac{b}{a}\right)^2 + 0.87\frac{b}{a} + 0.14 \qquad (22.2.3)$$

In formula 22.2.3, the following condition shall be taken into account: $2 \geq \frac{b}{a} \geq 1$.

If a plating panel is such that the values of modulus of elasticity E_g considerably differ in the longitudinal and transverse directions, the method of determining the value of k_k is subject to PRS consideration in each particular case.

22.2.4 While determining reinforcement mass of curved monolithic plating having camber f (Fig. 22.2.4) in accordance with the requirements of 22.6, coefficient k_p taking values specified in Table 22.2.4 shall be used.

Table 22.2.4
Coefficient k_p

f/a	k_p
≤ 0.03	1
0.03 < f/a < 0.1	1.15 – 5 f/a
≥ 0.1	0.65

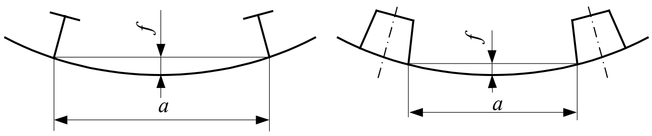


Fig. 22.2.4

22.2.5 Plating shall be stiffened transversely and longitudinally with structural members and stiffeners.

Scantling of those structural members and stiffeners shall be in accordance with the requirements specified in sub-chapter 22.7 which are based on the assumption that such elements are continuous (i.e. cannot be considered as multispan beams or frames) and are exposed to the transverse load evenly distributed throughout their length.

Where the above mentioned assumptions are not fulfilled, the required stiffness and strength of stiffeners and structural members shall be determined in agreement with PRS in each particular case.

22.2.6 All structural members shall be so designed as to maintain structural continuity. Any change of the dimension of structural members shall be smooth.

22.2.7 Longitudinal members shall not end at transverse members or bulkheads, but they shall extend beyond those structural elements in the form of member with gradually reduced cross-section.

22.2.8 Pillars and supporting stiffeners at bulkheads shall be arranged in vertical line with analogous structural members located below and above the ‘tweendeck under consideration.

22.2.9 Equipment of considerable mass or exposed to considerable loads as well as superstructure bulkheads and deckhouse bulkheads shall be arranged coplanarly with deck structural members or supported by pillars or vertical divisions.

22.3 Laminate Properties

22.3.1 Glass Reinforcement Content

22.3.1.1 Glass reinforcement mass in laminates with glass mats shall constitute 28÷35 % of total laminate mass.

22.3.1.2 In laminates with combined reinforcement (mats, fabrics, uniaxially oriented reinforcement), the reinforcement mass content shall be within limits determined in accordance with the following formulae:

$$z_{\min} = \frac{M_{zbr}}{3.6M_m + 2.2M_T + 2.0M_k} 100 \quad [\%] \qquad (22.3.1.2\text{-}1)$$

$$z_{\max} = \frac{M_{zbr}}{3.0M_m + 1.65M_T + 1.5M_k} 100 \quad [\%] \qquad (22.3.1.2\text{-}2)$$

$z_{\min}$ – minimum allowable reinforcement mass content in laminate, [%];
$z_{\max}$ – maximum allowable reinforcement mass content in laminate, [%];
M_{zbr} – total reinforcement mass in laminate, [g/m^2]:

$$M_{zbr} = M_m + M_T + M_k \qquad (22.3.1.2\text{-}3)$$

M_m – mass of mat reinforcement, [g/m^2];
M_T – mass of fabric reinforcement, [g/m^2];
M_k – mass of uniaxially oriented reinforcement, [g/m^2].

For uniaxially oriented reinforcement stabilized with mesh the reinforcement mass percentage may generally be higher than that specified above and its allowable value is subject to PRS consideration in each particular case.

22.3.2 Laminate Thickness

Thickness of glass reinforced plastic shall be approximate to the value determined in accordance with the following formula:

$$g = \frac{M_{zbr}}{1000}\left(\frac{83}{z} - 0.44\right) \quad [\text{mm}] \qquad (22.3.2)$$

M_{zbr} – total reinforcement mass in laminate, [g/m^2];
z – reinforcement mass content, [%] (see 22.3.1.2).

22.3.3 Mechanical Properties

22.3.3.1 Laminates reinforced with glass mats shall not have the mechanical properties less than the values determined in accordance with the following formulae:
– tensile strength:

$$R_m = 4\,z - 30 \text{ [MPa]} \qquad (22.3.3.1\text{-}1)$$

– bending strength:

$$R_g = 4\,z + 35 \text{ [MPa]} \qquad (22.3.3.1\text{-}2)$$

– tensile modulus:

$$E_m = 200\,z + 1000 \text{ [MPa]} \qquad (22.3.3.1\text{-}3)$$

– bending modulus:

$$E_g = 200\,z + 500 \text{ [MPa]} \qquad (22.3.3.1\text{-}4)$$

The required values of the above characteristics determined in accordance with formulae from 22.3.3.1-1 to 22.3.3.1-4 depending on the reinforcement content are specified in Table 22.3.3.2-1.

22.3.3.2 Laminates with combined reinforcement (interleaved layers of mats and balanced fabrics arranged evenly through laminate thickness; fabrics laid with their woof or warp along stiffeners) shall not have mechanical properties less than the values determined in accordance with the following formulae:
– tensile strength:

$$R_m = 0.19\,z^2 - 10\,z + 210 \text{ [MPa]} \qquad (22.3.3.2\text{-}1)$$

– bending strength:

$$R_g = 0.19\,z^2 - 10\,z + 270 \text{ [MPa]} \qquad (22.3.3.2\text{-}2)$$

– tensile modulus:

$$E_m = 400\,z - 5800 \text{ [MPa]} \qquad (22.3.3.2\text{-}3)$$

– bending modulus:

$$E_g = 12\,z^2 - 750\,z + 18400 \text{ [MPa]} \qquad (22.3.3.2\text{-}4)$$

The required values of the above characteristics determined in accordance with formulae from 22.3.3.2-1 to 22.3.3.2-4 depending on the reinforcement content are specified in Table 22.3.3.2-2.

Table 22.3.3.2-1
Mechanical properties of laminates reinforced with mats

Reinforcement content z, [%]	Reinforcement quantity in 1 mm thickness, [g/m²]	Laminate mass density, [g/cm³]	R_m, [MPa]	R_g, [MPa]	E_m, [MPa]	E_g, [MPa]
28	396	1.41	82	147	6600	6100
29	413	1.42	86	151	6800	6300
30	430	1.43	90	155	7000	6500
31	447	1.44	94	159	7200	6700
32	464	1.45	98	163	7400	6900
33	482	1.46	102	167	7600	7100
34	500	1.47	106	171	7800	7300
35	518	1.48	110	175	8000	7500

Table 22.3.3.2-2
Mechanical properties of laminates with combined reinforcement

Reinforcement content z, [%]	Reinforcement quantity in 1 mm thickness, [g/m²]	Laminate mass density, [g/cm³]	R_m, [MPa]	R_g, [MPa]	E_m, [MPa]	E_g, [MPa]
35	518	1.48	93	153	8200	6850
36	536	1.49	96	156	8600	6952
37	555	1.50	100	160	9000	7078
38	573	1.51	104	164	94 000	7228
39	592	1.52	109	169	9800	7402
40	612	1.53	114	174	10 200	7600
41	631	1.54	119	179	10 600	7822
42	651	1.55	125	185	11 000	8068
43	671	1.56	131	191	11 400	8338
44	691	1.57	138	198	11 800	8632
45	712	1.58	145	205	12 200	8950
46	733	1.59	152	212	12 600	9292
47	754	1.60	160	220	13 000	9658
48	776	1.62	168	228	13 400	10 048
49	796	1.63	176	235	13 800	10 462
50	820	1.64	185	245	14 200	10 900

22.3.3.3 Mechanical properties of laminates reinforced with fabrics whose woof or warp is non-parallel to the axis of stiffeners, with unbalanced fabrics (including unidirectional ones) or with fabrics unevenly distributed through the laminate thickness are subject to PRS consideration in each particular case.

22.3.3.4 The formulae provided in 22.3.3.1 and 22.3.3.2 specify the minimum parameters of mechanical parameters for sample plates cured in accordance with the requirements of 22.4.6. Suitability of laminates whose specimens taken from sample plates indicate values less than those required in 22.3.3.2-1 or 22.3.3.2-2 is subject to PRS consideration in each particular case.

22.3.3.5 PRS may also accept minimum strength characteristics specified in standard PN – EN ISO 12215-5.

22.3.4 Reference Laminate

22.3.4.1 The requirements specified in subsequent sub-chapters are related to the so called reference laminate reinforced with mats containing z = 34% of reinforcement (about 500 g/m² falls on 1 mm of laminate thickness) which has the following mechanical properties:
R_m = 106 MPa,
R_g = 171 MPa,
E_m = 7800 MPa,
E_g = 7300 MPa.

22.3.4.2 For a laminate containing less than 34% of reinforcement, the required mass of glass reinforcement may be determined like for the reference laminate, i.e. in accordance with the requirements specified in 22.6.

22.3.4.3 For a laminate containing more than 34% of reinforcement, the required mass of glass reinforcement, M_{zbr}, in plating shall be determined in accordance with the following formulae:

– to meet the strength criterion:

$$M_{zbr} = M_z \frac{z}{41.5-0.22z}\sqrt{\frac{171}{R_g}} \quad [\mathrm{g/m^2}] \qquad (22.3.4.3\text{-}1)$$

– to meet the stiffness criterion:

$$M_{zbr} = M_z \frac{z}{41.5-0.22z}\sqrt[3]{\frac{7300}{E_g}} \; [\mathrm{g/m^2}] \qquad (22.3.4.3\text{-}2)$$

M_z – required reference reinforcement mass, [g/m²], in sub-chapter 22.6 defined as M_{zd} , M_{zb} etc.;
z – actual reinforcement mass content in laminate, [%];
R_g – design strength of applied laminate for bending transverse to stiffeners or structural members, [MPa];
E_g – design modulus of elasticity for bending of the applied laminate, [MPa].

As design strength R_g and design modulus of elasticity E_g, 90% of the respective values obtained through strength tests of sample plates of the applied laminate (if such tests were conducted before the construction commencement) or the respective values in Table 22.3.3.2-2 corresponding to the actual reinforcement content, z, used in formula 22.3.4.3-2 (unless such tests were conducted before the construction commencement) shall be taken.

22.3.4.4 The required stiffener moment of inertia, I_1, and the required stiffener sectional modulus of, W_1, shall be determined in accordance with the following formulae:

$$I_1 = I\frac{7300}{E_g} \; [\mathrm{cm^4}] \qquad (22.3.4.4\text{-}1)$$

– for stiffeners fixed at their ends:

$$W_1 = W\frac{171}{R_c} \; [\mathrm{cm^3}] \qquad (22.3.4.4\text{-}2)$$

– for stiffeners their ends simply supported:

$$W_1 = W\frac{171}{R_m} \; [\mathrm{cm^3}] \qquad (22.3.4.4\text{-}3)$$

W – stiffener reference sectional modulus, [cm³], required in sub-chapter 22.7;
I – stiffener reference moment of inertia, [cm⁴], required in sub-chapter 22.7;
R_c – design strength of the stiffener flange laminate in longitudinal compression, [MPa];
R_m – design strength of the stiffener flange laminate in longitudinal tension, [MPa];
R_g – design strength of the applied laminate for bending along the stiffener, [MPa];

E_g – design modulus of elasticity of the applied laminate for bending along the stiffener, [MPa].

The above formulae apply to stiffeners made as a whole of laminate having structure as defined in 22.3.4.3. For stiffeners made of several types of laminates (having different mechanical properties) used simultaneously, their strength and stiffness at least equivalent to those determined in accordance with the above formulae shall be provided. Laminated beam model shall be taken for calculations.

Such calculations are subject to PRS consideration in each particular case.

22.3.4.5 Outer layers of mat reinforcement having surface mass density less than 300 g/m^2 are considered as non-structural therefore they shall not be taken into account in calculation of the prescribed reinforcement mass.

22.4 Laminate Ship Hull Construction Technology

22.4.1 General

22.4.1.1 Industrial plant constructing glass-reinforced laminate ships shall be approved by PRS.

22.4.1.2 For glass-reinforced laminate ship construction, unsaturated resins and fibre of type E glass (containing not more than 1% of alkali metal oxides) shall be used.

The possibility for the use of other resins or other reinforcement material is subject to PRS consideration in each particular case.

22.4.1.3 All materials used for the hull construction shall have been approved by PRS or be type-approved by PRS.

22.4.2 Material Storage Conditions

22.4.2.1 Resins shall be stored in tight containers (preferably in the original packagings provided by their manufacturers), in the dark room in the ambient temperature recommended by the manufacturer. Resins shall not be stored beyond their shelf life.

22.4.2.2 Initiators and accelerants shall be stored in cool dry cleaned and well ventilated spaces.

22.4.2.3 All other resin additives (e.g. bonding inhibitors) shall be stored in closed containers protected against dust and humidity in accordance with the manufacturer's recommendations.

22.4.2.4 Reinforcing materials shall be stored in genuine packagings in spaces which are dry and free from dust.

22.4.2.5 Temperature of the materials prepared for processing shall correspond to the workroom temperature.

22.4.3 Workrooms

22.4.3.1 Considering the size and type of production, workrooms shall be respectively separated from storerooms and different manufacturing process cycles (resin preparation, cutting of strengthenings and laminating) shall be conducted in separate, however adjoining, rooms.

22.4.3.2 Workrooms shall be capable of maintaining constant temperature within 16÷25 °C. Exceptionally, the temperature reduction to 12 °C may be accepted, however as late as after laminating and bonding of the hull structural components is complete and no sooner than 12 hours after the resin bonding is complete. The lowered temperature duration shall be reduced to the minimum with respect to the structure mass and time elapsed from the last lamination.

22.4.3.3 Workroom floor shall be clean and shall not emit dust. Cleanliness shall be maintained to the maximum practicable degree. The workroom air shall be free from dust, especially of such substances which may have an adverse effect on the polymerization process or form layers separating the particular components laminated. Operation of dust making machinery is not permitted in the workroom.

22.4.3.4 Relative humidity in the workroom shall not exceed 70%. For short periods, relative humidity up to 85% is permitted.

22.4.3.5 Continuous monitoring of temperature and humidity shall be provided in the lamination workroom.

22.4.3.6 Ventilation shall not cause excessive evaporation of styrene.

22.4.3.7 Laminated components shall be protected against the sunshine.

22.4.4 Forms

22.4.4.1 Materials used for forms shall not affect the resin polymerization process.

22.4.4.2 Forms shall have sufficient rigidity and their shape shall be such as to allow for easy removal of the laminated product.

22.4.4.3 Large forms shall be laminated from platforms providing access to the entire surface to be laminated.

22.4.4.4 It is recommended that revolving (or tilting) forms be used, especially for larger hulls to enable lamination to be performed in the downhand position.

22.4.4.5 The possibility for ship construction without the use of forms is subject to PRS consideration in each particular case.

22.4.5 Lamination

22.4.5.1 Resin intended for gelcoat and the laminate structural layers shall be prepared in accordance with the resin manufacturer’s recommendations.

22.4.5.2 Gel time of the prepared resin shall not exceed 1 hour. Gel time variation shall be achieved by changing the inhibitor content with constant recommended initiator quantity.

22.4.5.3 Inhibitor must not be mixed with the initiator directly as it poses the explosion hazard.

22.4.5.4 Glass reinforcement shall be applied in portions as large as practicable. It is recommended that the applied mat edges be torn rather than cut.

22.4.5.5 The proportion of resin to reinforcement shall be constantly monitored throughout the lamination process. When preparing glass mats for lamination, the bonding agent mass shall be taken into account (the bonding agent mass shall be deducted from the total mass of reinforcement).

22.4.5.6 Prior to the hull plating lamination commencement, the forms shall be thoroughly cleaned, dried and brought to the workroom temperature. Such putties and separating agents that do not react with the resins shall be used.

22.4.5.7 Gelcoat layer shall be applied with brush, roll or spraying apparatus. In general, the layer thickness shall be 0.4 ÷ 0.6 mm.

22.4.5.8 Gelcoat layer shall be covered, within no more than 6 hours (i.e. after gelation), with the first reinforcement layer of light fabric or mat having surface mass density not exceeding 30 g/m2. The layer shall be well deaerated and the reinforcement mass content shall be 20 ÷ 30%.

22.4.5.9 Lamination of the actual structural layers shall be performed using the manual contact method with soft and hard rolls as well as brushes. Lamination using the direct spray method is subject to PRS consent in each particular case.

22.4.5.10 Lamination shall be performed uninterruptedly ('the wet onto the wet"). Where breaks longer than 24 hours are necessary, the connection surface shall be effectively protected by laying polyamide fabric intended to be later removed or the lamination process shall be resumed after the surface adhesion has been improved, for instance, by scouring with abrasive paper or grinding.

22.4.5.11 Application of subsequent reinforcement layers shall be performed without waiting until the previous resin layers have set. Application of an excessive number of laminate layers simultaneously shall be avoided as it may result in the laminate overheating.

22.4.5.12 If lamination process has been interrupted, and the latest resin layer has already set, the lamination process shall be resumed by laying glass mat. It is recommended that the mat be applied on the final laminate layer of the bottom plating in way of the bilge.

22.4.5.13 Width of the glass reinforcement overlaps shall not be less than 50 mm. For thin reinforcement, this width may be reduced subject to PRS consent in each particular case. Overlaps of different layers shall be staggered by at least 100 mm.

Reinforcement content variation shall be stepped smoothly so as not to exceed 600 g/m^2 per each 25 mm of the transitional strake width.

22.4.5.14 Edges of such materials as wood, plywood, metals and core foam intended to be included in the plating laminate shall be thinned gradually and their outer edges shall be rounded to a radius respective for the particular reinforcement type.

22.4.6 Curing

22.4.6.1 After the lamination process is complete, the hull components shall be left in the moulds for the time necessary for the preliminary curing of the laminate, however not less than 24 hours.

22.4.6.2 Just after the components have been removed from moulds, the components shall be properly supported or so connected to other components as to avoid their distortion.

22.4.6.3 After the lamination process has been complete, the hull components shall be left in the workroom or other space at the ambient temperature not less than 16 °C until the required Barcol hardness (around 35÷40°) is achieved. Unless the hardness measurement is possible, sufficient curing time shall be considered as follows:
30 days – at temperature 16 °C

15 days – at temperature 25 °C
15 hours – at temperature 40 °C
9 hours – at temperature 50 °C
5 hours – at temperature 60 °C.

It is recommended that the hull be held at an elevated temperature avoiding rapid variation of temperature. The ambient temperature shall be risen gradually in accordance with the resin manufacturer's recommendations. The air shall be dry and the hull shall be properly supported while held at an elevated temperature. The heat resistance boundary temperature of the laminate or core foam used for the hull construction shall not be exceeded.

22.4.7 Quality Control

22.4.7.1 Throughout the lamination process, current quality control shall be conducted in respect of:

- material storage – in accordance with the requirements of sub-chapter 22.4.2,
- workroom – in accordance with the requirements of sub-chapter 22.4.3,
- mould condition – in accordance with the requirements of sub-chapter 22.4.4,
- GRP moulding and curing processes – in accordance with the requirements of sub-chapters 22.4.5 and 22.4.6,
- sequence, type and numbers of glass reinforcement layers applied for compliance with the classification documentation,

and countermeasures shall be taken in case any non-conformities have been found. Any repairs shall be made after PRS Surveyor's agreement on the method to be used has been obtained in each particular case.

22.4.7.2 Prior to moulding each constructed ship (including that built in series), a sample plate shall be made for testing the laminate properties for compliance with the requirements specified in sub-chapter 22.3 and the test results shall be enclosed to the classification documentation or submitted to PRS Surveyor during the hull moulding process.

Testing of specimens taken from sample plates is required for each ship constructed as a single vessel and for the ship constructed in series as requested at PRS Surveyor's discretion.

22.4.7.3 Sample plate shall be prepared, by those workers who make the hull plating, in the conditions corresponding to the lamination process and using the same materials as intended for the hull.

22.4.7.4 Typical sample plate shall have dimensions 400×500 mm. The thickness and structure of such a plate shall actually correspond to the laminate of the side shell plating amidships. Sample plate curing method shall be identical with that of the hull shell plating. Subject to previous consent by PRS Surveyor in each particular case, plating fragments obtained from cutting larger openings may be considered as test specimens.

22.4.7.5 Specimens taken from the sample plates shall be tested in a laboratory approved by PRS, and the test report shall indicate the characteristics specified in Table 22.4.7.5.

Table 22.4.7.5
Test scope and methods for sample plate specimens

Item	Cured GRP properties	To be tested in accordance with
1	Glass reinforcement content, [%]	PN-EN ISO 1172:2002
2	Tensile strength, [MPa]	PN-EN ISO 527-1:1998 PN-EN ISO 527-2:1998 PN-EN ISO 527-3:1998 PN-EN ISO 527-4:2000 PN-EN ISO 527-5:2009
3	Tensile modulus, [MPa]	PN-EN ISO 178:2006
4	Bending strength, [MPa]	PN-EN ISO 178:2006
5	Bending modulus, [MPa]	PN-EN ISO 178:2006
6	Barcol hardness	ASTM*)/D 2583-87

*) American Society for Testing Materials.

22.4.7.6 Specimens for bending tests shall be so loaded that the plating outer surface (gelcoat) is subjected to tension.

The specimens shall be so taken from the sample plate that their axes correspond to the direction perpendicular to plating stiffeners.

The requirements regarding the tests of specimens of plating made of laminate reinforced with glass mats whose woof or warp are not laid perpendicular to the axes of plating stiffeners are separately specified by PRS in each particular case.

22.5 General Strength

22.5.1 Calculations

Ships who fulfil the requirements specified in Chapter 22 do not require, in general, longitudinal strength calculations or local structural rigidity calculations.

In special cases PRS may require calculations of the hull sectional moduli, moments of inertia and local deflection – in accordance with the requirements specified in 22.5.2.

Hull sectional modulus, W, and its moment of inertia in the midship portion of the ship, I, shall not be less than those determined in accordance with the following formulae:

– for the zone in tension $W = 55L_W^2 B(\delta + 0.7)\frac{R_m}{106}$ [cm³] (22.5.1-1)

– for the zone in compression $W = 55L_W^2 B(\delta + 0{,}7)\frac{R_c}{106}$ [cm³] (22.5.1-2)

$$I = 4.2 W L_W \frac{E_m}{7800} \text{ [cm}^4\text{]} \qquad (22.5.1\text{-}3)$$

R_m – laminate strength in tension [MPa],
R_c – laminate strength in compression [MPa],
E_m – laminate modulous of elasticity for tension MPa.

The above formulae are applicable to a hull whose longitudinal members are made of laminate having structure as defined in 22.3.4.1, 22.3.4.2 or 22.3.4.3.

For a hull constructed of several types of laminate, strength and rigidity shall be at least equivalent to those obtained in accordance with the above formulae using the laminated beam model.

These calculations are subject to PRS consideration in each particular case.

22.5.2 Structural Rigidity

22.5.2.1 Plating panel deflection between stiffeners shall not exceed 1% of the plating panel width, a, (see 22.2.2) – for the design loads determined in accordance with the requirements specified in Chapter 14.

22.5.2.2 Stiffener deflection between its supports shall not exceed 1% of its span – for the design loads determined in accordance with the requirements specified in Chapter 14.

22.6 Plating

22.6.1 Bottom Plating

22.6.1.1 Reinforcement mass of the bottom, M_{zd}, shall not be less than the value determined in accordance with the following formula:

$$M_{zd} = 8ak\sqrt[3]{h} \quad [\mathrm{g/m^2}] \qquad (22.6.1.1\text{-}1)$$

a – plating panel width, [mm], (see 22.2.2);
k = $k_k\, k_p$;
k_k and k_p – coefficients defined in 22.2.3 and 22.2.4;
h – vertical distance, measured at the ship side, from the lower edge of the plating panel being calculated to the upper deck, [m].

If the ship speed (in knots) exceeds $2.7\sqrt{L_W}$, then h shall not be less than the value obtained in accordance with the following formula:

$$h = k_v k_d (0.007v^2 + 0.008v\sqrt{L_W} + 0.216L_W) \ [\mathrm{m}] \qquad (22.6.1.1\text{-}2)$$

v – ship speed, [knots];
L_W – see 1.2.1;
k_v = $2.5\frac{v}{\sqrt{L_W}} - 6.75$ for $2.7\sqrt{L_W} < v < 3.1\sqrt{L_W}$,
k_v = 1 for $v \geq 3.1\sqrt{L_W}$;
k_d – varies as shown in Fig. 22.6.1.1.

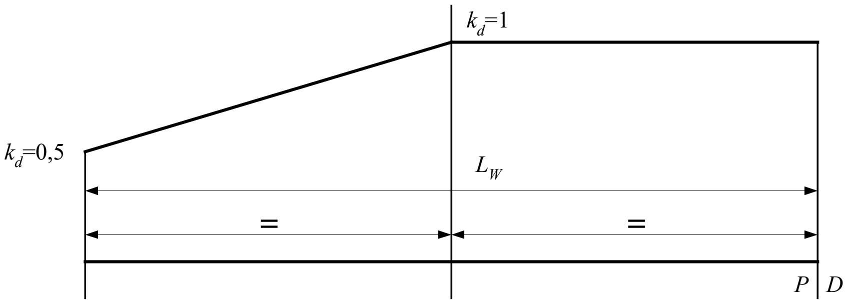


Fig. 22.6.1.1 Coefficient k_d

If the ship speed (in knots) exceeds $2.7\sqrt{L_W}$ and the rise of floors is less than 12°, then these loads are subject to PRS consideration in each particular case.

22.6.1.2 Keel plate made as a homogeneous solid shall have the reinforcement mass increased by 100% compared to the value determined in accordance with the requirements specified in 22.6.1.1, and width not less than 0.1B (see Fig. 22.6.1.2).

Keel reinforcement shall be connected to both stem and stern frame.

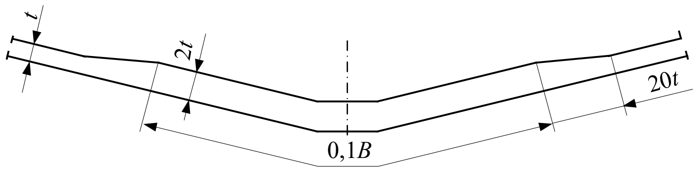


Fig. 22.6.1.2 Single keel

22.6.1.3 Complex keel plate made up of interconnected components shall have reinforcement mass increased by 100% compared to the value determined in accordance with the requirements specified in 22.6.1.1, and width not less than 0.1*B* (see Fig. 22.6.1.3).

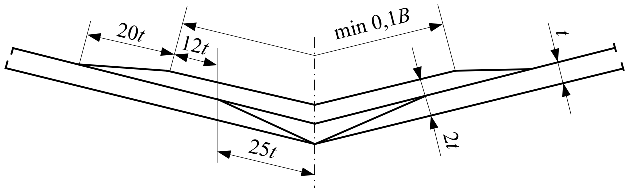


Fig. 22.6.1.3 Complex keel

22.6.1.4 Integral rudder vane plating or vertical blade plating shall be constructed as shown in Fig. 22.6.1.4. Dimension *e* shall not be less than 0.25 *h*, not less however than 50 mm.

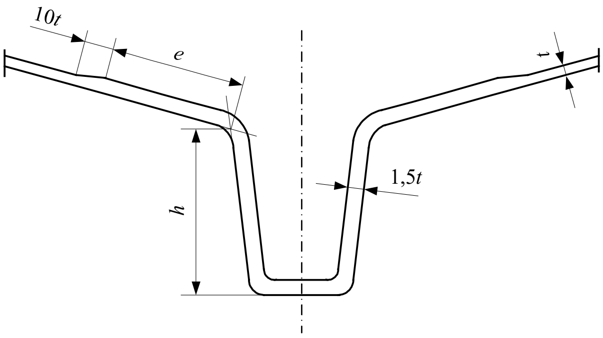


Fig. 22.6.1.4 Rudder vane

If rudder carrier bearing is fitted to the van or vertical blade, then the van dimensions shall be increased respectively.

22.6.1.5 Sharp bilge and transom shall have plating thickness increased by 50% over the width indicated in Fig. 22.6.1.5. Dimension *e* shall not be less than 0.025 *B*, not less however than 50 mm.

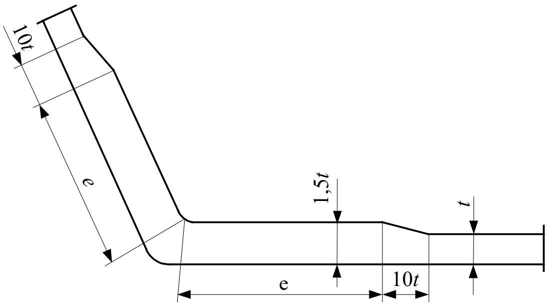


Fig. 22.6.1.5 Sharp bilge reinforcement or transom reinforcement

22.6.1.6 Sea chest installed in the bottom shall not have reinforcement mass less than the bottom plating.

22.6.1.7 Bottom plating exposed to increased loads shall be reinforced respectively. Such a reinforcement shall be connected to the nearest stiffeners.

22.6.1.8 All openings in the bottom shall have rounded corners, and openings with a diameter d ≥ 150 mm shall be compensated by doubling the laminate plating thickness over the area indicated in Fig. 22.6.1.8.

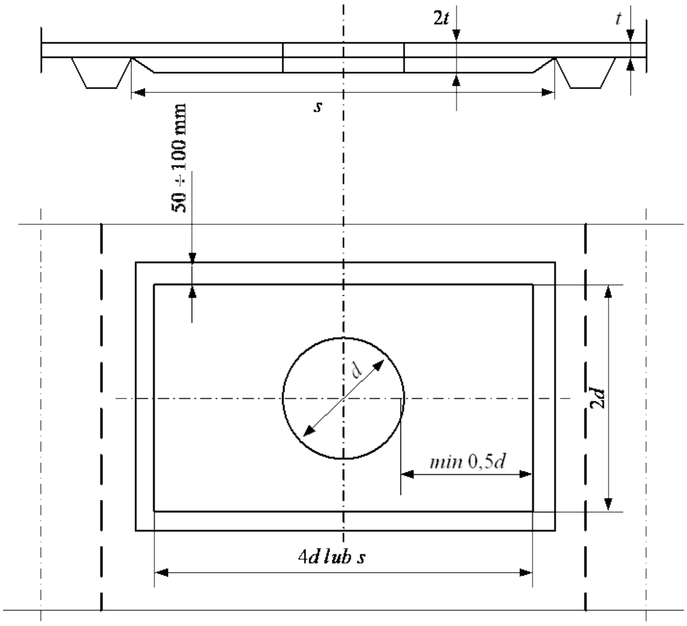


Fig. 22.6.1.8 Compensation of bottom openings

22.6.1.9 Sandwich Laminate Plating

Sandwich laminate plating shall fulfil the following requirements:

.1 moment of inertia of a sector having 1 cm in width, excluding the core, shall not be less than the value determined for the equivalent solid plating;

.2 total thickness t shall not be less than the value determined in accordance with the following formula (see Fig. 22.6.1.9):

$$t = 0.01 k_t h \frac{a}{R_t} \text{ [mm]} \qquad (22.6.1.9\text{-}1)$$

h – vertical distance, measured at the ship side, from the relevant plating panel lower edge to the upper deck, [m];

a – plating panel width, [mm] (see 22.2.2);

R_t – core shear strength, [MPa];

k_t = 0.89 for balsa wood;

$k_t = 0.62 + \frac{0.35}{\sqrt{n}}$ – for other core materials; however the value of k_t taken for calculations shall not be less than 0.7;

$n = \frac{t_1}{0.5(t_2+t_3)}$;

t_1, t_2, t_3 – as indicated in Fig. 22.6.1.9.

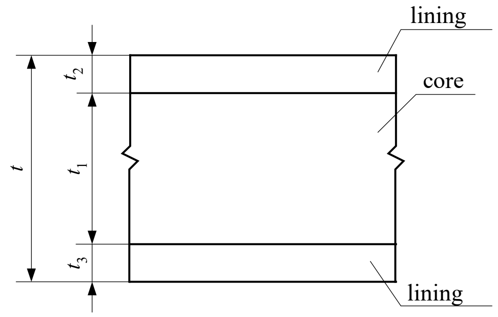


Fig. 22.6.1. 9 Sandwich laminate plating

.3 sectional modulus of the sandwich laminate plating sector having 1 cm in width shall not be less than the value determined in accordance with the following formulae:
– for outer lining (subjected to the loads due to water pressure):

$$W_z = 0.195h(\frac{a}{1000})^2 \frac{R_m}{106} \text{ [cm}^3\text{]} \qquad (22.6.1.9\text{-}2)$$

where:
a, h – like in formula 22.6.1.9-1;
R_m – lining laminate tensile strength (in the direction transverse to stiffener or member axis), [MPa];
– for inner lining:

$$W_w = 0.195h(\frac{a}{1000})^2 \frac{R_c}{106} \text{ [cm}^3\text{]} \qquad (22.6.1.9\text{-}3)$$

where:
a, h – like in formula 22.6.1.9-1;
R_c – lining laminate compression strength (in the direction transverse to stiffener or member axis), [MPa]; for typical GRPs and average content of glass, $R_c = R_m$ may be taken;

.4 laminate lining reinforcement mass shall not be less than:

$$M = 360\sqrt{L_0} \text{ [g/m}^2\text{]} \qquad (22.6.1.9\text{-}4)$$

22.6.2 Side Shell Plating

22.6.2.1 Side shell plating reinforcement mass, M_{zb}, shall not be less than the value determined in accordance with the following formula:

$$M_{zb} = 8ak\sqrt[3]{h} \text{ [g/m}^2\text{]} \qquad (22.6.2.1)$$

a – plating panel width, [mm] (see 22.2.2);
k = $k_k\, k_p$;
k_k and k_p – coefficients defined in 22.2.3 and 22.2.4;
h – vertical distance, measured at the ship side, from the relevant plating panel lower edge to the upper deck, [m]; $h_{\min} = 0.05L + 0.5$ m.

22.6.2.2 Sternframe reinforcement mass and stem reinforcement mass may be reduced gradually and at the freeboard deck shall not be less than:

$$M_{zk} = \frac{M_{zs}+M_{zb}}{2} \text{ [g/m}^2\text{]} \qquad (22.6.2.2)$$

M_{zs} and M_{zb} – reinforcement mass of keel and side shell, respectively [g/m²].

Reinforcement breadth in way of connection to the stem or sternframe shall not be less than the keel breadth, and at the deck – not less than 60% of the keel breadth.

22.6.2.3 Transom plating reinforcement mass shall not be less than the side shell plating reinforcement mass.

Where an outboard engine/motor is expected to be used, transom shall be reinforced respectively.

Sharp connection of the ship side to transom shall have the reinforcement mass increased by 50% within the area indicated in Fig. 22.6.2.3.

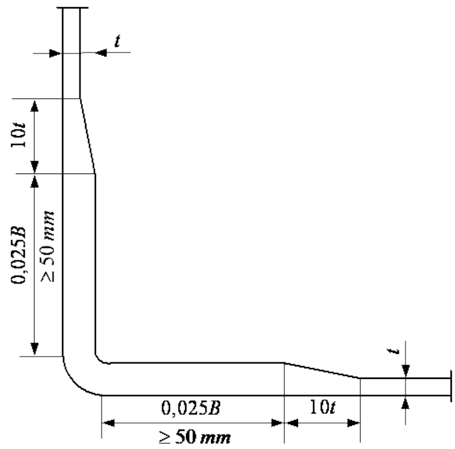


Fig. 22.6.2.3 Ship side connection to transom

22.6.2.4 For ships who may be subjected to impacts during their service, it is recommended that the side shell plating reinforcement be increased by 25% compared to the mass required in 22.6.2.1.

22.6.2.5 In fishing vessels the following ship side strengthenings are recommended:

.1 in the areas where major wear and tear of the plating is expected, application of metal plates or bars is recommended;

.2 in the line of gallows, it is recommended that the side shell plating reinforcement mass be increased by 20% compared to that required in 22.6.2.1; it is also recommended that in the areas exposed to friction by fishing equipment, the side shell plating be protected by guard rails made of half-round steel rods;

.3 plating reinforcement mass shall be increased in stern ramps by 30%, and in stern ramp walls by 10% – compared to that required in 22.6.2.1.

22.6.2.6 All openings in side shell plating shall have rounded corners, and large openings shall be compensated for respectively (see Figures 22.6.1.8 and 22.6.3.5).

Hawse pipes shall have circular cross-section and be fitted with proper shields.

Upper edges of side shell openings shall be at the distance from the nearest deck above such openings equal to at least twice the opening diameter.

Large openings in the side shell and bulwarks shall be as far from the deck recesses as practicable.

22.6.2.7 Superstructure side wall plating shall extend beyond the superstructure and pass smoothly into the side shell plating.

22.6.2.8 Side shell sandwich structure shall fulfil the requirements specified in 22.6.1.9, and *h* shall be taken in accordance with 22.6.2.1.

If the plating may be subjected to impacts or quick wear and tear, then the laminate outer layer reinforcement mass shall be increased by at least 50% compared to that required in 22.6.2.1 for monolithic plating.

22.6.3 Deck Plating

22.6.3.1 For each deck, reinforcement mass, M_{zp}, shall not be less than the value determined in accordance with the following formula:

$$M_{zp} = 8ak\sqrt[3]{h} \quad [\text{g/m}^2] \tag{22.6.3.1}$$

a – plating panel width, [mm] (see 22.2.2);
k = $k_k\, k_p$;
k_k and k_p – coefficients defined in 22.2.3 and 22.2.4;
h – loading height, [m], which is:

- for open deck in single deck ship which constitutes freeboard deck:
  $h = 0.02L_0 + 0.8$, [m];
- for open deck in a ship having another deck below, forecastle deck, superstructure deck within $0.25L_0$ aft of FP:
  $h = 0.02L_0 + 0.5$, [m], and $h_{min} = 0.7$ m;
- for freeboard deck situated inside the superstructure, for deck situated below the freeboard deck and for superstructure deck within $-0.3L_0 \le x \le 0.25L_0$ from AP
  $h = 0.01L_0 + 0.6$, [m];
- for other portions of deck (not specified above):
  $h = 0.01L_0 + 0.3$, [m];
- for cargo decks h if equal to deck height (for cargo density exceeding 0.7 t/m^3 , h shall be increased proportionally);
- for open cargo decks, h = 3.6 m (for cargo density exceeding 0.7 t/m^3, h shall be increased proportionally).

22.6.3.2 Reinforcement mass of the deck above a tank, M_{zp}, shall not be less than the value determined in accordance with the following formula (see also 22.6.5):

$$M_{zp} = 11.5ak\sqrt[3]{h} \quad [\text{g/m}^2] \tag{22.6.3.2}$$

a – plating panel width, [mm] (see 22.2.2);
k = $k_k\, k_p$;
k_k and k_p – coefficients defined in 22.2.3 and 22.2.4;
h – the greater out of the following values:

0.67 of the distance between the tank top (deck above the tank) and the overflow pipe upper end or the distance between the tank top (deck above the tank) and the bulkhead deck, [m].

22.6.3.3 Deck sandwich structure shall fulfil the requirements specified in 22.6.1.10, and h shall be taken in accordance with 22.6.3.1.

22.6.3.4 Corners of all deck openings shall be rounded and their edges shall be stiffened by coamings to ensure effective support and fixing of deck beams.

22.6.3.5 Plating in way of large openings, especially in corners, shall be effectively strengthened by overlay belts (see Fig. 22.6.3.5). In way of corners, it is recommended that the laminate reinforcement be oriented at the angle of 45° to the opening axis (see Fig. 22.6.3.5).

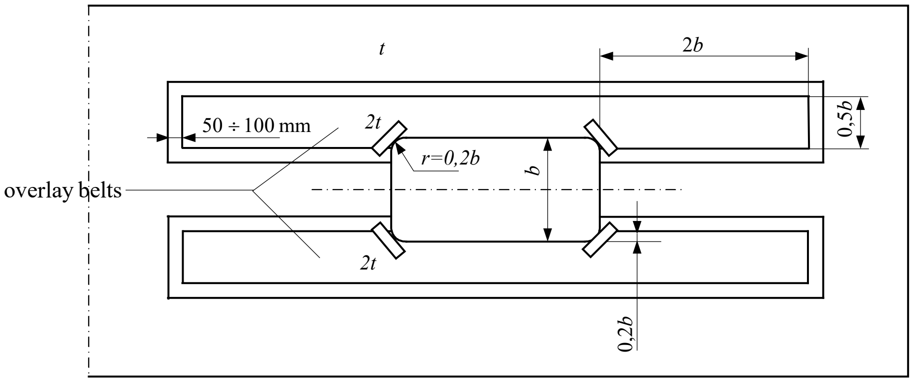


Fig. 22.6.3.5 Plating strengthening in way of large openings

22.6.4 Bulkhead Plating

22.6.4.1 Ships shall have watertight bulkheads in accordance with the requirements specified in sub-chapter 8.2.

22.6.4.2 Bulkhead reinforcement mass, M_{zg}, shall not be less than the value determined in accordance with the following formula:

$$M_{zg} = 6.2ak\sqrt[3]{h} \quad [\mathrm{g/m^2}] \qquad (22.6.4.2)$$

a – plating panel width, [mm] (see 22.2.2);
k = $k_k\, k_p$;
k_k and k_p – coefficients defined in 22.2.3 and 22.2.4;
h – vertical distance, measured on the ship centre plane, from the relevant plating panel to the level of deck forming the bulkhead boundary, [m].

22.6.4.3 Bulkhead sandwich structure shall fulfil the requirements specified in 22.6.1.9, and h shall be taken in accordance with 22.6.4.2.

22.6.4.4 All bulkhead penetration pieces shall be watertight and their number shall be reduced to the minimum.

Openings in bulkheads for watertight penetrations shall be strengthened and stiffened respectively – e.g. as shown in paragraphs 22.6.1.8 and 22.6.3.5.

Bulkhead penetrations shall be located as high above the bottom as practicable and as far from the ship side as practicable.

22.6.5 Tank Plating

22.6.5.1 Integrated tanks shall not have sandwich laminate structure.

Structure stiffeners shall not penetrate integrated tank walls. It is recommended that the stiffeners be arranged outside the tank cargo space. Tank plating with the stiffeners inside the tank which may disintegrate from the plating as a result of the pressure in the tank is subject to PRS consideration in each particular case.

Oil fuel tanks shall be arranged as independent tanks. Glass reinforced plastic tanks shall not be used for liquids having a flash-point not exceeding 55 °C.

Internal walls of tanks shall be additionally coated with a laminate containing glass mats having a total surface mass density not less than 600 g/m².

22.6.5.2 Tank wall glass reinforcement mass, M_{zz}, shall not be less than the value determined in accordance with the following formula:

$$M_{zz} = 8ak\sqrt[3]{h} \ \ [\text{g/m}^2] \qquad (22.6.5.2)$$

a – plating panel width, [mm] (see 22.2.2);
k = $k_k\, k_p$;
k_k and k_p – coefficients defined in 22.2.3 and 22.2.4;
h – the greatest of the three following distances measured vertically from the playing lower edge to the point at the level of:
a) the upper deck;
b) 0.67 of the distance between the tank top and the overflow pipe level;
c) 0.46 m above the tank top.

22.6.5.3 Metal plating of oil fuel tanks shall be earthed.

22.6.6 Superstructures

22.6.6.1 Superstructure and forecastle wall glass reinforcement mass, M_{zn}, shall not be less than the value determined in accordance with the following formula:

$$M_{zn} = 8ak\sqrt[3]{h} \ \ [\text{g/m}^2] \qquad (22.6.6.1)$$

a – plating panel width, [mm] (see 22.2.2);
k = $k_k\, k_p$;
k_k and k_p – coefficients defined in 22.2.3 and 22.2.4;
h = $0.02L_0 + 0.50$ m – for the fore wall;
h = $0.016L_0 + 0.27$ m – for side and after walls, [m].

In fishing vessels, the values of h for superstructure walls shall be taken in agreement with PRS in each particular case.

22.6.6.2 Sandwich structures of superstructures and forecastles shall fulfil the requirements specified in 22.6.1.10, and h shall be taken in accordance with the requirements specified in 22.6.6.1.

22.6.6.3 Openings in superstructures shall be so reinforced by a flat bar welded on the whole perimeter that the entire structure has the same strength as an equivalent structure with no openings.

22.7 Stiffeners and Structural Members

22.7.1 General

22.7.1.1 The requirements of sub-chapter 22.7 specify the minimum strength and stiffness requirements for stiffeners and structural members of the bottom, sides, decks, bulkheads, tank walls and superstructure walls.

22.7.1.2 Stiffener span and structural member span values which appear in the formulae used in this sub-chapter shall be taken with respect to the adopted model of construction of the supports of stiffeners and structural members.

If structural members having similar stiffness arranged perpendicularly to each other are used, then the calculation models in the form of grid, three-dimensional frameworks or three-dimensional models of shell finite elements shall be used.

22.7.1.3 The requirements specified in sub-chapter 22.7 are based on the assumption that the cross-section continuity of face plates/flanges, webs and effective strakes of plating along the axes of structural members or stiffeners is maintained.

Design solutions which do not fulfil the above requirements are subject to PRS consideration in each particular case. In particular, this applies to the regions where mutually perpendicular members or structural members of different structural regions are connected (e.g. floors to frames, etc.).

22.7.1.4 The formulae used in sub-chapter 22.7 for determining sectional moduli and sectional moments of inertia of structural members apply to reference laminate (see 22.3.4).

Strength and stiffness of members constructed with simultaneous application of various reinforcement types (mats, fabrics laid longitudinally and diagonally, unidirectional reinforcements) shall be at least equivalent to those of reference laminate structure (see 22.3.4.4).

22.7.1.5 Face plates/flanges of stiffeners and members supporting, or supported by, deck pillars shall be respectively strengthened in way of their contact with pillars to bear the pillar pressure, and their webs shall be suitable to bear shear forces induced by the pillars.

22.7.2 Bottom Stiffeners and Structural Members

22.7.2.1 Bottom Girders

Each ship shall have the bottom central girder. If the distance from the bottom central girder to the bottom transition into the bilge exceeds 2.5 m, then bottom side girders shall be applied, and their spacing shall not be less than 2.5 m. The girders shall extend as far fore and aft as practicable.

Ship longitudinal structural members, such as tank walls, bulkheads, engine foundation, etc., may play the role of girders if they are properly connected to those structural members which form their extensions. If a ship is provided with bar keel, the requirement for the bottom central girder may be waived subject to PRS consideration in each particular case.

Sectional modulus, W, and moment of inertia, I, of the bottom girder (together with the effective strake of plating determined in accordance with 22.1.2) shall not be less than the values determined in accordance with the following formulae:

$$W = 17{,}5\ bhl^2\ [\text{cm}^3] \tag{22.7.2.1-1}$$

$$I = 29.6\ bhl^3\ [\text{cm}^4] \tag{22.7.2.1-2}$$

b – width of the strake of plating supported by girder, [m], (the sum of halves of the distances to nearest girders and/or longitudinal bulkheads/divisions on both sides of girder;

l – girder span, [m]; if girder span has been assumed – while scantling bottom girders in accordance with 22.7.1.2 – equal to the distance between the frame face plates on both ship sides (or the distance between the longitudinal bulkhead/division and the frame face plate), then l may be taken as the distance between the walls (webs) of the nearest bottom girders or distance between the transverse bulkhead/division and the edge (web) of the nearest bottom girder; otherwise, where the girders supports a floor, l shall be taken as the distance between the bulkheads/transverse divisions;

h – vertical distance, measured at the ship side, between the geometric centre of an area supported by the girder and the upper deck, [m];

for ships whose speed exceeds $2.7\sqrt{L}$ knots, h shall also not be less than the value determined in accordance with formula 22.6.1.1-2.

22.7.2.2 Floors

Distances between floors or between transverse bulkheads and the nearest floors shall not exceed 2.5 m.

Floors shall also be arranged in way of engines, shaft brackets and rudders.

Sectional modulus, *W*, and moment of inertia, *I*, of floors together with the effective strake of plating, determined in accordance with 22.1.2 shall not be less than the values determined in accordance with the following formulae:

$$W = 17.5\ bhl^2\ [\text{cm}^3] \quad (22.7.2.2\text{-}1)$$

$$I = 29.6\ bhl^3\ [\text{cm}^4] \quad (22.7.2.2\text{-}2)$$

b – floor spacing, [m]

l – floor span, [m]; if floor span has been assumed – while scantling bottom girders in accordance with 22.7.1.2 – equal to the distance between the transverse bulkheads/divisions, then *l* may be taken as the distance between and the edges (webs) of the nearest bottom girders or longitudinal bulkheads/divisions; otherwise *l* represents the distance between the frame face plates on both ship sides or the distance between the longitudinal bulkhead/division and the frame face plate;

h – vertical distance, measured at the ship side, between floor midpoint and the upper deck, [m]; in deep tanks *h* shall not be less than the value determined in accordance with 22.6.5.2; for ships whose speed exceeds $2.7\sqrt{L}$ knots, *h* shall also not be less than the value determined in accordance with formula 22.6.1.1-2.

22.7.2.3 Bottom Stiffeners

Sectional modulus, *W*, and moment of inertia, *I*, of bottom stiffeners (together with the effective strake of plating determined in accordance with 22.1.2) shall not be less than the values determined in accordance with the following formulae:

– for transverse stiffeners:

$$W = 16.6\ hsl^2\ [\text{cm}^3] \quad (22.7.2.3\text{-}1)$$

$$I = 28\ hsl^3\ [\text{cm}^4] \quad (22.7.2.3\text{-}2)$$

– for longitudinal stiffeners:

$$W = 21\ hsl^2\ [\text{cm}^3] \quad (22.7.2.3\text{-}3)$$

$$I = 35.5\ hsl^3\ [\text{cm}^4] \quad (22.7.2.3\text{-}4)$$

s – stiffener spacing, [m];

l – bottom girder span between support points on the walls of structural members, bulkheads or ship sides, [m];

h – vertical distance, measured at the ship side, between bottom girder midpoint and the upper deck, [m]; in deep tanks *h* shall not be less than the value determined in accordance with 22.6.5.2 (see also 22.6.1.1).

22.7.3 Side Stiffeners and Structural Members

22.7.3.1 Web Frames

Web frame sectional modulus, *W*, and moment of inertia, *I*, (together with the effective strake of plating determined in accordance with 22.1.2) shall not be less than the values determined in accordance with the following formulae:

$$W = 17.5\ hbl^2\ [\text{cm}^3] \quad (22.7.3.1\text{-}1)$$

$$I = 29.6\ hbl^3\ [\text{cm}^4] \quad (22.7.3.1\text{-}2)$$

b – web frame spacing, [m];

l – web frame span between support points at the bottom and deck(s), [m];
h – vertical distance, measured at the ship side, between web frame midpoint and the upper deck, [m].

Web frames situated in tanks shall fulfil the requirements specified in 22.7.5.2.

22.7.3.2 Side Stringers

Ships with transverse framing system and the side height (from the bilge transition into the ship side) exceeding 2.5 m shall have side stringers.

Side stringer spacing shall not exceed 2.5 m.

Side stringer sectional modulus, *W*, and moment of inertia, *I*, (together with the effective strake of plating determined in accordance with 22.1.2) shall not be less than the values determined in accordance with the following formulae:

$$W = 17.5\ hbl^2\ [\text{cm}^3] \qquad (22.7.3.2\text{-}1)$$

$$I = 29.6\ hbl^3\ [\text{cm}^4] \qquad (22.7.3.2\text{-}2)$$

b – average width of the ship side sector supported by side stringer, [m];
l – side stringer span between support points on web frames, [m];
h – vertical distance, measured at the ship side, between side stringer midpoint and the upper deck, [m].

Side stringers situated in tanks shall fulfil the requirements specified in 22.7.5.2.

22.7.3.3 Frames

Sectional moduli, *W*, and moments of inertia, *I*, (together with the effective strake of plating determined in accordance with 22.1.2) of transverse or longitudinal frames shall not be less than the values determined in accordance with the following formulae:

$$W = 19.5\ hsl^2\ [\text{cm}^3] \qquad (22.7.3.3\text{-}1)$$

$$I = 32.9\ hsl^3\ [\text{cm}^4] \qquad (22.7.3.3\text{-}2)$$

s – frame spacing, [m];
l – frame span between support points at the bottom, side stringers and decks (for transverse frames) or on web frames and transverse bulkheads/divisions (for longitudinal frames), [m];
h – vertical distance, measured at the ship side, between longitudinal frame midpoint or transverse frame midpoint and the upper deck, [m].

22.7.3.4 For ships who may be subjected to impacts during their service, it is recommended that the sectional modulus and moment of inertia determined in accordance with 22.7.3.3 be increased by at least 25%.

22.7.4 Deck Stiffeners and Structural Members

22.7.4.1 Deck Beams

In the case of transverse framing system, deck beams may be applied at every other frame. In decks above tanks, in recesses and tunnels, deck beams shall be fitted at each frame.

In superstructure decks, deck beams shall be fitted at the same planes as the main deck beams.

Sectional modulus, *W*, and moment of inertia, *I*, (together with the effective strake of plating determined in accordance with 22.1.2) of transverse or longitudinal deck beams shall not be less than the values determined in accordance with the following formulae:

– for deck beams above tanks:

$$W = 19.5\ hsl^2\ [\text{cm}^3] \qquad (22.7.4.1\text{-}1)$$

$$I = 32.9\ hsl^3\ [\text{cm}^4] \qquad (22.7.4.1\text{-}2)$$

– for other deck beams:

$$W = 13.6\ hsl^2\ [\text{cm}^3] \qquad (22.7.4.1\text{-}3)$$

$$I = 23\ hsl^3\ [\text{cm}^4] \qquad (22.7.4.1\text{-}4)$$

s – deck beam spacing, [m];
l – deck beam span between support points on structural members (deck longitudinals, transverse girders, ship sides, bulkheads), [m];
h – to be determined in accordance with 22.6.3.1, [m].

22.7.4.2 Longitudinal and Transverse Deck Girders

Sectional modulus, *W*, and moment of inertia, *I*, of longitudinal and transverse deck girders (together with the effective strake of plating determined in accordance with 22.1.2) shall not be less than the values determined in accordance with the following formulae:

– for deck above tanks:

$$W = 17.5\ hbl^2\ [\text{cm}^3] \qquad (22.7.4.2\text{-}1)$$

$$I = 29.6\ hbl^3\ [\text{cm}^4] \qquad (22.7.4.2\text{-}2)$$

– in other regions:

$$W = 11.7\ hbl^2\ [\text{cm}^3] \qquad (22.7.4.2\text{-}3)$$

$$I = 19.75\ hbl^3\ [\text{cm}^4] \qquad (22.7.4.2\text{-}4)$$

b – average width of the deck sector supported by longitudinal or transverse girder, [m];
l – longitudinal or transverse girder span between its support points, [m]; if longitudinal deck girder span *l* has been assumed as the distance between transverse bulkheads, then for transverse deck girders *l* may be taken as the distance between the longitudinal deck girders or as the distance between the transverse deck girder face plates and the longitudinal deck girder/bulkhead; if transverse deck girder span *l* has been assumed as the distance between the web frame face plates at both ship sides (or distance between the web frame face plate and longitudinal bulkhead), then longitudinal deck girder span *l* may be taken as the distance between deck beams or between bulkhead and the nearest transverse deck girder;
h – to be determined in accordance with 22.6.3.1, [m].

22.7.4.3 In the areas subjected to large local loads, stiffeners and structural members shall be strengthened respectively, and additional deck strengthening shall be fitted as necessary.

22.7.5 Bulkhead Stiffeners and Structural Members

22.7.5.1 Bulkhead Stiffeners

Sectional modulus, *W*, and moment of inertia, *I*, of horizontal or vertical stiffeners of bulkheads (together with the effective strake of plating determined in accordance with 22.1.2) shall not be less than the values determined in accordance with the following formulae:

– for stiffeners with free ends:

$$W = 11.3\ hbl^2\ [\text{cm}^3] \qquad (22.7.5.1\text{-}1)$$

$$I = 19.1\ hbl^3\ [\text{cm}^4] \qquad (22.7.5.1\text{-}2)$$

– for stiffeners with their ends so fixed to the stiffeners or structural members of the deck, bottom or ship sides that bending moments be transmitted by the node:

$$W = 8.95\ hsl^2\ [\text{cm}^3] \qquad (22.7.5.1\text{-}3)$$

$$I = 15.2\ hsl^3\ [\text{cm}^4] \qquad (22.7.5.1\text{-}4)$$

s – stiffener spacing, [m];
l – stiffener span between support points at the bottom/deck or ship sides and structural members, [m];
h – vertical distance, measured in the ship centre plane, between the stiffener midpoint to deck to which the bulkhead extends, [m].

Sectional modulus and moment if inertia of the collision bulkhead shall be increased by 25% compared to the values required above.

22.7.5.2 Bulkhead Structural Members

Sectional modulus, *W*, and moment of inertia, *I*, of vertical and horizontal members of bulkheads (together with the effective strake of plating determined in accordance with 22.1.2) shall not be less than the valued determined in accordance with the following formulae:

$$W = 11.7\ hbl^2\ [\text{cm}^3] \qquad (22.7.5.2\text{-}1)$$

$$I = 19.75\ hbl^3\ [\text{cm}^4] \qquad (22.7.5.2\text{-}2)$$

b – half the sum of span of the spans of bulkhead stiffeners adjoining the girder on both sides, [m];
l – vertical or horizontal member span between its support points at the bottom/deck or ship sides/longitudinal bulkheads, [m];
h – vertical distance, measured in the ship centre plane, between the horizontal or vertical member midpoint to the deck to which the bulkhead extends, [m].

22.7.6 Tank Stiffeners and Structural Members

22.7.6.1 Tank Outside Stiffeners

Sectional modulus, *W*, and moment of inertia, *I*, of tank wall stiffeners (together with the effective strake of plating determined in accordance with 22.1.2) shall not be less than the values determined in accordance with the following formulae:

– for stiffeners with free ends:

$$W = 19.5\ hsl^2\ [\text{cm}^3] \qquad (22.7.6.1\text{-}1)$$

$$I = 32.9\ hsl^3\ [\text{cm}^4] \qquad (22.7.6.1\text{-}2)$$

– for stiffeners with their ends fixed to structural members or other stiffeners:

$$W = 14.6\ hsl^2\ [\text{cm}^3] \qquad (22.7.6.1\text{-}3)$$

$$I = 24.7\ hsl^3\ [\text{cm}^4] \qquad (22.7.6.1\text{-}4)$$

s – tank stiffener spacing, [m];
l – stiffener span between its points of support on structural members or tank walls, [m];
h – the maximum value of the following three vertical distances (in metres) between the stiffener midpoint to the point at the level of:
a) deck;
b) 0.67 of the distance between the tank top and the overflow pipe level;
c) 0.46 m above the tank top.

22.7.6.2 Structural Members Located inside Tanks

Sectional modulus, *W*, and moment of inertia, *I*, of tank structural members (together with the effective strake of plating determined in accordance with 22.1.2) shall not be less than the values determined in accordance with the following formulae:

$$W = 17.5\ hbl^2\ [\text{cm}^3] \qquad (22.7.6.2\text{-}1)$$

$$I = 29.6\ hbl^3\ [\text{cm}^4] \qquad (22.7.6.2\text{-}2)$$

b – half the sum of span of the spans of tank stiffeners adjoining the tank primary stiffener on both sides, [m];
l – see 22.7.6.1;
h – the maximum value of the following three vertical distances (in metres) between the stiffener midpoint to the point at the level of:
  a) deck;
  b) 0.67 of the distance between the tank top and the overflow pipe level;
  c) 0.46 m above the tank top.

22.7.6.3 Stiffeners and structural members located inside the tank which might be detached from the plating due to pressure in the tank are subject to PRS consideration in each particular case.

22.7.7 Superstructure Stiffeners

Sectional modulus, *W*, and moment of inertia, *I*, of vertical stiffeners of superstructure walls and deckhouse walls (together with the effective strake of plating determined in accordance with 22.1.2) shall not be less than the values determined in accordance with the following formulae:

$$W = 19.5\ hsl^2\ [\text{cm}^3] \qquad (22.7.7\text{-}1)$$

$$I = 32.9\ hsl^3\ [\text{cm}^4] \qquad (22.7.7\text{-}2)$$

s – stiffener spacing, [m];
l – height of moulded superstructure or deckhouse, [m];
h – to be determined in accordance with 22.6.6.1, [m].

22.8 Pillars and Foundations

22.8.1 Pillars

22.8.1.1 General

Pillars shall be made of steel or aluminium alloys. The structures under pillars shall have adequate strength to ensure suitable stress distribution.

Axes of pillars between decks and in cargo holds shall be in line vertically.

Apart from pillars supporting deck girders, additional pillars may be required under deckhouses, windlasses, cargo winches and elsewhere, if necessary.

22.8.1.2 Pillar Scantlings

Pillar scantlings shall be determined in accordance with the requirements specified in paragraphs from 12.8.3.1 to 12.8.3.4 using the following values in formula 12.8.3.1-3:

$$p = 10h\ [\text{hPa}] \qquad (22.8.1.2)$$

where:
h – load height in accordance with 22.6.3.1, [m].

22.8.1.3 Vertical Stiffeners of Bulkheads Supporting Deck Girders

Vertical stiffeners of bulkheads supporting deck girders shall fulfil the requirements for pillars.

22.8.2 Foundations

Engines and other ship equipment shall be seated on robust longitudinals adequately supported and stiffened.

The structures of longitudinals shall be connected to structural members of the bottom, sides and decks and shall ensure proper transmission of forces, induced by the supported engines/ equipment, acting in both longitudinal and transverse directions.

Engine foundation exemplary solution is shown in Fig. 22.8.2.

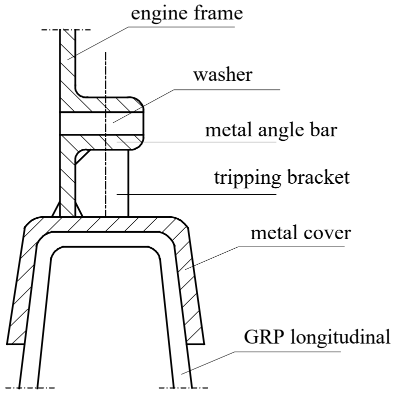


Fig. 22.8.2 Exemplary solutions of foundation longitudinal

22.9 Connections of Hull Structural Elements

22.9.1 General

The connections specified in sub-chapter 22.9 shall be considered as recommended ones.

Application of other solutions is subject to PRS consent in each particular case.

22.9.2 Butt Connections

22.9.2.1 In butt connections, greater strength is achieved for stepped chamfering of both connected elements (Fig. 22.9.2.1).

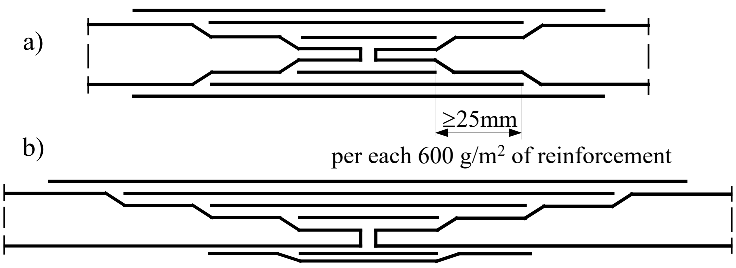


Fig. 22.9.2.1 Butt connections with chamfered elements

22.9.2.2 Less loaded elements and elements of small thickness may be connected without chamfering (Fig. 22.9.2.2).

The number of layers of the connecting laminate on each side shall not be less than the number of layers in the thinner element laminate.

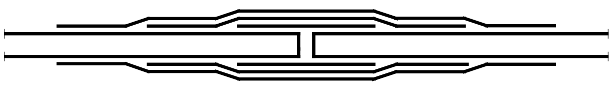


Fig. 22.9.2.2 Butt connections without chamfering of elements

22.9.2.3 Prior to connecting elements of different thicknesses, thickness of the stronger element shall be reduced outside the connection region (Fig. 22.9.2.3).

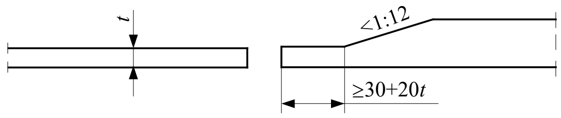


Fig. 22.9.2.3 Elements of different thicknesses prepared for butt connection

22.9.2.4 Recommended method of connecting the hull plating in the transverse plane is shown in Fig. 22.9.2.4.

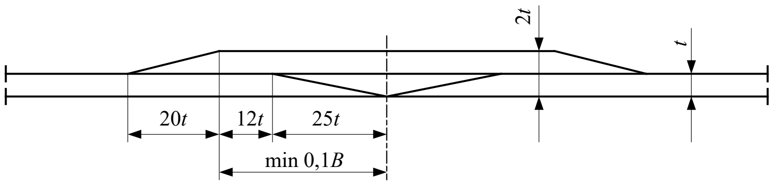


Fig. 22.9.2.4 Recommended method of connecting hull plating elements in transverse plane

22.9.3 Deck to Ships Side Connection

Deck shall be connected to the ship side by means of lap connection with screws. The connection shall be protected with shield made of metal, wood or rubber (Fig. 22.9.3).

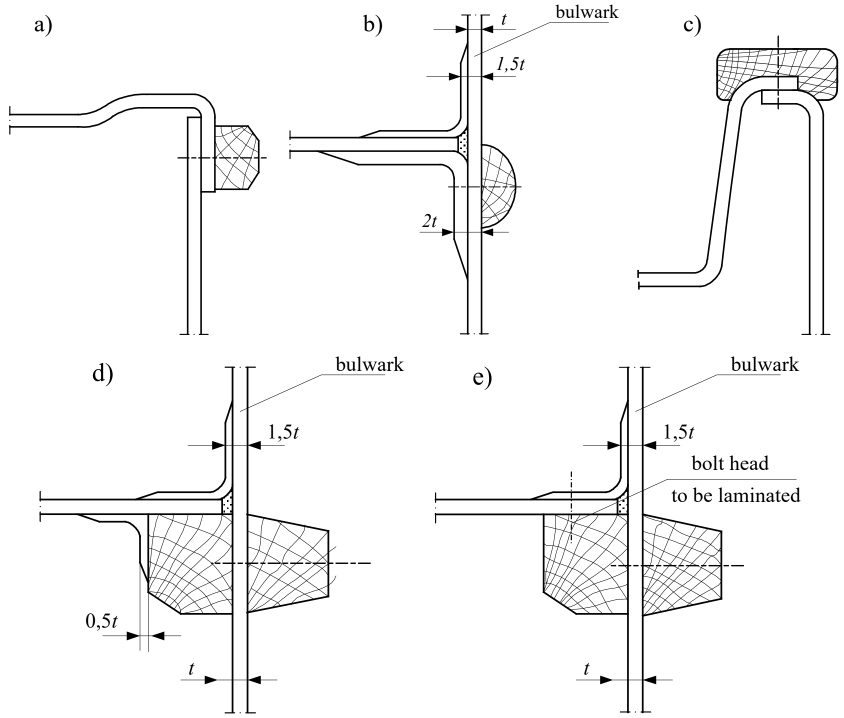


Fig. 22.9.3 Recommended construction pattern for the connection of deck to ship side

The required minimum parameters of such a connection, depending on the ship length, are specified in Table 22.9.3. Intermediate values of L shall be determined by linear interpolation.

Table 22.9.3
Required minimum parameters of deck connection to the ship side

L, [m]	Flange width, [mm]	Bolt diameter, [mm]	Connection spacing, [mm]
9	63.5	6.50	152.5
12	75.0	7.75	165.0
15	87.5	7.00	177.5
18	100.0	10.25	190.5
21	112.5	11.5	203.0
24	125.0	12.75	216.0

Other constructions of the connection of deck to ship side is subject to PRS consideration in each particular case.

22.9.4 Angular Connections

22.9.4.1 Typical angular connections shall have the construction as shown in Fig. 22.9.4.1.

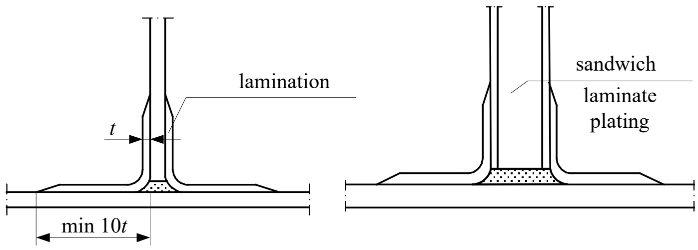


Fig. 22.9.4.1 Typical angular connection

Other angular connection construction is subject to PRS consideration in each particular case.

22.9.4.2 Glass reinforcement mass in overlamination on one side shall not be less than:
– 50% of the reinforcement mass in the thinner element – for elements of monolithic laminate,
– glass reinforcement mass in the thinner overlapping element – for sandwich laminate plating elements.

For one-side overlamination, the values specified above shall be doubled.

Glass reinforcement mass in overlamination shall not be less than:
– 2000 g/m² – in ships having a length $L < 18$ m;
– 2500 g/m² – in ships having a length L within 18 m $\leq L \leq$ 24 m.

22.9.5 Bulkhead to Shell Plating and Bulkhead to Deck Connections

Bulkhead to shell plating and bulkhead to deck connections shall be constructed as shown in:
– Fig. 22.9.5 a – in ships having a length $L \leq 15$ m;
– Fig. 22.9.5 b – in ships having a length $L > 15$ m.

Bolt diameter in the conncetion shown in Fig. 22.9.5*b* shall not be less than *t*, not less – however – than 6.5 mm.

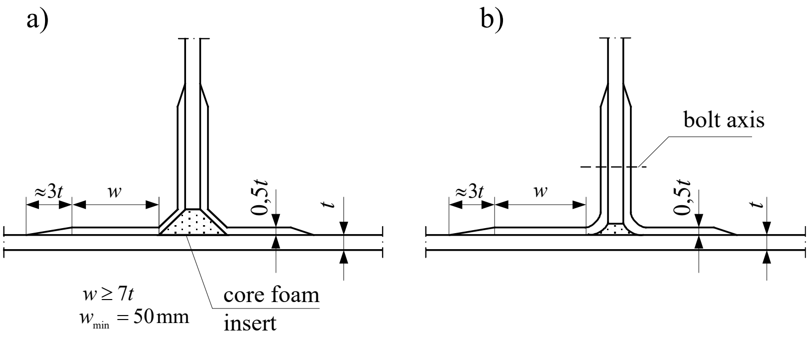


Fig. 22.9.5 Bulkhead to shell plating or bulkhead to deck connections

22.9.6 Stiffener Fixing

22.9.6.1 It is recommended that stiffeners and structural members with empty cores or made of non-structural materials be constructed as shown in Fig. 22.9.6.1.

The required mutual proportions of dimensions of particular elements of stiffeners are specified in Fig. 22.9.6.1.

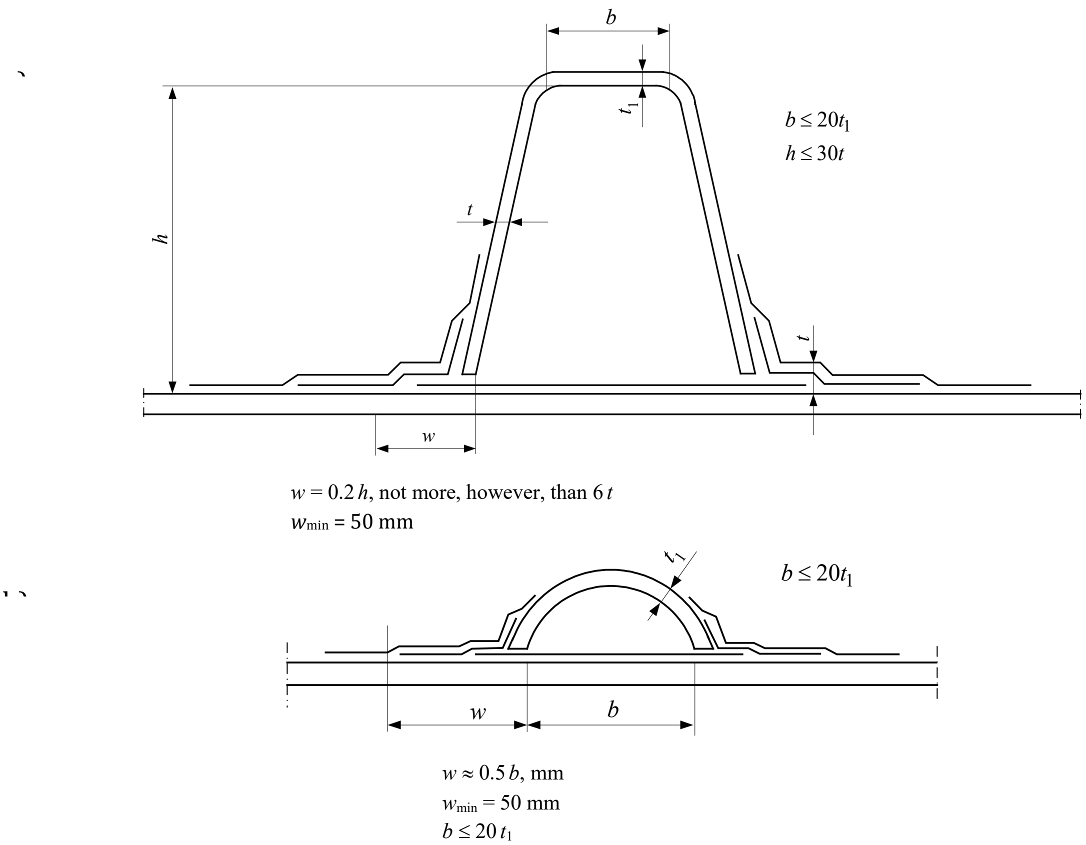


Fig. 22.9.6.1
Construction of stiffeners and structural members with empty cores or made of non-structural materials

Application of other stiffeners is subject to PRS consent in each particular case.

22.9.6.2 Stiffeners of shapes made of laminate may be connected to the plating as shown in Fig. 22.9.6.2, and the dimensional proportions as well as the minimum dimensions shall fulfil the requirements specified in Fig. 22.9.6.1.

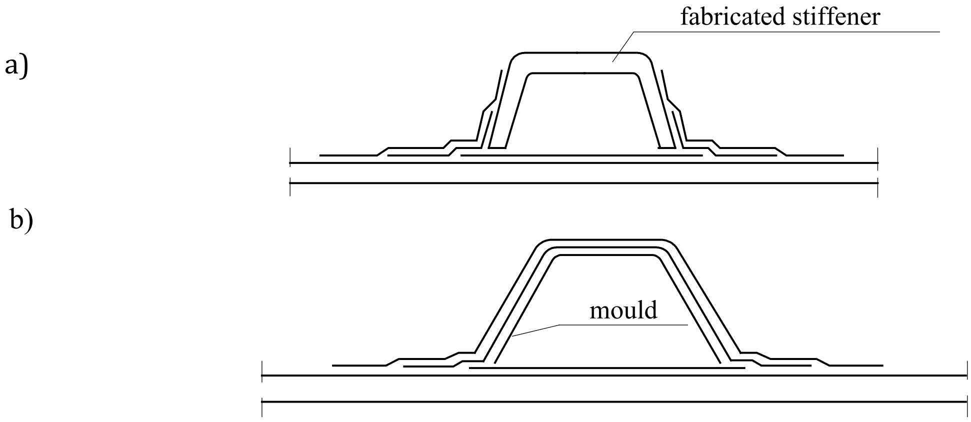


Fig. 22.9.6.2 Stiffeners made of shapes

22.9.6.3 Bulkheads and other divisions made of plywood shall be connected to the plating with laminate angle bars whose total reinforcement mass shall be at least:
2700 g/m² – for bulkheads of not more than 12 mm in thickness,
3600 g/m² – for bulkheads of more than 12 mm and not more than 20 mm in thickness,
4500 g/m² – for bulkheads of more than 20 mm and not more than 25 mm in thickness.

For structural members of height $h > 30t$ (h, t – see Fig. 22.9.6.1a), adequate web stiffening is required.

22.9.6.4 Stiffener penetrations through structural members (Fig. 22.9.6.4-1) and bulkheads (Fig. 22.9.6.4-2) shall be continuous – except for penetrations through tank end bulkheads.

The recommended construction pattern for the longitudinal stiffener connection to bulkhead is shown in Fig. 22.9.6.4-2. These members shall be connected to bulkheads like stiffeners to bulkheads.

Stiffener penetrations through bulkheads shall not impair the bulkhead watertight integrity which also applies to trapezoid stiffeners.

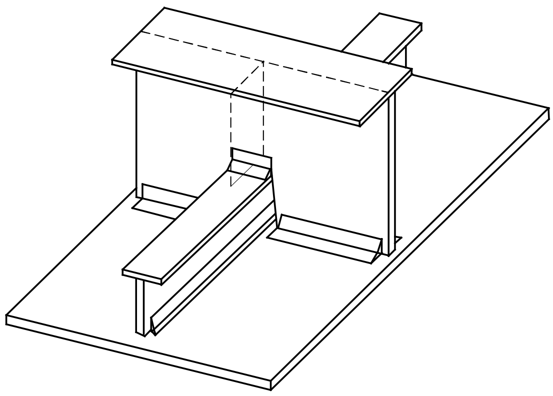


Fig. 22.9.6.4-1 Stiffener to member connection

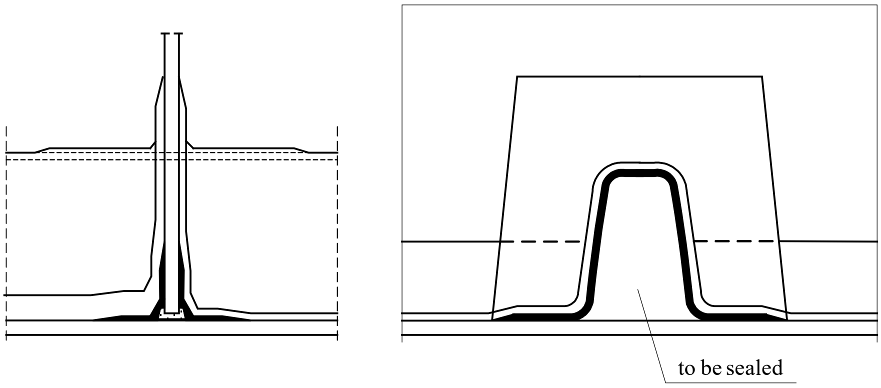


Fig. 22.9.6.4-2 Longitudinal stiffener to bulkhead connection

22.9.7 Sandwich Laminate Plating and Solid Plating

22.9.7.1 In the locations where ship equipment is installed, plywood inserts shall be applied (between the lining layers) instead of core foam or solid plating shall be arranged there. The recommended pattern for the connection of sandwich laminate plating with the solid plating is shown in Fig. 22.9.7.1.

The thickness and scope of application of solid plating shall be determined by calculations taking account of the type and magnitude of stresses occurring in the relevant location.

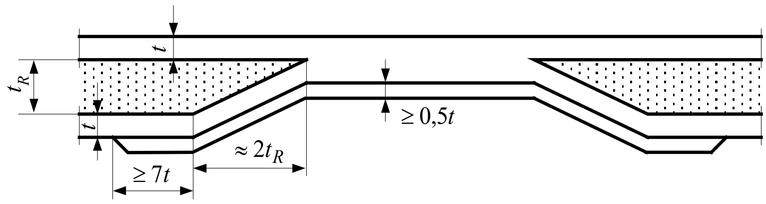


Fig. 22.9.7.1 Connection of sandwich laminate plating to solid plating

22.9.7.2 In way of all transitions of sandwich laminate plating into solid plating, core foam shall be chamfered at 1:2 (see Fig. 22.9.7.1).

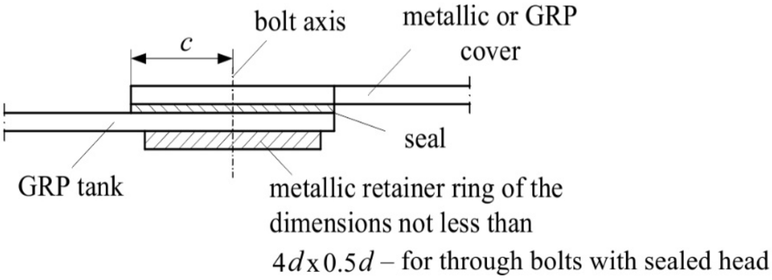
22.9.8 Openings and Edges

22.9.8.1 All the protruding laminate edges shall be sealed with resin.

Multilayer plate edges and edges of openings in such plates shall be sealed with mat and resin.

22.9.8.2 Recommended methods of fixing manholes to tanks are shown in Fig. 22.9.8.2.

a)



$c = 3d$ – for GRP cover
$c = 2d$ – for GRP metallic cover
d – bolt diameter (not less than 6.5 mm).

b)

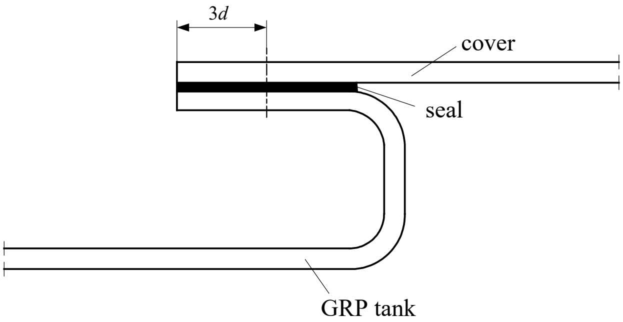


Fig. 22.9.8.2 Tank manhole fixing

23 WOODEN HULLS OF FISHING VESSELS

23.1 General Requirements

23.1.1 The scantlings specified in this Chapter apply to vessels whose main dimensions and their ratios, as well as propulsion engine power output are within the limits specified in Table 23.1.1.

Table 23.1.1
Main dimensions and propulsion engine propulsion engine power output

Typical length L, [m]	Length overall L_c, [m]	Maximum allowable length L_{pp}, [m]	B [m]	H [m]	N [kW]
10	$10 \le L_c < 12.0$	9.5	3.4	1.4	37.0
12	$12 \le L_c < 14.0$	11.5	4.0 ÷ 4.3	1.6 ÷ 2.1	55.0
14	$14 \le L_c < 16.0$	13.5	4.3 ÷ 4.7	1.8 ÷ 2.2	74.0
16	$16 \le L_c < 18.0$	15.0	4.6 ÷ 5.0	2.1 ÷ 2.3	92.0
18	$18 \le L_c < 20.0$	17.0	5.3	2.5	110.0
20	$20 \le L_c < 22.0$	18.5	5.6	2.8	129.0
22	$22 \le L_c < 24.0$	20.5	6.2	3.0	166.0

L – the so called typical length, [m], specified in column 1 of Table 23.1.1 depending on the length overall, L_c, [m].
N – engine power output, [kW].

23.1.2 If the propulsion engine power output exceeds the value specified in Table 23.1.1 by more than 10%, the required scantlings of the hull structural members are subject to PRS agreement in each particular case.

23.2 Materials

23.2.1 Wood brands, adhesives and other materials used for the construction of fishing vessels shall fulfil the requirements specified in *Part VI – Materials*, of the *Rules for Construction and Classification of Sea-going Yachts*.

In this Chapter, it has been assumed that the rudder stock assembly (keel, stem, stern), bottom floors, frames, longitudinals, deck beams as well as the bottom and side shell planking are made of oak-wood while the deck planking – of coniferous tree wood. Some of the above mentioned structural elements may be reinforced with steel plates or flat bars of category A (see 2.2). Keel and keel planking woodstaves are permitted to be made of beechwood. The hull shell planking may be made of coniferous tree wood subject to PRS consent in each particular case following the successful wood test results.

23.2.2 For a wood brand of density less than that required, the scantlings shall be increased in accordance with the following formula (see also Table 23.2.2):

$$a_z = (1 + g_p - g_z)a \text{ [mm]} \quad (23.2.2)$$

a_z – scantling of member made of irregular wood brand, [mm];
g_p – required wood density, [t/m^3];
g_z – applied wood density, [t/m^3];
a – scantling of member made of regular wood brand, [mm].

Table 23.2.2
Average wood density (for 15% humidity)

Wood brand	Required density, g_p, [t/m^3]
Oak	0.71
Beech	0.73
Elm	0.68
Ash	0.75
Larch	0.68
Pine	0.55
Spruce	0.47
Fir	0.45

23.2.3 Timber used for the construction shall not have more humidity than:
.1 rudder stock assembly with brackets – without limitation;
.2 frames, deck beams, longitudinals – 20%;
.3 shell planking below the waterline – 25%;
.4 shell planking above the waterline – 20%.

If the timber is intended for laminated wood constructions, its humidity shall fulfil the requirements specified in Table 23.18.3.2.

23.2.4 Timber used for constructions shall be treated with a wood preservative approved by PRS. After woodworking and during the hull construction operations adequate wood preservation procedures shall be applied.

Other wood treatment methods for modification of its properties (e.g. thermal or chemical) are subject to PRS consideration in each particular case.

23.2.5 Approximate durability of hull structural members is specified in Table 23.2.5.

Table 23.2.5

Wood brand *	Durability of hull structural members, [years]							
	Keel	Stem, stern	Keelson	Frames, floors	Shell planking below the waterline	Shell planking above the waterline, deck stringer and side stringers	Deck	Deck beams, longitudinal deck girders, beam knees
Oak (0.75)	15	15	15	15	15	15	15	15
Oak (0.70)	13	13	13	13	13	13	13	13
Oak (0.60)	12	11	11	12	12	11	11	11
Ash (0.70)	–	–	–	12	–	–	–	–
Elm (0.70)	12	10	10	12	–	–	–	–
Maritime pine (0.65)	–	–	12	–	12	12	12	12
Pine (0.60)	–	–	10	–	10	10	10	10
Pine (0.50) Fir (0.42) Spruce (0.42)	–	–	–	–	–	–	7	6

* The number in brackets next to the specific wood brands represents the minimum mass density (t/m^3) for 15% humidity.

23.3 Keel and Keelson

23.3.1 Keel and keelson required scantlings are specified in Table 23.3.1 depending on the ship length. Keelson is required for ships of 16 m in length and above.

23.3.2 Keel may be made as a complex structure which consists of the outer keel and inner keel. Their combined cross-sectional area shall not be less than that corresponding to the dimensions specified in Table 23.3.1. It is recommended that the specific components be shaped as shown in Fig. 23.3.2.

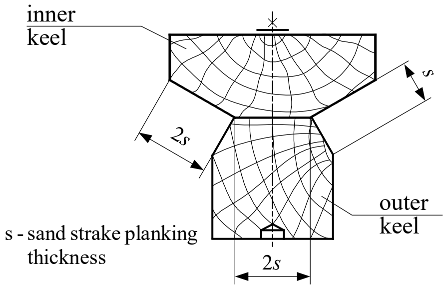


Fig. 23.3.2 Complex structure keel

23.3.3 If the keel or keelson is split along, the segments shall be connected with hooked scarf joint or sealing double page (see Fig. 23.3.3). The minimum length of scarf shall be 5 times the prescribed keel siding.

The number of pins in a joint shall be determined depending on the scarf length:
$l_z \leq 1.5$ m – 3 pins
$1.5 < l_z \leq 1.7$ m – 4 pins
$1.7 < l_z \leq 1.9$ m – 5 pins
$1.9 < l_z \leq 2.1$ m – 6 pins.

Other pins (e.g. those connecting the keel to floors or keel to keelson) do not count in that case.

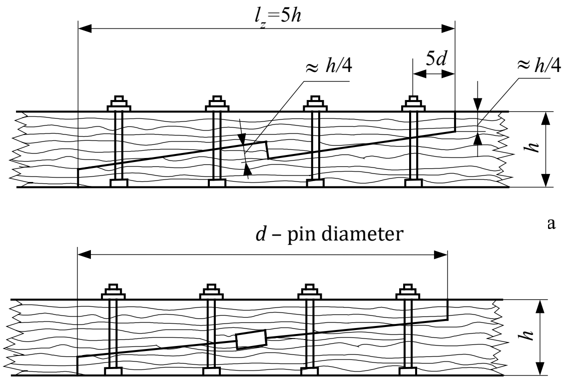


Fig. 23.3.3 Keel scarves

Scarves on the outer keel, inner keel and keelson shall be mutually shifted by at least 3 m.

23.3.4 Scarves shall not be situated in the midship portion of the hull or under the engine.

23.3.5 Keel scarves shall be additionally strengthened with galvanized steel bars fitted on both sides.

23.3.6 Under the prescribed keel, an oak slab keel of at least 50 mm in thickness shall be applied. Between the keel and slab keel an insulation layer (tarred felt, miniumed fabric etc) shall be put.

Table 23.3.1
Required scantlings of structural members, [mm]

Item	Structural member		Typical length L, [m] (in acc. with Table 23.1.1)						
			10	12	14	16	18	20	22
1	Spacing of:	single frames	360	380	400	420	440	450	460
		double frames	410	430	460	490	520	540	560
2	Outer keel:	breadth	140	160	175	190	210	230	250
		height	130	140	175	190	210	230	250
3	Inner keel:	breadth	200	220	250	275	300	325	350
		height	90	100	110	125	135	145	160
4	Keelson [1]:	breadth	–	–	–	150	175	200	220
		height	–	–	–	150	175	200	200
5	Outer stem:	breadth	130	140	160	170	180	200	220
		height	120	130	140	150	170	180	210
6	Inner stem:	breadth	190	210	230	250	270	290	330
		height	80	90	110	120	130	150	170
7	Sternframe:	breadth	propeller shaft liner diameter shall be added to the outer breadth of sternframe						
		height	200	220	250	260	300	330	380
8	Floors:	height	180	250	300	350	400	400	400
		thickness	80	90	100	110	120	130	140
9	Connections of keel, stem, sternframe and floors – bolt or pin diameter		16	16	19	22	22	25	25
10	Frames:	height at the bottom and bilge	130	150	170	180	190	200	210
		height at the deck	100	110	120	130	140	150	150
		single frame thickness	80	90	100	110	120	130	140
		double frame thickness	65	70	80	90	100	110	120
11	Bottom and side shell planking: thickness		32	35	38	42	45	48	52
		maximum breadth of washboard under water	220	220	220	250	280	350	350
		maximum breadth of washboard above water	120	140	160	160	170	200	200
12	Sheer strake:	breadth	200	300	400	500	750	1000	1000
		thickness	40	45	50	55	60	65	70
		gunwale maximum breadth	200	300	300	300	300	300	300

Item	Structural member		Typical length L, [m] (in acc. with Table 23.1.1)						
			10	12	14	16	18	20	22
13	Bottom longitudinal:	height/thickness	–	–	–	–	–	–	400/70
	Bilge stringer:	breadth	200	250	300	300	300	400	500
		thickness	50	50	60	60	70	80	90
	Longitudinal deck girder:	height	180	200	250	340	350	370	400
		thickness	50	55	60	65	70	80	90
	Longitudinal deck subgirder	height	–	–	150	150	170	200	200
		thickness	–	–	50	55	60	65	70
14	Wooden watertight bulkheads [2]:								
		stave thickness	55	55	65	65	65	75	75
		stiffener height	80	90	100	110	120	140	140
		stiffener thickness	55	60	70	75	80	90	90
	Steel watertight bulkheads [2]:								
		planking thickness	4	4	5	5	5	6	6
		stiffeners	60×40×6	75×50×6	75×50×8	90×60×8	90×60×8	100×75×8	100×75×8
15	Bulwark:	thickness	25	25	25	30	30	35	35
16	Engine seating:	height	150	180	200	220	240	250	250
		breadth	160	180	200	220	240	250	250
		plate thickness	15	15	15	20	20	25	25

[1] Keel transverse scantlings and keelson height may be altered by not more than 20% on the condition of maintaining the prescribed cross-sectional area.
[2] The maximum stiffener spacing for both wooden and steel bulkheads is 600 mm, whereas for bulkheads with plywood planking 500 mm.

23.4 Stem

23.4.1 The required stem scantlings are specified in Table 23.3.1. Stem breadth above the summer load waterline may be reduced gradually to 80% of the value indicated in the table.

23.4.2 The minimum breadth of stem measured between the inner edges of stave keys shall not be less than the double stave thickness as specified in Table 23.3.1, item 11 (see Fig. 23.4.2).

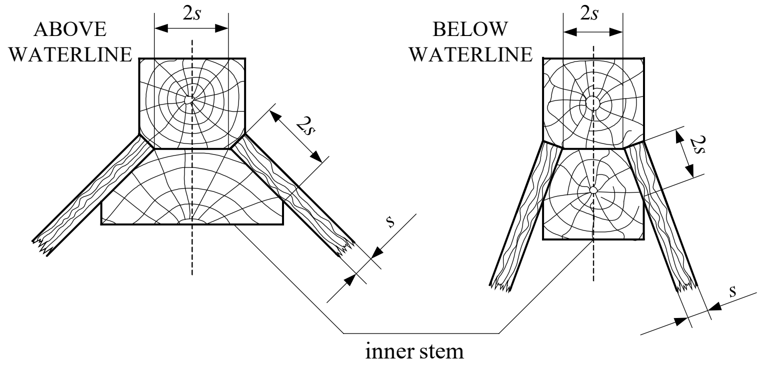


Fig. 23.4.2. Stem

23.4.3 The stem forward plane shall be protected with a flat bar having 10÷12 mm in thickness and breadth equal to 75% of the stem breadth.

23.5 Sternframe

23.5.1 Required sternframe scantlings are specified in Table 23.3.1.

23.5.2 Propeller post shall have such breadth that distance *e* between the edge of hole for the stern tube and the inner edge of the stave key be not less than 0.8 of planking stave thickness *s*, not less, however, than 20 mm (see Fig. 23.5.2). If this condition is impossible to be fulfilled for the sternframe thickness required in Table 23.3.1, item 7, the local thicknesses of the sternframe shall be increased by the application of aprons.

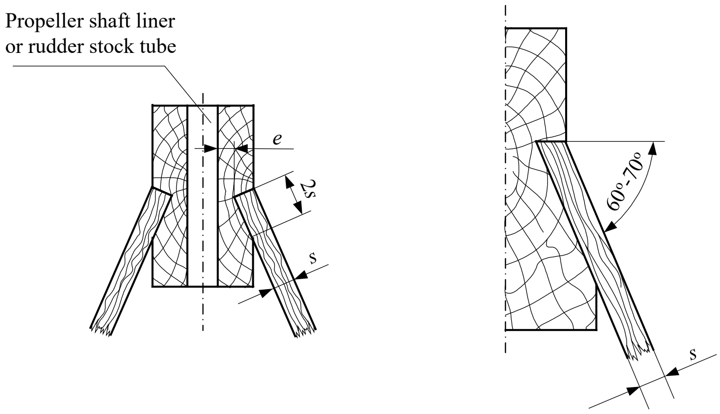


Fig. 23.5.2 Sternframe

23.5.3 In way of propeller shaft liner, the planking stave thickness may be reduced in accordance with 23.8.5.

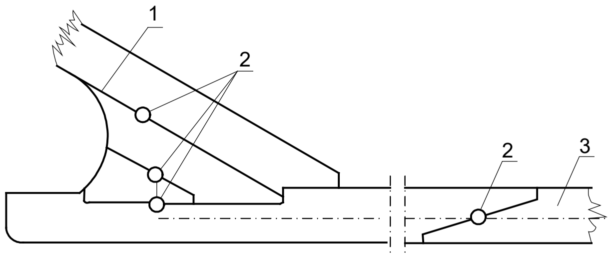
23.5.4 Sternframe structural members shall have such scantlings that the connecting bolts do not split the wood and the propeller shaft liner fixing be watertight.

23.6 Keel Connection to Stem and Sternframe

23.6.1 Stem and sternframe shall be connected to the keel with robust wooden brackets with the appropriate ring configuration (see 23.9.3.4).

23.6.2 Keel connection to the stem and sternframe shall be additionally strengthened with aprons of galvanized steel bars fitted on both sides.

23.6.3 All the connections of keel, stem and stern (including the keel scarves) in line with the stave planking key shall be sealed with pinewood dowel pins of 22÷25 mm in diameter. Keel scarves shall be additionally sealed with pages (see Fig. 23.3.3).



1 – planking stave feather line, 2 – pinewood dowels, 3 – keel

Fig. 23.6.3 Keel, stem and stern sealing

23.7 Bottom and Side Framing

23.7.1 General

Required frame spacing and scantlings of frames, floors and longitudinal girders are specified in Table 23.3.1. Frame spacing shall be measured between their axes of symmetry.

23.7.2 Frames

23.7.2.1 Single frames shall be made of properly grown wood. Single frame segments may be connected with oakwood apron fixed on one side. The apron shall have the same thickness as the frame and length at least 4 times the frame depth. Frame butt shape may be straight (Fig. 23.7.2.1-1*a*) or Z-shaped (Fig. 23.7.2.1-1*b*). Connections of frame segments may also be overlapping (see Fig. 23.7.2.1-1*c*). The overlapping length of the frame segments shall not be less than 700 mm. The overlapping lengths of floor segments shall be as long as practicable (see Fig. 23.7.2.5).

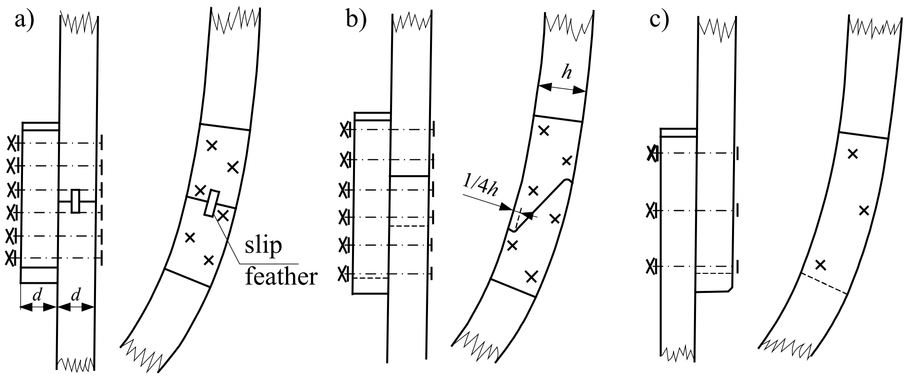
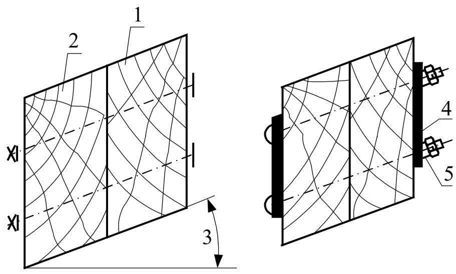


Fig. 23.7.2.1-1 Connection of frame segments

Additional explanation of the recommended connection of frame segments is provided in Fig. 23.7.2.1-2.

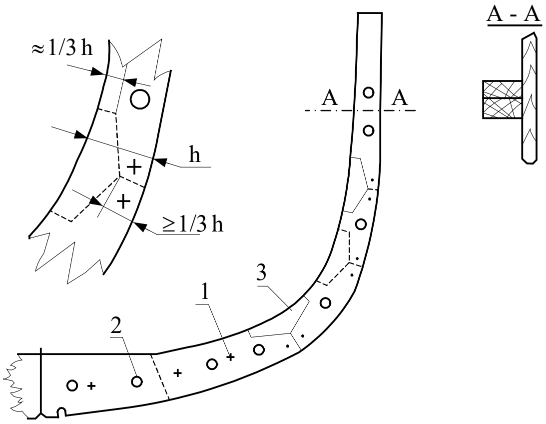


1 – frame segment, 2 – apron or frame segment, 3 – bevel angle
4 – galvanized steel apron, 5 – galvanized wedge-shaped pad

Fig. 23.7.2.1-2
Connection of frame segments – section in the plane perpendicular to the frame axis

23.7.2.2 Double frames consisting of two layers with staggered butt connections are permitted. The double frame thickness specified in Table 23.3.1 applies is the thickness of one layer. Individual layers of frame may be arranged with one wedge strut (Fig. 23.7.2.2).

The wedge struts of particular layers shall staggered along the frame.



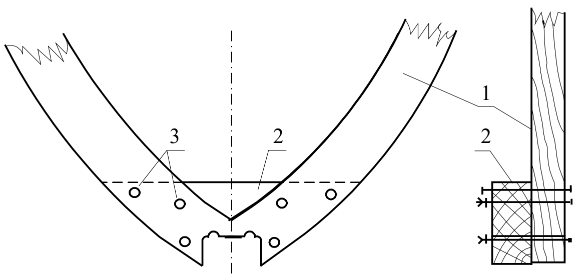
1 – bolts, 2 – dowel, 3 – wedge strut

Fig. 23.7.2.2 Double frame with wedge strut

23.7.2.3 Double frames may be constructed with gaps of 12÷15 mm between the specific layers. The oakwood struts shall be provided at each bolt connecting the layers. For such a construction wedge struts mentioned in 23.7.2.2 are not permitted.

23.7.2.4 Frame depth required at the bottom and bilge (specified in Table 23.3.1) may be gradually reduced (from the bilge) to the depth required at the deck.

23.7.2.5 Each frame shall be connected to a floor with at least 3 bolts (Fig. 23.7.2.5).



1 – frame, 2 – floor, 3 – bolt

Fig. 23.7.2.5 Connection of frame to floor

23.7.3 Floors

23.7.3.1 Floor height required in Table 23.3.1 shall be measured from the keel top edge.

23.7.3.2 Under the engine foundation, the floor thickness shall be increased by at least 20%.

23.7.3.3 If steel floors are provided over wooden floors at each frame in way of the engine foundation, then the requirement specified in 23.7.3.2 may be waived.

23.7.3.4 In floors cross-flood openings shall be provided to ensure the bilge water drainage.

23.7.4 Longitudinals

23.7.4.1 Bilge stringers shall extend from the stem to sternframe. If the bilge stringer is not provided in the bow and stern due to their shape, then steel structural members of the cross-section dimensions as specified in 23.7.4.6 shall be fitted in the bow and stern. The steel shall comply with the requirements for category A (see 2.2.2).

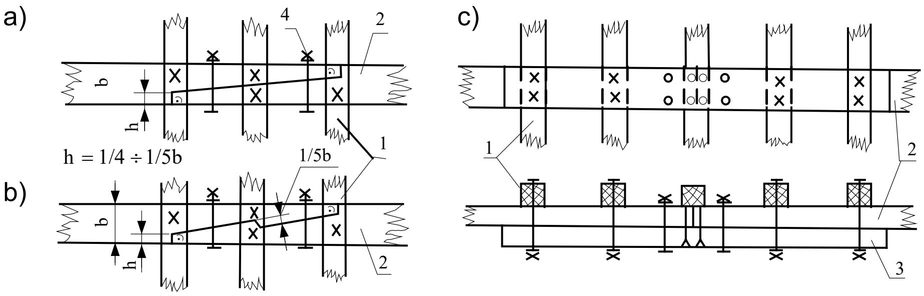
23.7.4.2 Longitudinal deck stringers shall penetrate bulkheads and shall extend from the stem to sternframe continuously.

23.7.4.3 In ships of a length Lc ▯ 14 m, a continuous longitudinal deck subgirder shall also be provided.

23.7.4.4 Longitudinal deck girder connections and planking stave connections shall be staggered in way of the girder in accordance with 23.8.3.

The girders shall be connected with scarves or overlapping connections having a length not less than 2 frame spacings so that they are connected to 3 frames (see Fig. 23.7.4.4).

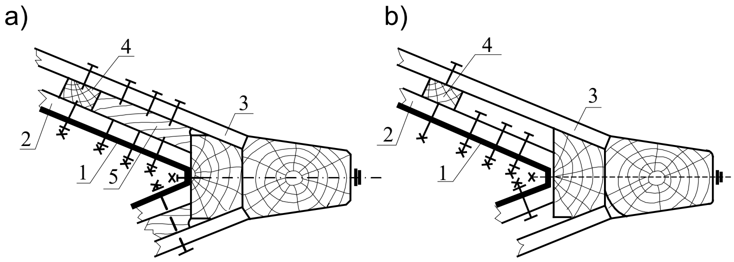
Girder overlapping connections with aprons of the length equal to quadruple frame spacing is permitted (see Fig. 23.7.4.4).



1 – frame, 2 – girder, 3 – apron, 4 – bolt

Fig. 23.7.4.4 Girder connections

23.7.4.5 Longitudinal deck and bilge girders shall be connected with the stem and sternframe by means of horizontal steel members of an arm length not less than 600 mm, and the bow members shall extend as far as to the second frame aft of the stem. The connections shall be made with scarf bolts and for thinner elements an insert shall be used to fill the space between the girder and planking (Fig. 23.7.4.5*a*) or fixing the steel member straight to the girder (Fig. 23.7.4.5*b*). The bolt diameters shall be taken the same as for fixing the longitudinal bilge and deck girders in accordance with 23.15.4.1.



1 – steel member, 2 – girder, 3 – planking, 4 – frame, 5 – filler insert

Fig. 23.7.4.5 Connection of girders with stem and sternframe using steel member

For high values of the moulded block coefficient, wooden horizontal brackets fixed to the sternframe (stem) having a thickness not less than that of single frames may be used.

23.7.4.6 Steel members mentioned in 23.7.4.1 and 23.7.4.5 shall be made of steel bar having the following dimensions:
– 80×20 – for ships of L_c < 18.0 m,
– 80×30 – for ships of L_c ≥18.0 m.

At the arm ends the structural member thickness may be reduced, by forging, to 10 and 15 mm respectively.

23.7.4.7 On small ships, i.e. for L_c ≤ 14 m, oak wood members may be applied instead of steel ones required in 23.7.4.1 and 23.7.4.5. Their scantlings shall correspond to those required for the single frame cross-section.

23.8 Hull Shell Planking

23.8.1 The required stave dimensions of the bottom and side shell planking as well as the sand strake and sheer strake are specified in Table 23.3.1.

23.8.2 Hull shell planking of ships with a length L_c ≥ 14 m shall be laid on frames in butt configuration (smooth planking).

Ships with a length L_c ≥ 14 m may have planking in overlapping configuration.

23.8.3 Planking staves shall be as long as possible. Individual staves may be extended by laminating on the butt surfaces diagonal to the stave axis and the lamination length shall be at least 8 times the stave thickness. Staves may also be extended by means of overlapping joints in accordance with the requirements specified in 23.8.4. and 23.15.5.5.

Butts shall be so arranged that they are (see Fig. 23.8.3):
– staggered on the adjoining staves by at least 3 frame spacings,
– staggered on staves separated by one continuous stave by at least 2 frame spacings,
– staggered on staves separated by two continuous staves by at least 1 frame spacing,

Two stave buts may be coaxial vertically, if they are separated by three continuous staves.

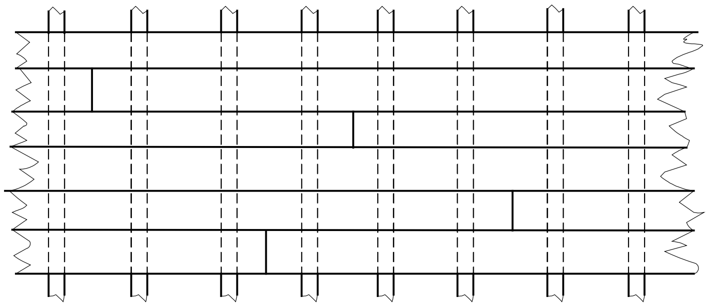


Fig. 23.8.3 Arrangement of butts on staves

23.8.4 In the case of double frames, stave butts shall be arranged on the frames. In the case of bent or laminated single frames, stave butts shall be arranged between the frames using wooden or metallic aprons overlapping the adjoining staves over at least 25 mm (see Fig. 23.8.4).

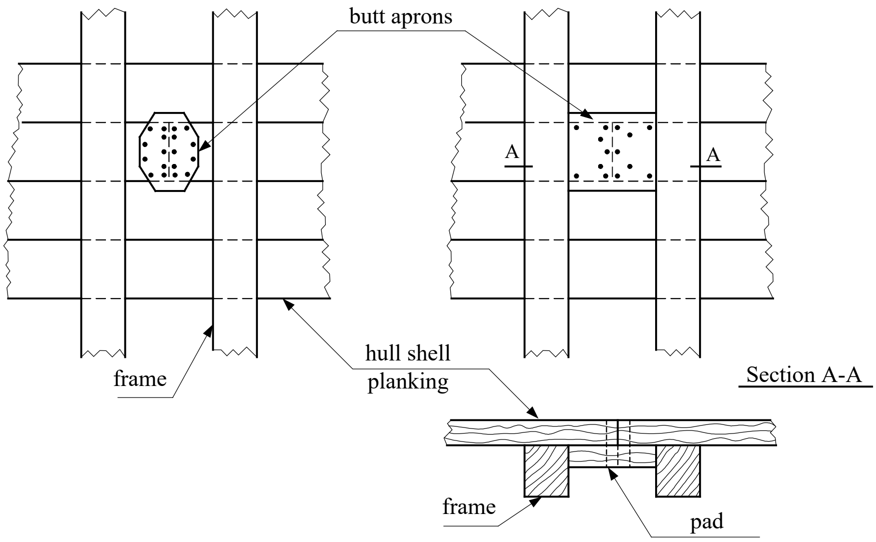


Fig. 23.8.4 Planking stave butts

If a wooden apron extends to the adjoining frames, then its vertical edges at the planking shall be bevelled to enable water flowing down.

The wooden apron thickness shall be more than that of the planking stave by at least 5 mm. The metallic apron thickness shall not be less than 15% of the planking stave thickness.

23.8.5 In way of the stern tube fixing in the sternframe, the ends of planking staves may have thickness reduced to 75% of the prescribed value.

23.8.6 Planking openings having a diameter more than 1/3 of the stave breadth shall be compensated by doubling the planking thickness over the distance equal to the frame spacing.

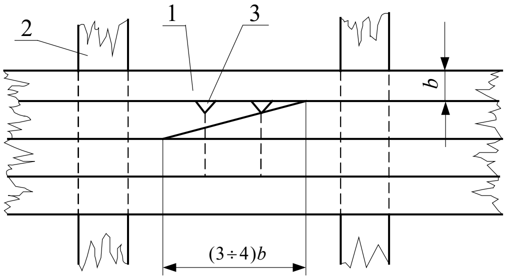
In way of openings whose diameter is more than the stave breadth, particularly such openings which require frame shifting, planking shall be strengthened by doubling both the planking and structural members fixed to the adjacent frames.

23.8.7 Strip planking of strips having thickness equal to the stave thickness required in Table 23.3.1 (item 11) is permitted provided that the sand strake and sheer strake are constructed in accordance with the requirements specified in Table 23.3.1, items 11 and 12. Strip planking shall be fixed in accordance with the requirements specified in 23.15.5.4.

23.8.8 Strip connections shall be made by diagonal cutting of their ends over the distance equal to 3÷4 times the strip breadth. The butt shall be connected by means of two nails with the planking strip beneath (Fig. 23.8.8).

Strip butts shall be so arranged that:
– on the adjoining strips they are staggered by at least 3 frame spacings,
– on strips separated by one continuous strip, they are staggered by at least 2 frame spacings,
– on strips separated by two continuous strips, they are staggered by at least 1 frame spacing.

Two strip connections may be coaxial vertically it they are separated by three continuous strips.



1 – planking strip, 2 – frame, 3 – nails

Fig. 23.8.8 Strip butts

23.8.9 Individual strips of strip planking shall be interconnected with nails of a length approximately 1.7 times the strip breadth driven in the fore layer with the spacing equal to 1/3 of the frame spacing (Fig. 23.8.9). Nails of square cross-section shall have side of not less than 0.1 the planking thickness.

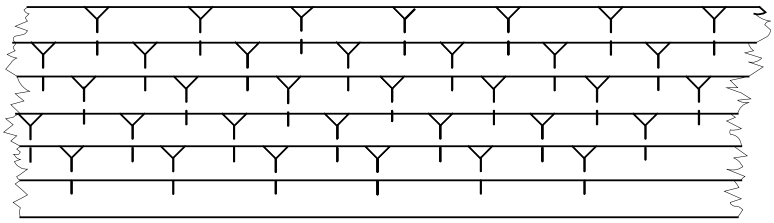


Fig. 23.8.9 Interconnection of strip planking strips

23.9 Deck

23.9.1 General

Deck beam spacing shall not be greater and the number of deck structural members shall be not less than specified in Table 23.9.1.

Table 23.9.1

Item	Structural member (scantlings in mm)		Breadth of ship, *B*, [m]						
			3.4	4.0	4.6	5.2	5.8	6.4	7.0
1	Deck beam spacing		615	645	690	730	780	810	840
2	Deck beams:	– thickness	65	75	85	95	100	110	125
		– depth	110	120	140	160	170	180	200
3	Transverse deck girders:	– thickness	85	100	115	125	135	145	165
		– depth	110	120	140	160	170	180	200
4		– thickness	35	35	40	40	50	60	60
	Stringer plate:	– breadth	200	220	220	300	300	300	400
5		– thickness	35	35	40	40	50	60	60
6	Deck planking staves:	– number,	5	5	5	6	7	9	10

Item	Structural member (scantlings in mm)		Breadth of ship, *B*, [m]						
			3.4	4.0	4.6	5.2	5.8	6.4	7.0
7	Wooden horizontal brackets:	– thickness[1]	75	75	100	100	120	120	140
		– ∅ of bolts	14	14	16	16	18	18	20
	Steel sections (angular, forged, galvanized):	– breadth	50	55	60	60	70	70	75
		– thickness[2],	30	40	45	45	50	50	55
		– length of horizontal arms	440	480	560	640	68	720	800
		– length of vertical arms	660	720	840	960	1020	1080	1200
		– ∅ of bolts	14	14	16	16	18	18	20

1 Bracket thickness shall be measured at the vertex perpendicularly to the arms. The thickness at the arm ends shall not be less than 1/3 of thickness at the vertex.

2 Thickness of angular steel forged structural members may be reduced to 1/3 of thickness at the vertex.

23.9.2 Deck Beams

23.9.2.1 Spacing of deck beams specified in Table 23.9.1 may be changed to enable their connection to frames. In that case, the beam sectional modulus shall not be less than that of the prescribed beam multiplied by the ratio of the applied spacing to the prescribed one. In no case shall the beam spacing exceed 2 frame spacings.

23.9.2.2 Fore and aft of each mast as well as at the ends of deck openings in way of which no beam extends from side to side of the ship, transverse deck girders shall be provided in accordance with the requirements specified in Table 23.9.1, item 3.

Transverse deck girders shall also be applied under cranes unless other local strengthenings have been provided.

23.9.3 Horizontal and Vertical Brackets

23.9.3.1 Deck beams at masts, in the machinery space, under heavy components of deck equipment and in way of deck openings shall be strengthened by horizontal brackets connected to deck longitudinals.

The number of applied horizontal brackets at each side of CP shall not be less than that specified in Table 23.9.1 item 6.

23.9.3.2 Transverse deck girders may be connected to the coplanar frames with steel sections in accordance with the requirements specified in Table 23.9.1, item 7, or by means of wooden brackets.

23.9.3.3 Horizontal brackets required in 23.9.3.1 shall be connected – by means of at least two bolts – to the sheer strake, deck strake and deck planking.

23.9.3.4 Wood fibre orientation and bracket shape shall be in accordance with the requirements as shown in Fig. 23.9.3.4.

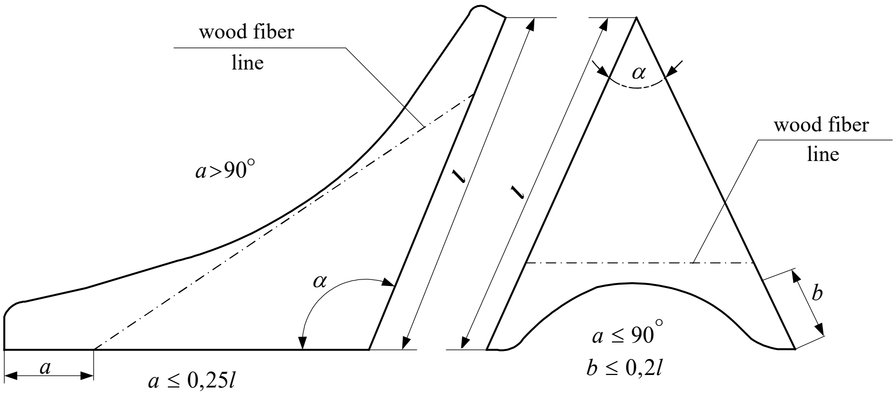


Fig. 23.9.3.4 Correct wood fibre orientation on the bracket outline and bracket shape

23.9.4 Yokes and Gunwale Bars

23.9.4.1 Next to mast fixing and along the deck coamings gunwale bars shall be fitted between deck beams.

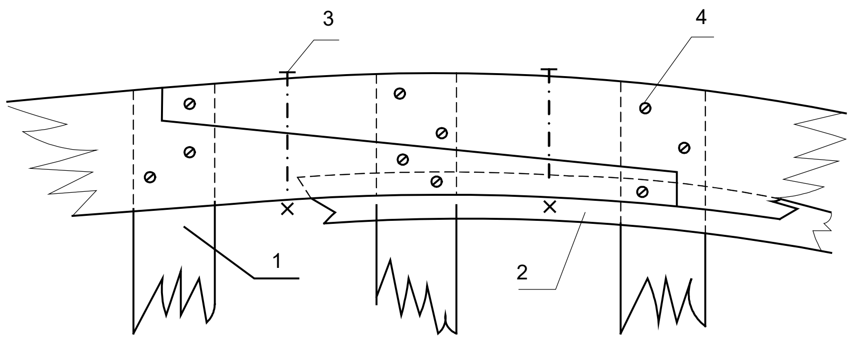
23.9.4.2 If foundation bolts of winches, bollards, gallows, etc., are not in line with deck beams, adequate gunwale bars connecting the adjacent beams shall be applied.

23.9.5 Deck Planking

23.9.5.1 Width of deck staves shall range from 75 to 100 mm. For ships of 16 m in length and above, wider staves – up to 130 mm – are permitted.

23.9.5.2 Distance between the inner edge of deck stringer plate and the inner edge of bulwark supports shall not be less than 1.5 the thickness of such supports.

23.9.5.3 Segments of deck staves and deck stringer plates shall be as long as practicable. Deck stringer plate butts in ships of more than 12 m in length shall be made with scarves (see Fig. 23.9.5.3). Distance from the deck stringer plate to sheer strake, measured fore-and-aft, shall not be less than 1.5 m, and to the deck longitudinal butts – not less than 1.2 m.



1 - deck beam, 2 - binder, 3 - bolt, 4 - screw

Fig. 23.9.5.3 Deck stringer plate scarf

23.9.5.4 Butts of deck planking staves shall be arranged on deck beams (see Fig. 23.9.5.4) or between beams with an apron applied, like in the shell planking (see Fig. 23.8.4).

It is recommended that pattern *a*) in Fig. 23.9.5.4 be applied. Pattern *c*) in Fig. 23.9.5.4 may be applied for connections of short stave segments (e.g. at the end of planking).

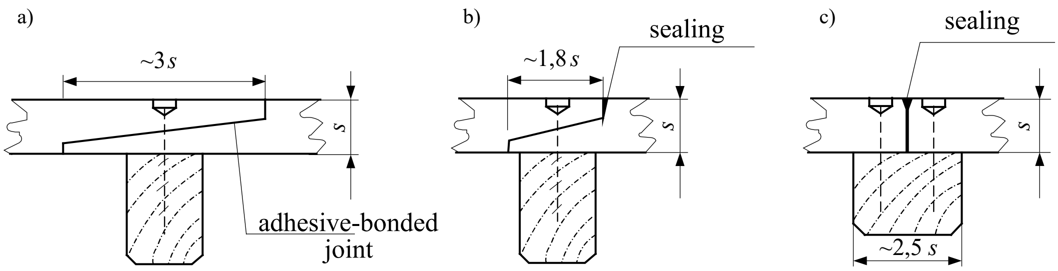
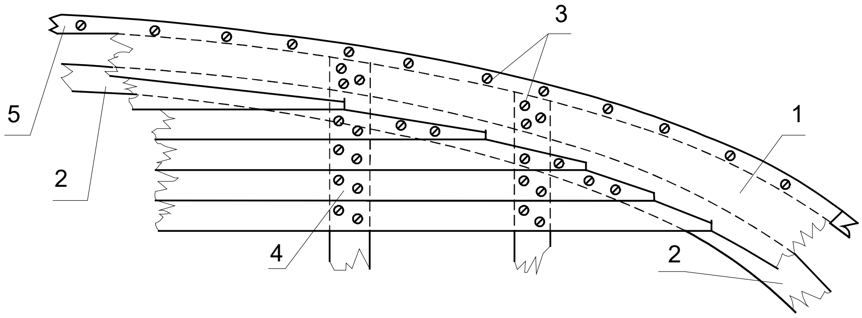


Fig. 23.9.5.4 Permitted patterns of deck planking stave buts

Butts of adjoining staves shall be staggered by at least 3 frame spacings.

23.9.5.5 Deck planking staves at the deck stringer shall be fitted by means of screws on binder (see Fig. 23.9.5.5).



1 – deck stringer, 2 – binder, 3 – screw, 4 – beam, 5 – sheer strake

Fig. 23.9.5.5 Connection of deck staves to deck stringer

23.9.5.6 Coniferous-tree wood for deck planking shall be thoroughly selected, evenly-grained without splinters or knots and of a diameter more than 20 mm.

23.9.6 Deck and Side Diagonals

23.9.6.1 Deck Diagonals

If a ship of more than 9 m in length has the deck covered only with staves, steel deck diagonals made of flat bars shall be fitted and so arranged that they cross each other in the centre plane as close to large openings in the deck. Deck diagonal ends shall be fitted to deck stringer plates. The diagonals shall be interconnected at their intersections.

The thickness of steel diagonals shall not be less than:

$$t = 0.9\sqrt{L} \text{ [mm]} \qquad (23.9.6.1\text{-}1)$$

The thickness of galvanized diagonals may be reduced to:

$$t = 0.81\sqrt{L} \text{ [mm]} \qquad (23.9.6.1\text{-}2)$$

The breadth of steel diagonals shall not be less than:

$$b = 7(L - 5) \text{ [mm]} \qquad (23.9.6.1\text{-}3)$$

and not less than 40 mm
where: L – typical length [m].

23.9.6.2 Side Diagonals

On ships defined in 23.9.6.1 having the shell planking butt connections, side diagonals extending from the midship section forwards and aftwards shall be applied. Scantlings of side diagonals shall not be less than those required in 23.9.6.1 for deck diagonals.

23.10 Watertight Bulkheads

23.10.1 The requirements for subdivision, minimum bow height and forecastle extent specified in sub-chapter 8.2 shall be fulfilled.

Each ship of a length overall L_c > 14 m shall have at least three watertight bulkheads: the collision bulkhead and two bulkheads forming the cargo hold boundaries.

The collision bulkhead location shall be in accordance with the requirements specified in 8.2.2.

23.10.2 Ships of a length overall L_c < 14 m shall have the collision bulkhead.

Ships of a length overall L_c > 20 m shall also have the afterpeak bulkhead.

23.10.3 Scantlings of structural members of watertight bulkheads are specified in Table 23.3.1.

23.10.4 Watertight bulkheads may be constructed of wood, waterproof plywood or steel. The upper part of the bulkhead may be constructed of wood and the lower – of steel as a high floor.

23.10.5 The connection of floor to the bulkhead seated on it shall be made by means of steel angle situated below the floor upper edge (so that the bulkhead is supported by the floor) or by means of wooden beam having respective scantlings. The beam horizontal dimension shall be equal to the sum of the planking thickness and the bulkhead stiffener vertical section height. Bulkhead stiffener ends shall be fixed to the lower horizontal beam as well as frames and deck beams in way of the bulkhead (see 23.10.10) by means of short steel angle bars whose arms shall be bent to suit the frame and beam shapes.

23.10.6 Bulkhead stiffeners shall extend downwards as far as practicable below their connections to the floor – as far as practicable considering the bottom structure – the stiffeners shall be fixed to the floor robustly.

23.10.7 In the case of connecting steel elements of bulkheads protected with anti-corrosive paint to wooden elements, these elements shall be separated by a damp-proof course: tarred felt or fabric impregnated with oil-paint (or other paint fast to water).

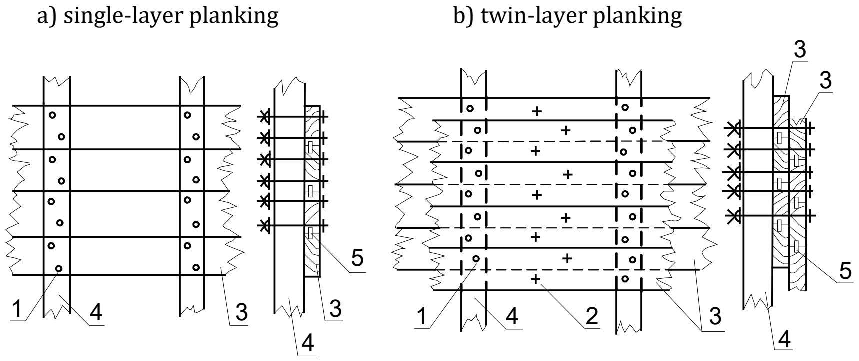
23.10.8 Wooden bulkheads may be constructed as single- or twin-layer ones (Fig. 23.10.8).

Bulkhead planking staves shall be arranged horizontally and interconnected with slip feather. Between two layers of wood in twin-layer bulkhead, a layer of fabric impregnated with boiled oil or oil-paint (or other paint fast to water).

Thickness of single-layer bulkhead staves shall not be less than that specified in Table 23.3.1.

Stave thickness in each layer of twin-layer bulkhead planking shall be (depending on typical length L) not less than:

25 mm – for $L \leq 12$ m,
30 mm – for 12 m < $L \leq 18$ m,
35 mm – for 18 m < L < 24 m.



1 – bolt, 2 – rivet, 3 – bulkhead planking stave, 4 – stiffener, 5 – slip feather

Fig. 23.10.8 Bulkhead planking

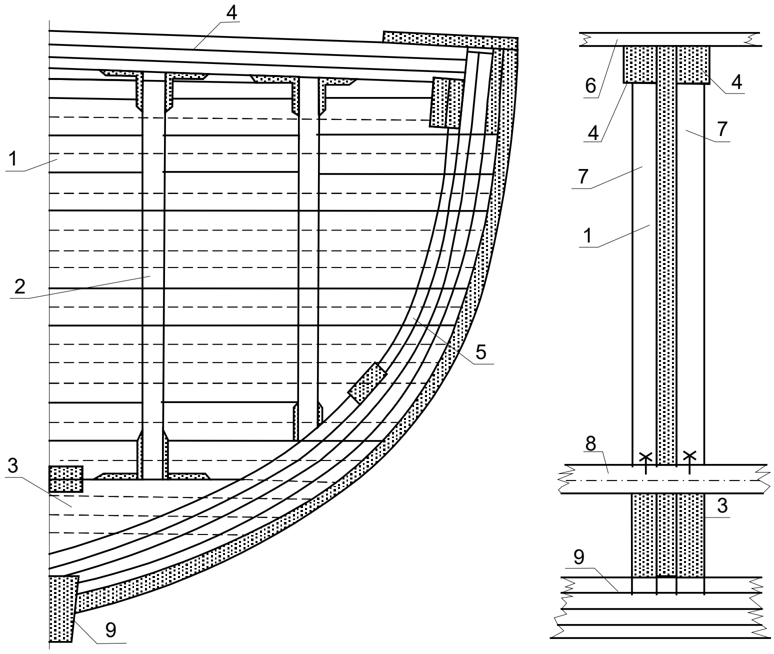
23.10.9 Bulkheads made of water-proof plywood may be constructed as:

– single-planking bulkheads consisting of two laminated layers of plywood having the following total thickness (for the maximum frame spacing 600 mm):
  36 mm – for $L \leq 12$ m,
  42 mm – for 12 m < $L \leq 18$ m,
  48 mm – for 18 m < L < 24 m;
– twin-planking bulkheads with stiffeners between the plankings of the minimum thickness of each planking (for the maximum frame spacing 500 mm):
  18 mm – for $L \leq 12$ m,
  21 mm – for 12 < $L \leq 18$ m,
  24 mm – for 18 < L < 24 m.

Bulkhead stiffeners of waterproof plywood shall fulfil the requirements specified in Table 23.3.1 for stiffeners of watertight wooden bulkhead stiffeners.

23.10.10 Bullheads shall be connected to planking with the so called 'bulkhead frames' situated on both sides of the bulkhead (see Fig. 23.10.10) using separators in the form of thick fabric impregnated with oil paint. Bulkhead planking shall be fixed to frames and deck beams by means of screws, rivets or bolts.

Scantlings of bulkhead frames shall be the same as those of regular frames. Bulkhead frames shall be strengthened by additional layer of space between longitudinals in order to improve sealing of the bulkhead planking.



1 – bulkhead planking, 2 – bulkhead stiffener, 3 – floor, 4 – deck beam,5 – inner segments of additional layer of frames, 6 – deck stringer plate, 7 – frames, 8 – overkeel, 9 – keel

Fig. 23.10.10 Bulkhead planking fixing to frames

23.10.11 Bulkhead planking staves shall be fixed to stiffeners by means of through scarf bolts and they shall be interconnected by means of rivets.

Bolts shall selected in accordance with Table 23.15.5.1, column 2, taking the single-layer planking stave thickness or the total of stave thicknesses for twin-layer planking. Rivet diameter shall be taken as the required dimension of square nails – in accordance with Table 23.15.5.1, column 4.

23.10.12 Cargo hold bulkhead stiffeners shall be fixed outside the hold.

23.11 Deckhouses

23.11.1 Deckhouses and wheelhouses shall be of robust construction so as to be protected against the sea effectively. Foundations, frames and deck beams shall be made of oak wood, whereas coniferous-tree wood may be used for filling frames and for deckhouse planking (see Fig. 23.11.1).

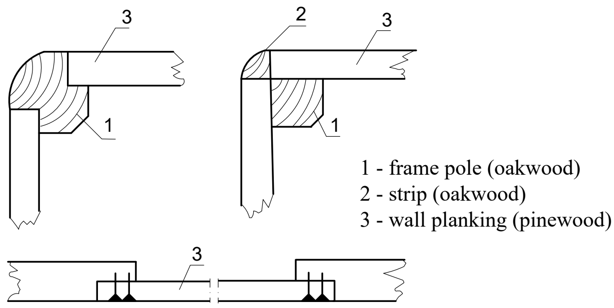
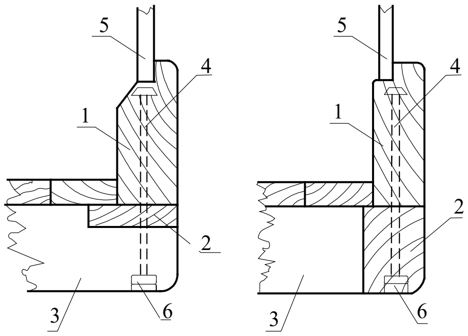


Fig. 23.11.1 Deckhouse corners and wall planking

23.11.2 If in the deckhouse or wheelhouse doors are provided for access under the deck, then closing appliances of such doors, windows and other openings are subject to PRS consideration in each particular case.

23.11.3 Wheelhouses and deckhouses shall be fixed by means of foundation bolts with deck structural members (see Fig. 23.11.3). Bolt diameter shall be determined in accordance with Table 23.15.5.1, taking the coaming thickness as stave thickness and their minimum number shall be 4, i.e. the bolts shall be located at least in way of the wheelhouse or deckhouse corners.



1 – coaming, 2 – hatch strut, 3 – half-beam, 4 – bolt, 5 –wall, 6 – nut

Fig. 23.11.3 Deckhouse fixing

23.12 Bulwarks

23.12.1 Bulwark height in ships of a length not exceeding 10 m shall be at least 600 mm and in ships of more than 24 m in length – at least 1000 mm. For ships of an intermediate length the bulwark height shall be determined by linear interpolation.

23.12.2 Bulwark stave thickness shall be determined in accordance with Table 23.3.1.

23.12.3 Bulwark supports dimensions shall not be less than those specified in Table 23.3.1 for frame scantlings at the deck and their spacing shall not exceed the double frame spacing. If a ship is fitted with double frames, bulwark support thickness may be equal to that of the frame single layer.

23.12.4 Bulwark upper edge shall be ended with a rail having a width not less than the height of the bulwark support section. In the regions where the bulwark rail is likely to be damaged by fishing equipment, the rail shall be protected by appropriate steel aprons.

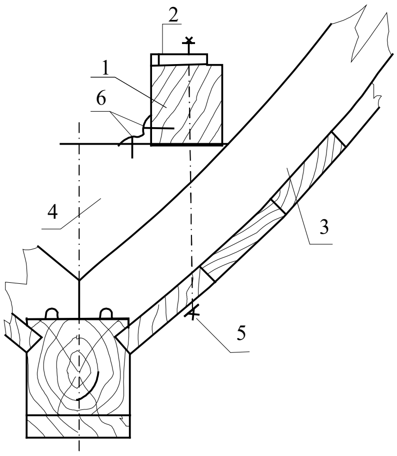
23.12.5 Freeing ports in bulwarks of an area not exceeding that required in 9.5.3 in proportion to the bulwark height. The freeing ports shall be so arranged as to ensure free drainage of deck water.

23.12.6 Openings with the vertical dimension not exceeding 230 mm shall be protected with bars. If freeing ports are provided with flaps, their bearing shall be constructed of stainless materials. Application of flap closing appliances is subject to PRS consideration in each particular case.

23.12.7 Where the bulwark height is less than 1 m, the possibility for its raising with rail shall be provided in accordance with the requirements specified in *Part III – Hull Equipment*.

23.13 Engine Foundations

23.13.1 Engine, gearbox and thrust bearing shall be seated on the common framework supported by the foundation beams strengthened with steel plates (Fig. 23.13.1).



1 – foundation beam, 2 – upper steel plate, 3 – frame, 4 – floor, 5 – foundation fixing bolt, 6 – screw

Fig. 23.13.1 Foundation of engine, gear box and thrust bearing

23.13.2 Scantlings of foundations beams as well as thickness of strengthening plates shall not be less than those specified in Table 23.3.1.

23.13.3 Foundation beams shall be fixed to the machinery space bulkhead, cut into floors and they shall extend by at least 3 frame spacings beyond the engine body.

23.13.4 In foundation beams, cuts for flywheel or other engine components or gear boxes shall be avoided. Where such cuts are necessary, longitudinals strengthening the foundation beams shall be applied. Their cross-sectional area may be less than that of the foundations beams by 20%.

An additional longitudinal shall overlap with the foundation beam over at least 3 frame spacings. The longitudinals shall be connected to the foundation beams, floors and frames with through bolts.

23.13.5 The foundation beams shall be made of hard wood, e.g. oakwood. Application of larchwood is permitted.

23.13.6 Pins fixing foundation beams to the bottom structure shall penetrate the shell planking. The pin heads shall be countersunk in the planking staves and sealed properly.

23.13.7 Wooden foundation beams may be replaced by equivalent steel beams whose scantlings and construction are subject to PRS consideration in each particular case.

23.13.8 If the main engine is fixed on wooden foundations beams when the ship is ashore, then the main engine positions related to the shafting shall be checked and adjusted where necessary in two weeks after her launching.

23.14 Ice Strengthening

23.14.1 Ships with ice strengthening in accordance with the requirements of this sub-chapter are assigned additional mark Lm2 in the symbol of class as defined in Part I – Classification Regulations.

23.14.2 Hull shell planking shall be covered with copper sheets not less than 2 mm in thickness or with stainless steel not less than 1.5 mm in thickness. Application of galvanized steel sheets is not recommended.

23.14.3 Ice shield made of metal sheet shall extend from the stem to the section where the breadth of ship is maximum and it shall extend – in this section – from the level of 300 mm below the minimum waterline to the level of 300 mm above the maximum waterline whereas on the stem –

from the level of 500 mm below the minimum waterline to the level of 500 mm above the maximum waterline respectively. In the intermediate region, the ice shield width shall vary gradually.

23.14.4 Ice shield made of metal sheet shall be fixed to the hull shell planking with screw selected properly taking account of the hardness and thickness of planking staves as well as of the metal sheet grade. Screw heads shall not protrude above the metal sheet surface.

23.14.5 Ice shield may be constructed of oakwood or other brand of hard wood. It shall extend throughout the ship length. Thickness of ice shield staves in the afterbody may be less than the prescribed planking thickness by 25 mm, and in other regions – by 15 mm.

Each stave of the wooden ice shield shall be fixed to the actual planking with 2 screws at each frame.

The screws shall be embedded in the actual planking to the depth approximately equal to 0.8 of its thickness.

23.15 Connections of Hull Structural Members

23.15.1 Allowable Methods of Connection of Hull Structural Members

The following methods of connection of hull structural members are permitted:

.1 through connections:
– pins riveted on backing,
– bolts (with nuts),
– clench nails,
– dowels;

.2 blind connections:
– regular screws,
– countersunk screws,
– forged nails,
– regular nails.

All steel bolts, pins, screws and nails shall be hot-galvanized.

23.15.2 Connections of Keel, Stem, Stern and Floors

23.15.2.1 For connections of the keel to floors, overkeel and brackets to the stem and stern, bolts with nuts or riveted pins shall be used as far as practicable.

23.15.2.2 The dimensions of pins and bolts for overkeels, stems, sterns and for connections of floors to the keel shall not be less than those specified in Table 23.3.1.

23.15.2.3 In each arm of brackets in both stem and stern, at least 3 bolts shall be provided.

23.15.3 Connections of Frame Components

23.15.3.1 For frames of a thickness not exceeding 100 mm, their components shall be connected with scarf bolts at least 13 mm in diameter (ended with M12 thread), whereas for frames of a thickness above 100 mm – with scarf bolts at least 16 mm in diameter (ended with M16 thread).

23.15.3.2 In overlapping connections of single frames, at least 2 bolts shall be provided, however 3 bolts are recommended.

23.15.3.3 Individual components of one layer of a double frame shall be connected to the other layer with at least 4 bolts, and if the particular component length is more than 1.4 m – with 6 bolts.

23.15.3.4 Under the bolt heads and nuts, washers of the diameter 3.5 times the bolt diameter and thickness equal approximately 0.3 the bolt diameter shall be provided. The diameter of washers for pins to be upset shall be around 2.5 times the pin diameter.

23.15.3.5 In inaccessible positions, application of key-driven screws or tight steel pins is permitted.

23.15.4 Connections of Bilge Stringers, Longitudinal Deck Girders and Foundation Beams

23.15.4.1 Bilge stringers, longitudinal deck girders and foundation beams less than 100 mm in thickness shall be connected to frames by means of scarf bolts of at least 16 mm in diameter, whereas for a thickness more than 100 mm – with scarf bolts not less than 19 mm in diameter.

23.15.4.2 Bolt diameter shall not exceed 20% of the width of the cross-section of the component to be connected.

23.15.4.3 Bilge stringers, longitudinal deck girders shall be connected to each layer of frames with bolts and nuts.

23.15.4.4 Engine foundation framework shall be connected to the foundation beams with bolts and nuts.

23.15.5 Fixing of Shell and Deck Planking Staves

23.15.5.1 The required dimensions of bolts and nuts for fixing of the shell and deck planking staves are specified in Table 23.15.5.1.

Table 23.15.5.1
Required dimensions of bolts and nuts for fixing of the shell and deck planking staves, [mm]

Stave thickness	Diameter of bolts for fixing planking staves	Screws for fixing planking staves[1] $d \times l$	Nails for fixing planking staves [2] $s \times l$
35	8	7 × 80	5 × 80
40	10	7 × 100	5 × 90
45	10	8 × 120	6 × 100
50	12	8 × 120	6 × 110
55	12	8 × 120	7 × 120
60	12	10 × 150	7 × 130
70	14	12 × 170	8 × 150

d – screw diameter, [mm];
s – square section side, [mm];
l – length of screw or nail, [mm].

[1] The screw length applies to screws with heads not undersunk.
[2] The total nail length assuming that the heads are undersunk to the depth of 0.25 of the stave thickness.

23.15.5.2 Planking staves shall be connected to frames by means of scarf bolts and screws.

Planking of a ship of $L \leq 10$ m in length may be fixed with blacksmith's nails. Planking of a ship of more than 10 m in length may be partly fixed with blacksmith's nails, provided that bolts with nuts are used at every other frame. Stave ends shall be fixed with bolts.

Cross-section of blacksmith's nails for ships of less than 12 m in length shall be 6×6 mm, and for ships of 12 m in length and more – 8×8 mm. The nail length shall be equal to triple stave thickness.

23.15.5.3 Staves in way of the keel shall be connected to the keel, stem and sternframe solely by means of screws.

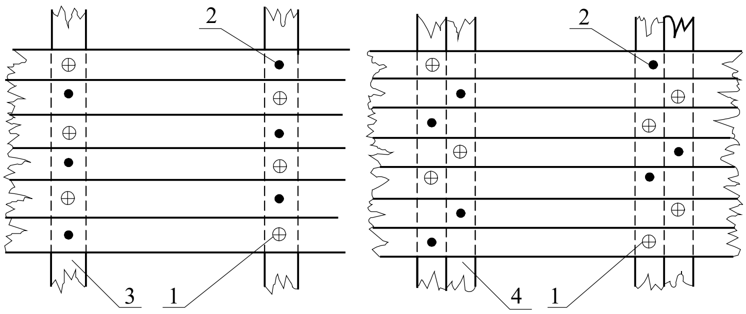
23.15.5.4 Each planking stave of a breadth not exceeding 200 mm shall be connected to each frame by means of two fixings, and in the case of double frames – it shall be connected to each frame layer. A fixing is understood as a bolt, screw, pin or nail. Application of staves having a breadth more than 200 mm is not recommended.

Staves more than 250 mm in breadth, if applied, shall be connected to frames with three fixings, and staves of more than 350 mm in breadth – with four fixings. Half the number of these fixings shall be of through type.

23.15.5.5 Stave butts on double frames or on wooden or metallic inner aprons shall be made in accordance with the requirements specified in 23.8.4, by means of scarf bolts of the diameter specified in Table 23.15.5.1, the number of which (on one side of the connection) shall be as follows:
– 3 – for staves of not more than 100 mm in breadth,
– 4 – for staves of more than 100 mm but not exceeding 200 mm in breadth,
– 5 – for staves of more than 200 mm but not exceeding 250 mm in breadth,
– 5 + 1 per each 50 mm of breadth above 250 mm – for staves of more than 250 mm in breadth.

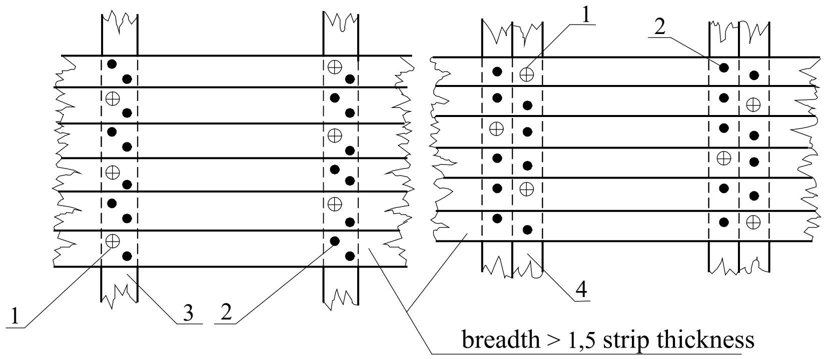
23.15.5.6 Strip planking shall be fixed to frames in accordance with Fig. 23.15.5.6 – depending on the breadth to thickness ratio for the strip.

a) strip breadth not exceeding 1.5 of their thickness



1 – rivets, 2 – nails, 3 – single frame, 4 – double frame

b) strip breadth more than 1.5 of their thickness



1 – rivet, 2 – nail, 3 – single frame, 4 – double frame

Fig. 23.15.5.6 Planking fixing to frames

23.15.5.7 Deck staves shall be connected to deck beams with nails. Deck staves more than 100 mm in breadth shall be fixed to each beam with two nails.

23.15.5.8 Heads of nails, bolts and screws fixing the deck staves shall be undersunk to a depth not exceeding 0.25 mm the stave thickness and covered with wooden spiles. The arrangement of spile fibres shall be in accordance with that of the staves.

23.15.6 Deck Stringer Plate Fixing

23.15.6.1 Deck stringer plate shall be connected to deck beams and longitudinals by means of through bolts and screws of the dimensions in accordance with Table 23.15.5.1 for the stave thickness equal to the deck stringer plate thickness.

23.15.6.2 At each deck beam two fixings shall be arranged in the same section as bulwark supports.

23.15.7 Fixing of Bulkhead Structural Members

For fixing of bulkhead structural members bolts with nuts of the following diameters shall be used:
10 mm – for member thickness ≤ 70 mm,
14 mm – where 70 mm < member thickness ≤ 100 mm,
16 mm – for member thickness > 100 mm.

23.16 Hull Construction Procedure, Sealing and Maintenance

23.16.1 All the hull structural members shall be accurately made and adjusted to the intermating ones before the assembly. Inserts or filler backings are not permitted.

23.16.2 Hull shell planking shall accurately stick to the frames on its inner side. Individual staves shall accurately stick to each other over at least 0.3÷0.4 of their thickness. The remaining rift shall be filled with sealant.

23.16.3 Bolt and nail connections shall be made with meticulous care taking acocunt of the following requirements:

.1 bolts shall be so arranged that the space between the bolt edge and the side edge of the element does not exceed 3 bolt diameters, and to the front edge of the element – 5 diameters;
.2 pins, screws and nails shall be arranged in staves diagonally;
.3 diameters of the holes drilled for bolts shall be less 2÷3 mm than the bolt diameter;
.4 while driving nails, wood splitting shall be avoided; that is why it is recommended that preliminary holes of 50÷60% of the nail diameter be drilled.

23.16.4 Where steel components meet wooden ones, separators in the form of tarred felt or other insulating material shall be provided.

23.16.5 Wood connections shall be sealed taking account of the following requirements:

.1 sealing shall be performed after all the through pins, bolts and spiles have been applied;
.2 seams as well as edges of the shell planking, deck and watertight bulkheads shall be sealed with twisted tarred hemp hurds (Fig. 23.16.5); thickness of individual hurd lines to be hammered into the seam rifts shall be graded and each line shall be inserted and hammered before another one is laid; the proof of correct hammering of the last sealing line is the hammer bouncing after hitting the gasket iron;
.3 the number of sealing lines depending on the stave thickness (see Table 23.16.5);
.4 after the lines have been hammered in, the seams and contact edges shall be filled with special marine tar or approved waterproof putty (sealing) (Fig. 23.16.5).

Table 23.16.5
Required number of lines

Stave thickness, [mm]	Number of lines	
	shell planking	deck, bulkheads
30 to 40	2	2
41 to 70	3	3
71 to 90	4	3

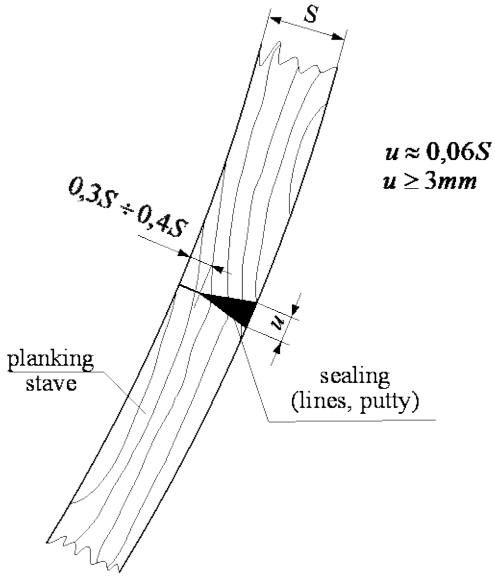


Fig. 23.16.5 Planking sealing

23.16.6 To protect the wood against decay/perishing, all the spaces covered with lining shall be provided with continuous and effective ventilation. Adequate size flaps shall be provided in internal lining to enable periodical maintenance.

23.16.7 Ships navigating beyond the Baltic Sea shall be protected against teredo (*Teredo Navalis*) by means of:

.1 impregnating the planking staves by appropriate chemicals;

.2 lining with metallic sheet, or wood on the tarred base, of the belt to the depth of around 1 m below the deck throughout the ship length.

23.17 Fixing of Ship Equipment Components

23.17.1 Tanks shall be fixed to the hull structure by means of through bolts.

23.17.2 Solid ballast shall be preserved, stowed on pads and secured not to move.

23.18 Laminated Structures

23.18.1 General Requirements

Wooden ship hulls may be constructed as laminated structures provided that the requirements and guidelines regarding the manufacturing procedures specified in sub-chapter 23.18 are fulfilled.

For specific structural members made of laminated wood, their scantlings may be reduced as compared to those required in this part of the *Rules* for members made of solid wood (see Table 23.18.1).

Table 23.18.1
Allowable reduction in scantlings of structural members made of laminated wood as compared to those of solid wood

Item	Hull structural member	Scantling	Allowable reduction, [%]	Notes
1 2 3	Outer keel Outer stem Stern	 breadth height	10 – 15 10 – 15 10 – 15	In specific layers to be adhesive-bonded in butt
4 5	Single frames Floors	height thickness	20 – 25 20 – 25	Double frames are not applied
6	Brackets	thickness	20 – 25	
7	Bilge stringers and longitudinal deck subgirders	thickness breadth	up to 10 25 – 30	Elements of specific layers to be adhesive-bonded in butt
8	Bulkheads	thickness	30 – 40	At least 2 planking layers to be applied
9	Bulkhead stiffeners	thickness height	10 – 30 20 – 30	
10	Shell planking for 2 layers for 3 layers	 thickness thickness	 25 – 40 25 – 50	Shell planking thickness shall not be less than 22 mm, and inner planking – not less than 12 mm
11	Sleeper: for 2 layers for 3 layers	thickness thickness	15 – 25 25 – 40	Diagonal or semi-diagonal system to be applied
12	Main engine foundation	thickness	15 – 30	

23.18.2 Adhesives

23.18.2.1 For bonding hull structure elements, waterproof adhesives approved by PRS may only be used.

23.18.2.2 Adhesive manufacturer's instructions shall be strictly complied with.

23.18.3 Wood Preparation for Adhesive-bonding

23.18.3.1 Wood to be used for bonding shall be of good grade. Surfaces to be bonded shall be clean, smooth and mutually adjusted with an accuracy of 0.25 mm.

23.18.3.2 Humidity of wood to be bonded shall range from 8 to 15% unless the adhesive manufacturer's requirements state otherwise. Samples for humidity measurement shall be taken from at least 5 planks of each batch of dried wood. Samples shall be taken from the plank segment situated at the distance at least 600 mm from its end.

23.18.3.3 Thickness of strips to be bonded shall not exceed:
for oakwood– 20 mm,
for pinewood– 50 mm.

23.18.3.4 For bent elements, the allowable radii of curvature are specified in Table 23.18.3.4 depending on the thickness and brand of wood.

Table 23.18.3.4

Oakwood		Pinewood	
Thickness [mm]	Minimum bending radius, [mm]	Thickness [mm]	Minimum bending radius, [mm]
6	450	6	750
10	750	10	1350
15	1400	15	2400
30	2000	20	3250
		25	4500

Note: for intermediate thicknesses, the minimum bending radius shall be determined by linear interpolation.

23.18.3.5 Prior to bonding an element composed of several parts of different lengths, the ends of each component shall be bevelled.

The length of bevel shall be about 12 times the strip thickness.

Butts in the adjacent layers in the stem shall be staggered by at least 0.6 m whereas in the keel – 0.8 m and in the frame – 0.4 m. In other elements, such as bilge stringers and longitudinal deck girders, the butts may be staggered by 1.0 m.

23.18.4 Bonding Conditions

23.18.4.1 Adhesive-bonding shall not be performed at the temperature less than 10 °C.

23.18.4.2 While bonding, the pressure of workshop pads shall be neither less than 1 MPa nor more than 14 MPa.

23.18.4.3 For straight elements, the spacing of clamps shall not exceed 225 mm whereas for bent ones it shall not exceed 100 mm (to be measured inside the bend). Under the clamp jaws, pads made of hard wood at least 20 mm in thickness shall be used for straight elements. For bent elements, the pads may be thinner.

23.18.4.4 While bonding bent elements, clamps shall be closed beginning from the middle of an element.

23.18.4.5 Pressure exerted by the press shall be controlled for the period ranging from 30 to 45 minutes after the pressure application has ended as well as while increasing the pressure.

23.18.5 Testing of Adhesive-bonded Structures

23.18.5.1 Adhesive-bonded structure samples shall be taken from 25% of the total number of frames. Samples from other longitudinal hull members shall be taken as required by PRS Surveyor in charge.

23.18.5.2 Samples shall be taken from the actual adhesive-bonded structure and shall not be made separately. For this reason, bonded elements shall be made respectively longer to enable samples to be taken.

23.18.5.3 Test specimen – having 200 mm in length, 100 mm in width and of a thickness containing at least 3 layers – shall be machined prior to testing.

23.18.5.4 Test specimen shall be subjected to boiling for 3 hours and then broken apart when wet.

Adhesive-bonded joints shall not delaminate.

If the test result is unsuccessful, the test may be repeated with another test specimen made from the same sample.

List of amendments effective as of 1 July 2023

Item	*Title/Subject*	*Source*
Page 2	Reference to Publication 100/P, added	PRS
16.2.1	Amendments related to the issuance of the new Publication 100/P	PRS