Polski Rejestr Statków

RULES
FOR THE CLASSIFICATION AND CONSTRUCTION OF SEA-GOING YACHTS

PART II

HULL

1996

(Consolidated text incorporating Amendments No. 1/1998, status on 15 October 1998)

GDAŃSK

Polski Rejestr Statków

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RULES FOR THE CLASSIFICATION AND CONSTRUCTION OF SEA-GOING YACHTS consist of the following, separately edited Parts:

Part I	–	Classification Regulations
Part II	–	Hull
Part III	–	Equipment and Stability
Part IV	–	Machinery Installations
Part V	–	Electrical Equipment
Part VI	–	Materials
Part VII	–	Masting and Rigging

Part II – "Hull", 1996 of the Rules for the Classification and Construction of Sea-going Yachts was approved by the PRS Director General on 14 May 1996 and entered into force on 1 July 1996.

The present Part was considered and accepted by the PRS Technical Committee on 26 March 1996.

Amendments No. 1/1998 have been included.

The requirements of Rules which were in force during construction of a sea-going yacht, still apply to this yacht during its service.

PRS/TW, 08/2000 (29.08.2000)

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1 GENERAL

1.1 Application

1.1.1 The requirements of the present part of the Rules apply to constructions of yachts of up to 24 metres in length.

1.1.2 For steel yachts of more than 24 metres in length the requirements of the Rules for the Classification and Construction of Sea-going Ships are in force.

1.1.3 Constructions of yachts of more than 24 metres in length made from glass reinforced plastics (GRP), aluminium alloy or wood shall by considered by PRS in each case separately.

1.2 Definitions

1.2.1 General definitions used in the Rules are given in "General Survey Regulations".

1.2.2 Definitions

L_c – Overall length, [m] – length of a yacht measured between extreme points on stem and stern without elements being part of hull equipment ie: rudder, bowsprit, fender guards and others which in some constructions exceed the hull outline.

L_w – Waterline length, [m] – length of a yacht measured at the designed waterline between extreme points on stem and stern.

L – Length, [m] – classification length equal to arithmetic mean of overall and waterline length.

B – Breadth, [m] – breadth of a yacht hull measured in the widest part on the outer plating without fender guards.

T – Draught, [m] – draught of a yacht measured between designed waterline and lower edge of keel, ballast keel or sliding keel in lowered position – as applicable.

T_m – Minimum draught, [m] – draught of a yacht with sliding keel or sliding ballast keel measured between designed waterline and lower edge of keel or sliding keel / sliding ballast keel in upper position – the lowest element applicable.

H – Depth, [m] – depth of a hull measured amidships between lower edge of keel or ballast keel and upper edge of main deck or superstructure deck at the side or edge of intersection point of deck extension and side extension.
For yachts with sliding keel or sliding ballast keel, depth shall be measured in each case separately.

V_k – Volume of moulded displacement, [m^3] – volume of underwater part of the yacht hull completely equipped for operation but without crew, fuel, water or food.

R_m – Tensile strength of the material, [MPa].

R_g – Bending strength of the material, [MPa].

E_m – Young's modulus of the material at tension, [MPa].

E_g – Young's modulus of the material at bending, [MPa].

1.2.3 Definitions

Midship section – yacht hull cross-section outline at the middle of the designed waterline.

Midship – middle part of the yacht hull equal to 0,6 L ie 0,3 L from the midship section towards the stem and the stern.

Designed waterline – line of intersection of the hull body by water surface at the moulded displacement and designed trim.

1.3 Plating

1.3.1 The requirements specified in the Rules and concerning the plating refer to a rectangular plate with small curvature stiffened on the border.

1.3.2 The basic dimensions of the plate (breadth *a* and length *b*) are measured to the nearest edge of the stiffeners (Fig. 1.3.2-1). It is assumed that b≥a.

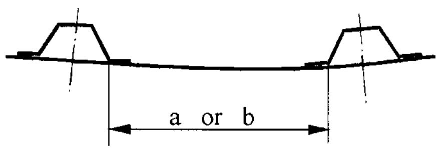


Fig. 1.3.2-1

For plates which are not rectangular, the dimensions *a* and *b* – parallel with the middle ones, are to be measured according to Fig 1.3.2-2.

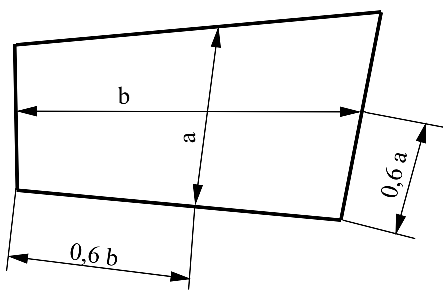


Fig. 1.3.2-2

1.3.3 If the ratio of length b to breadth a is less than 2, the plate thickness can be reduced according to the factor:

$$k_k = -0{,}22\left(\frac{b}{a}\right)^2 + 0{,}87\frac{b}{a} + 0{,}14 \qquad (1.3.3)$$

where: $2 \geq \frac{b}{a} \geq 1$

1.3.4 If the ratio of the curvature camber f according to Fig. 1.3.4 to plate breadth a exceeds 0,03, then the plate thickness can be reduced according to the factor k_p given in Table 1.3.4:

Table 1.3.4

f/a	k_p
0 ÷ 0,03	1
0,03 ÷ 0,1	1,15 – 5 f/a
≥ 0,1	0,65

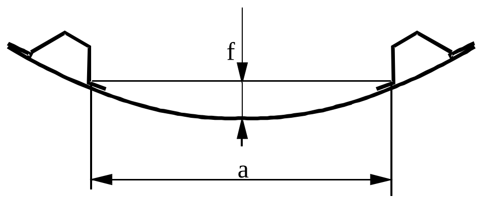


Fig. 1.3.4

1.3.5 The thickness of flat, heavy loaded plates, such as flat fragments of bottom, big flat transoms, non-cambered decks, flat bow plating is to be increased by not less than 10 per cent.

1.4 Stiffeners

1.4.1 The yacht shell plating is to be stiffened by means of transverse and longitudinal stiffeners.

Frames, bulkheads and transverse partitions, transverse elements of internal furniture, floors and beams are to be considered as transverse stiffeners. Stringers, longitudinal bulkheads, partitions and longitudinal elements of internal furniture are to be considered as longitudinal stiffeners.

1.4.2 A sharp edge of plating (chine) can be considered as stiffener, provided that the angle between adjacent plating plates does not exceed 150° and the edge is brought to other appropriate stiffeners. The laminated plating on such edge is to be in compliance with 6.1.6.

1.4.3 The edges of plating imitating a clinker planking (zigs) can be considered as longitudinal stiffeners. The equivalent section modulus ”W_z” of such stiffener is to be assumed as:

$$W_z = 1{,}2gc^2 \text{ , [cm}^3\text{]} \qquad (1.4.3)$$

- g – plating thickness, [cm],
- c – height of the zig, [cm].

1.4.4 The calculations of the minimum bending strength section moduli specified in the Rules include width of co-acting stripe a_w according to the formula:

$$a_w = k_E\left(e + 2b_w\right), \text{ [cm]} \qquad (1.4.4\text{-}1)$$

k_E – coefficient of Young's modulus:

$$k_E = \frac{E_p}{E_u}$$

E_p – Young's modulus of plating, [MPa],

E_u – Young's modulus of stiffener, [MPa],

k_E =0,4 ÷ 0,6 for plywood plating;
k_E can be assumed approximately as equal to the ratio of number of layers laid along the stiffener to the total number of the layers;

$k_E \approx$ 0,25 for moulded plywood laid diagonally in relation to the stiffener,

e – stiffener width in the place adjacent to the plating, [cm],

b_w – co-acting width (one-sided), [cm], equal to:

b_w = 10 g for GRP plating,

b_w = 50 g for metal plating,

b_w = 20 g for plywood and moulded plywood plating,

g – plating thickness, [cm].

The assumed values of $e + 2\ b_w$, shown in Fig. 1.4.4, are not to be greater than the stiffener spacing or 1/6 of the respective stiffener span.

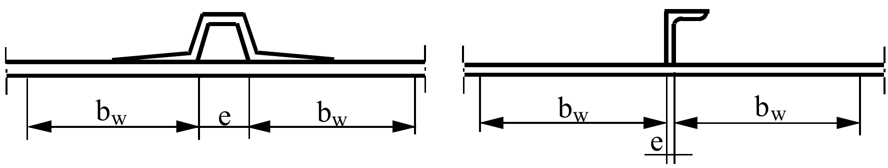


Fig. 1.4.4

For stiffener laid at the plating edge width of the co-acting stripe a_w is to be calculated according to formula:

$$a_w = k_E\left(e + b_w\right), \text{ [cm]} \qquad (1.4.4\text{-}2)$$

1.4.5 The section moduli for wooden structures are to be calculated with the co-acting stripe only in the case when the stiffener is firmly connected to the plating in a way guarantying constant co-operation.

The co-acting stripe is not to be taken into consideration for all stiffeners of smooth planking (caravel planking) and for web frames of plywood plating.

1.4.6 The required section moduli are given for continuous stiffeners with firmly fixed ends. The required section modulus is to be kept on the whole length of the stiffener, especially in its support points.

1.4.7 In the case of stiffeners with pivot supported ends, the required section modulus is to be increased by 50 per cent. Such increased modulus is to be kept in the central part of stiffener and can be reduced towards the ends.

1.4.8 The parts of internal furniture can be considered as stiffeners, provided that they comply with the requirements specified for stiffeners.

2 DESIGN LOADS

2.1 General Provisions

The calculation of hull plating and stiffeners is based on the multi-support beam scheme subjected to uniform hydrostatic load. The design load is the height of water column.

The water column height is calculated, if not stated otherwise by the Rules, to the lowest edge of the considered plating shell – for plating, and to the centre of the stiffener span – for stiffeners. Deviations from this requirement are given each time in appropriate paragraphs.

2.2 Load of Bottom

2.2.1 The total hydrostatic load of bottom should be assumed as the greater value of the following two functions:

$$h_1 = k_{sd}\left(h_s + 0{,}05L + 0{,}5\right), \text{ [m]} \qquad (2.2.1\text{-}1)$$

$$h_2 = k_v k_d\left(0{,}007v^2 + 0{,}008v\sqrt{L_w} + 0{,}216L_w\right), \text{ [m]} \qquad (2.2.1\text{-}2)$$

k_{sd} – coefficient of distribution of static load of bottom, changing according to Fig. 2.2.1-1;

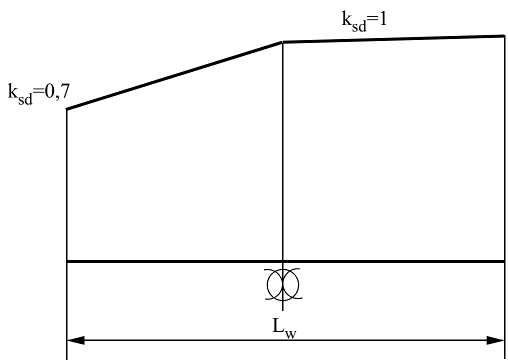


Fig. 2.2.1-1

h_s – vertical distance from the calculated part of the construction to the edge at the joint between the yacht's side and the main or superstructure deck in the considered place, [m],

k_v – the coefficient depending on the speed v:

$k_v = 0$ for $v \le 2{,}7\sqrt{L_w}$,

$k_v = 2{,}5\dfrac{v}{\sqrt{L_w}} - 6{,}75$ for $2{,}7\sqrt{L_w} \le v \le 3{,}1\sqrt{L_w}$,

$k_v = 1$ for $v \ge 3{,}1\sqrt{L_w}$,

k_d – coefficient of distribution of dynamic load, changing according to Fig. 2.2.1-2,

v – yacht's speed in knots, assumed as follows:

- for motor yacht – design or trial speed,
- for classic (cruising) sailing yacht or motor-sailing yacht – speed not exceeding $2{,}7\sqrt{L_w}$,
- for light (racing) sailing yacht – speed not less than $3{,}1\sqrt{L_w}$,
- for multi-hull yachts – speed not less than $3{,}5\sqrt{L_w}$.

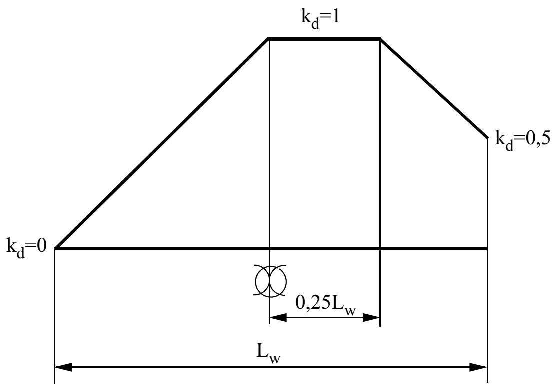


Fig. 2.2.1-2

2.2.2 If the yacht's speed V is greater than $2{,}8\sqrt{L_w}$ and the rise of floor at the midship section is less than 12°, then the load of bottom will receive individual consideration.

2.3 Load of Sides

2.3.1 The total hydrostatic load of sides h is to be assumed as the greater value of the following two functions:

$$h_1 = k_{sb}\left(h_s + 0{,}05L + 0{,}5\right), \text{[m]} \qquad (2.3.1\text{-}1)$$

$$h_2 = 0{,}6k_v k_d\left(0{,}007v^2 + 0{,}008v\sqrt{L_w} + 0{,}216L_w\right), \text{[m]} \qquad (2.3.1\text{-}2)$$

k_{sb} – coefficient of distribution of static load of sides, changing according to Fig. 2.3.1,

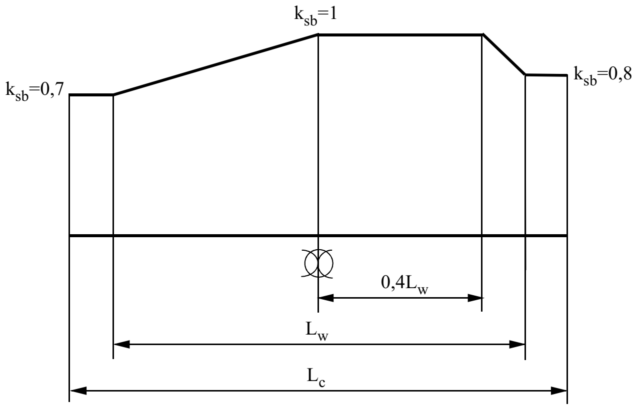


Fig. 2.3.1

h_s, k_v, k_d, v – see 2.2.1.

2.3.2 Load of superstructure side walls is to be calculated as the load of sides in the same area.

2.4 Load of Deck

2.4.1 Hydrostatic load of deck h is to be calculated from the formula:

$$h = k_{sp} k_p \left(0{,}05L + 0{,}5\right), \text{ [m]} \qquad (2.4.1)$$

k_{sp} – coefficient of longitudinal distribution of load, changing according to Fig. 2.4.1.

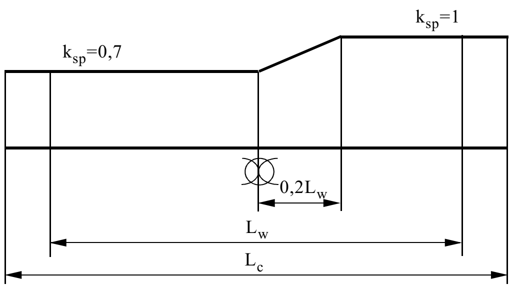


Fig. 2.4.1

k_p – coefficient of distribution of loads of deckhouses:

k_p = 1,0 for the main or superstructure deck,

for structural parts of deckhouses situated h_p [m] above the main deck,

k_p = 1,2 for slightly inclined front wall of the deckhouse or superstructure located forward of amidships,

k_p = 1,1 for cockpits.

2.4.2 Load h of the structural parts subjected to the load of walking crew is to be not less than 0,5 m.

2.5 Load of Bulkheads

2.5.1 Load of bulkheads h is to be calculated from the formula:

$$h = k_{sg}\left(h_g + 0{,}05L + 0{,}5\right),\ [\mathrm{m}] \tag{2.5.1}$$

k_{sg} – coefficient of distribution of static load of bulkhead:
k_{sg} = 1,5 for collision bulkhead,
k_{sg} = 1,0 for other bulkheads,
h_g – the vertical distance from the calculated fragment of the bulkhead construction to the deck above the bulkhead, [m].

2.6 Load of Tanks

2.6.1 Load of integral water or fuel tanks h is to be calculated from the formula:

$$h = \gamma\left(h_z + 0{,}6h_p + 1\right),\ [\mathrm{m}] \tag{2.6.1}$$

γ – a specific mass of liquid, [g/cm^3],
h_z – the vertical distance from the calculated part to the tank top, [m],
h_p – the height of air venting pipe above the tank top, [m].

2.7 Reduction of Load in Restricted Navigation Areas

2.7.1 For yachts sailing in restricted area III with fixed weather limitations, or in restricted area V, the load values can be reduced according to the Table 2.7.1.

2.7.2 For the structural parts which can be subjected to the load of walking crew, the reduced load is not to be less than 0,5 m.

Table 2.7.1
Permissible reduction of hull load

Structural part	III	V
Bottom plating h_1	15%	20%
Bottom plating h_2	20%	30%
Side plating h_1	10%	15%
Side plating h_2	15%	30%
Bottom and side stiffeners h_1	15%	25%
Bottom and side stiffeners h_2	25%	40%
Deck and superstructure	15%	20%
Tanks and bulkheads	6%	12%

3 GLASS REINFORCED PLASTIC /GRP/ STRUCTURES

3.1 General Requirements

3.1.1 Requirements of these Rules apply to GRP structures. The materials of which glass reinforced plastics are made should meet the requirements specified in Part VI “Materials”.

3.1.2 Other structural materials, such as steel, aluminium and copper alloys, timber, etc., used for the construction are to meet the requirements specified in Part VI “Materials”. Satisfactory joints between additional materials and the laminate are to be ensured by a proper selection of materials, choice of joint or a proper treatment of its surface. Metal alloys containing copper are not to be used in a direct contact with polyester resins.

3.1.3 Constructions of laminates other than GRP shall be considered by PRS individually.

4 CONSTRUCTION PROCESS OF GLASS REINFORCED PLASTIC STRUCTURES

4.1 Stores

4.1.1 The resins are to be stored in hermetic containers (preferably in original factory package), in a place without access of light and in the temperature recommended by the manufacturer. The storage time of each resin is not to exceed its warranty period.

4.1.2 Initiators and accelerants are to be stored in cool, dry, clean and well ventilated spaces.

4.1.3 All resin additives are to be stored in closed containers and protected against dust and humidity.

4.1.4 Reinforcement materials are to be stored in original packages in dry and dust-free spaces.

4.1.5 All the materials, prior to their using, are to be brought to the temperature not less than the temperature existing in the production space.

4.2 Production Spaces

4.2.1 In respect of size and type of production, the production space is to be properly separated from the storage spaces. Various cycles of the construction process (such as: preparation of resin, reinforcement cutting, laminating) are to be carried out in separate but adjacent spaces.

4.2.2 Production space should enable to maintain constant temperature within l6–25°C. In exceptional cases the temperature can be lowered to 12°C but not during laminating or gelation of any structural part of the hull and not earlier than 12 hours after resin gelation. Period of time of lowered temperature should be minimised with respect to the construction weight and the period of time from the latest lamination.

4.2.3 Production space floor is to be clean and is not to emit the dust. It is to be kept as clean as practicable. The air in the space is to be dust-free. Particularly the dust of substances affecting the polymerisation process or separating the laminated parts is to be avoided. Dust emitting machines cannot be used in the production space.

4.2.4 The relative humidity in the space is not, in general, to exceed 70 per cent. For short periods of time, the relative humidity up to 85 per cent can be accepted.

4.2.5 Continuous temperature and humidity control in the production space is to be provided.

4.2.6 Ventilating system used in the production space should not cause excessive vaporisation of styrene.

4.2.7 Laminated parts are to be protected against sun radiation.

4.2.8 Moulds

4.2.9 Materials used for moulds cannot affect the resin polymerisation process.

4.2.10 The moulds are to be of sufficient rigidity and their shape should enable easy removal of the moulded part from the mould.

4.2.11 Big moulds are to he provided with proper stagings enabling access to the whole laminated surface.

4.2.12 It is recommended, particularly for bigger hulls, to use rotable (or swinging) moulds in order to enable the downhand laminating.

4.2.13 Construction of yachts without hull moulds is to be considered by PRS individually.

4.2.14 Laminating

4.2.15 Resin for gelcoat and for structural layers of laminate is to be prepared according to the manufacturer's recommendations.

4.2.16 Gelating time of the resin is not to exceed 1 hour. Each alteration of gelating time should be controlled by alteration of accelerant quantity without altering the recommended quantity of the initiator.

4.2.17 Accelerant must not be mixed directly with the initiator (explosion danger).

4.2.18 Glass reinforcement should be used in as large sections as possible. It is recommended to use mats with torn out rather than cut out edges.

4.2.19 Continuous control of resin-reinforcement proportion is to be ensured during the whole laminating process. When preparing the glass mates for lamination process, the mass of binder is to be taken into consideration (the binder mass is to be subtracted from the total mass of the reinforcement).

4.2.20 Prior to beginning the hull plating laminating, the moulds are to be thoroughly cleaned, dried and brought to the space temperature. The lutes used for maintenance of the moulds and the separating agents cannot react chemically with the resins.

4.2.21 Gelcoat layer can be put on with the use of brush, roller or spraying device. Generally, the gelcoat layer thickness is to be within 0,4 – 0,6 mm.

4.2.22 Gelcoat layer, after a period of time not longer than 6 hrs (after hardening), is to be coated with the first layer of the laminate reinforced with light fabric or mat of surface mass not greater than 300 g/m^2. This layer should be particularly well deaerated, the glass content being 20 - 30 per cent.

4.2.23 Laminating of proper structural layers is to be made manually with contact method using soft and hard rollers and brushes. Laminating method of spraying resin together with the cut roving needs separate agreement with PRS.

4.2.24 Laminating is to be carried out without pauses ("wet to wet"). If the pauses occur and are longer than 24 h, the contact surface should be properly prepared by grinding or by putting on formerly a polyamide fabric, which is torn off before the next layer is laid on.

4.2.25 The successive layers of reinforcement are to be laid on without waiting until the resin of the former layer becomes hardened. Too great number of laminate layers should not be laid because this can produce overheating of the laminate.

4.2.26 If laminating is stopped in such a moment that the last resin layer has been already hardened, then the first of the successive layers should be begun with the glass mat. It is also recommended to use mat for the last layer of laminate in the bottom area.

4.2.27 Reinforcement overlap width of the same layer is not to be less than 50 mm. The overlaps should be shifted in relation to these belonging to other layers by at least 100 mm.

4.2.28 Steps of the reinforcement content in the laminate are not to exceed 600 g/m^2 for each 25 mm of the transient band width.

4.2.29 Edges of materials such as wood, plywood, metals and core foams, laminated into the plating, are to be tapered.

4.3 Hardening

4.3.1 Upon the completion of the laminating, the hull parts are to be left in the moulds for the time necessary for initial hardening of the laminate. This time cannot be shorter than 24 hours.

4.3.2 Parts removed directly from the moulds are to be properly supported or joined with other parts in the way preventing their distortion before acquiring the proper rigidity.

4.3.3 Upon the completion of the laminating, the hull parts are to be left in the production space or other room of temperature not less than 16° C, until a proper hardness (about 35 - 40 acc. to Barcol) is attained.

If the hardness cannot be measured, then the hardening time may be assumed as:

30 days in 16°C,
15 days in 25°C,
15 hours in 40°C,
9 hours in 50°C,
5 hours in 60°C.

4.3.4 Heating of the hull is recommended. Abrupt changes of the temperature should be avoided. Gradual raising of the temperature is to be carried out according to the resin manufacturer's recommendations. The air in the beating room is to be properly dried /4.2.4/ and the hull is to be properly supported during the heating process. The thermal resistance temperature of laminate or core foam used for the yacht construction must not be exceeded.

4.4 Quality Control

4.4.1 The whole laminating process is to be constantly controlled for the compliance with:

- the requirements of 4.1 – as regards storing of materials,
- the requirements of 4.2 – as regards production spaces,
- the requirements of 4.3 – as regards condition of forms,
- the requirements of 4.4 and 4.5 – as regards GRP moulding and hardening process,
- the approved classification documentation – as regards succession, type and number of put-on glass reinforcement layers,

4.4.2 In the case of disclosed defects, the corrective means are to be taken. Any repairs can be performed in the way previously agreed with PRS surveyor.

4.4.3 The Builder should submit the results of the control panel GRP test in order to determine strength properties according to chapter 5:

- for each yacht built individually,
- for a yacht selected by the Surveyor in the case of yachts built in series.

4.4.4 A control panel should have dimensions of 400 x 500 mm. Its construction and thickness should exactly correspond to the plating laminate. The control panel hardening process is to be identical with the yacht's hull hardening. After having agreed that with PRS Surveyor, pieces of plating obtained while cutting out significant holes can be regarded as samples.

The control panel should be made by the same persons that make the hull, in the conditions corresponding to those of the laminating process and of the same materials as the hull.

4.4.5 The control panel should be made for each yacht, also each one built in series, prior to beginning the hull forming process and the test results are to be then enclosed with the classification documentation or during the hull forming process.

4.4.6 Tests of control panel samples are to be carried out in the PRS–recognised laboratory. The test report should contain the following:

Hardened GRP properties	Test acc. to the standard
Glass reinforcement content, [%]	ISO 1172
Tensile strength, [MPa]	PN-81/C-89034 or ISO R527-1966
Tensile Young’s modulus, [MPa]	PN-82/C-89051 or ISO R527-1966
Bending strength, [MPa]	PN-79/C-89027 or ISO R178-1975
Bending Young’s modulus, [MPa]	PN-82/C-89051 or ISO R178-1975
Hardness acc. To Barcol	ASTM[*)]/D 2583-87

[*)]American Society for Testing Materials

5 PROPERTIES OF LAMINATE

5.1 Content of Reinforcement

5.1.1 Laminates reinforced with glass mats are to have the reinforcement content within 28 – 35 % with respect to the mass of laminate.

5.1.2 Laminates with alternate reinforcement (mats with other reinforcements alternatively) are to have the reinforcement content z within the following limits:

$$z_{\min} = \frac{M_{zb}}{3{,}6\ M_M + 2{,}2\ M_T + 2{,}0\ M_K}\ 100\% \qquad (5.1.2\text{-}1)$$

$$z_{\max} = \frac{M_{zb}}{3{,}0\ M_M + 1{,}65\ M_T + 1{,}5\ M_K}\ 100\% \qquad (5.1.2\text{-}2)$$

M_{zb} – total mass of reinforcement in laminate, [g/m^2],
M_M – mass of mat reinforcement, [g/m^2],
M_T – mass of fabric reinforcement, [g/m^2],
M_K – mass of unidirectional reinforcement, [g/m^2].

5.1.3 The use of laminates of glass reinforcement content other than specified above is separately considered by PRS.

5.2 Laminate Thickness

5.2.1 For average correct handwork, the laminate thickness *g* is to approach value:

$$g = \frac{M_{zb}}{1000}\left(\frac{83}{z} - 0{,}44\right), \text{ [mm]} \qquad (5.2.1)$$

M_{zb} – total mass of reinforcement in laminate, [g/m^2],
z – reinforcement content in laminate, [%].

5.3 Mechanical Properties

5.3.1 Laminates reinforced with glass mats are to have at least the following mechanical properties:

Tensile strength $R_m = 4z - 30$, [MPa] (5.3.1-1)
Bending strength $R_g = 4z + 35$, [MPa] (5.3.1-2)
Tensile Young's modulus $E_m = 200z + 1000$, [MPa] (5.3.1-3)
Bending Young's modulus $E_g = 200z + 500$, [MPa] (5.3.1-4)

z – reinforcement content in laminate, [%].

For detailed values, see Table 5.3.1.

Table 5.3.1
Mat reinforced laminates

Reinforcement content [%]	Reinforcement quantity for 1 mm of thickness [g/m^2]	Specific mass of laminate [g/m^2]	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*

[*)] see 5.1.1 i 5.1.3

5.3.2 Laminates with alternate reinforcement are to have at least the following mechanical properties:

Tensile strength $R_m = 0{,}19z^2 - 10z + 210$, [MPa] (5.3.2-1)
Bending strength $R_g = 0{,}19z^2 - 10z + 270$, [MPa] (5.3.2-2)
Tensile Young's modulus $E_m = 400z - 5800$, [MPa] (5.3.2-3)

Bending Young's modulus $E_g = 12z^2 - 750z + 18400$, [MPa] (5.3.2-4)

z – reinforcement content in laminate, [%].

For detailed values, see Table 5.3.2.

Table 5.3.2

Laminates with alternate reinforcement

Reinforcement content [%]	Reinforcement quantity for 1 mm of thickness [g/m^2]	Specific mass of laminate [g/m^2]	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	9400	7228
39	592	1,52	109	169	9800	7402
40	612	1,53	114	174	10200	7600
41	631	1,54	119	179	10600	7822
42	651	1,55	125	185	11000	8068
43	671	1,56	131	191	11400	8338
44	691	1,57	138	198	11800	8632
45	712	1,58	145	205	12200	8950
46	733	1,59	152	212	12600	9292
47	754	1,60	160	220	13000	9658
48	776	1,62	168	228	13400	10048
49	796	1,63	176	236	13800	10462
50	820	1,64	185	245	14200	10900

5.3.3 Mechanical properties specified in 5.3.1 and 5.3.2 are minimum values for the control panel samples hardened according to 4.5.3.

5.3.4 The use of laminates, the control panel samples of which have strength or modulus values lower than those specified in 5.3.1 or 5.3.2 is to be separately considered by PRS.

5.4 Rule Laminate

5.4.1 The requirements given in further chapters refer to rule laminate of reinforcement content z = 34 % (about 500 g/m^2 of reinforcement for 1 mm of the laminate thickness) with the following strength properties:

R_m = 106 MPa,
R_g = 171 MPa,
E_m = 7800 MPa,
E_g = 7300 MPa.

5.4.2 For laminates of reinforcement content lower than 34 %, the required mass of glass reinforcement may be calculated as for the rule laminate.

5.4.3 For laminate of reinforcement content higher than 34 %, the required mass of glass reinforcement M_1 for plating is to be calculated according to the following formulae:

– for strength criterion:

$$M_1 = M \frac{z}{41{,}5 - 0{,}22\, z} \sqrt{\frac{171}{R_g}} \text{ , [g/m}^2\text{]} \qquad (5.4.2\text{-}1)$$

– for stiffeness criterion:

$$M_1 = M \frac{z}{41{,}5 - 0{,}22\, z} \sqrt[3]{\frac{7300}{E_g}} \text{ , [g/m}^2\text{]} \qquad (5.4.2\text{-}2)$$

M – required rule mass of reinforcement, [g/m^2],
z – true content of reinforcement in the laminate,
R_g – design bending strength of the laminate, [MPa],
E_g – design Young's bending modulus, [MPa].

The following criteria are to be assumed as design strength and design Young's bending modulus:

– 90% of appropriate values obtained during strength tests of control panels of applied laminate (if such tests were performed prior to construction commencement), or,
– appropriate values given in Table 5.3.2 for reinforcement content z_{max} calculated from the formula 5.1.2-2 (if no strength tests were performed prior to construction commencement).

Required section modulus W_1 and inertia moments I_1 for stiffenings are to calculated in a similar way:

$$W_1 = W \frac{171}{R_g} \text{ , [cm}^3\text{]} \qquad (5.4.2\text{-}3)$$

$$I_1 = I \frac{7300}{E_g} \text{ , [cm}^4\text{]} \qquad (5.4.2\text{-}4)$$

W – rule bending section modulus, [cm^3],
I – rule moment of inertia, [cm^4].

5.5 Construction of Hull without Strength Test

5.5.1 In the case of yachts of classification length less than 9 m, PRS can depart from the requirement of specimen testing (4.6.3), provided that:

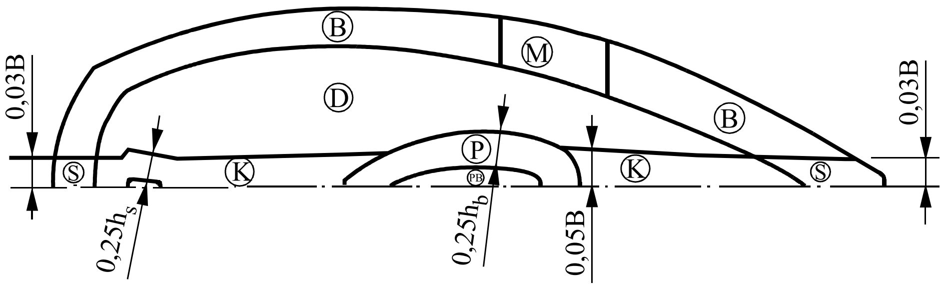
– proper manufacturing of laminate has been stated,
– plating reinforcement is increased by 15 per cent in respect of the Rules requirements,
– reinforcement section moduli are increased by 10 per cent in respect of the Rules requirements,

– reinforcement content within z_{min} – z_{max} has been stated (from plating thickness measurement).

6 GRP PLATING

6.1 Bottom and Sides

6.1.1 Bottom and sides plating of a sailing yacht and a motor-sailing yacht is to meet all the following criteria specified in Table 6.1.1 for all plating areas indicated in Fig.6.1.1.



h_b – height of ballast fin, [m],
h_s – height of rudder fin, [m].

Fig. 6.1.1

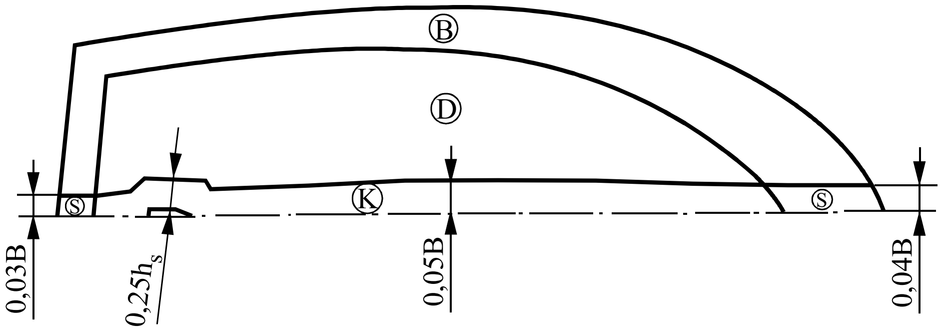
Table 6.1.1
Rule reinforcement mass for bottom and sides of a sailing yacht and a motor-sailing yacht, [g/m^2]

Plating area		Criterion			Other requirements
		Bending strength	Rigidity	Min. mass of reinforcement	
1		2	3	4	5
Ballast fin	P	$6{,}5ak\sqrt{h}$	$8{,}9ak\sqrt[3]{h}$	$1600\sqrt{L}$	6.1.5
Keel	K	$6{,}0ak\sqrt{h}$	$7{,}2ak\sqrt[3]{h}$	$1350\sqrt{L}$	6.1.3
Bottom	D	$4{,}6ak\sqrt{h}$	$5{,}5ak\sqrt[3]{h}$	$920\sqrt{L}$	6.1.6, 7
Stem and stern	S	$6{,}0ak\sqrt{h}$	$7{,}2ak\sqrt[3]{h}$	$1100\sqrt{L}$	
Sides	B	$4{,}6ak\sqrt{h}$	$4{,}8ak\sqrt[3]{h}$	$750\sqrt{L}$	6.1.6
Mast area	M	$5{,}0ak\sqrt{h}$	$6{,}3ak\sqrt[3]{h}$	$800\sqrt{L}$	6.1.8
Integral ballast fin	PB	$6{,}5ak\sqrt{h}$	$8{,}9ak\sqrt[3]{h}$	$1800\sqrt{L}$	6.1.4
Integral rudder fin		$6{,}0ak\sqrt{h}$	$7{,}2ak\sqrt[3]{h}$	$1350\sqrt{L}$	*)

*) acc. to 2.8 of Part III – “Equipment and Stability”.

a – breadth of plating shell, [mm],
k = $k_k \cdot k_p$ acc. to 1.3.3 and 1.3.4,
h – load height acc. to 2.2, 2.3 and 2.7.

6.1.2 Bottom and side plating of a motor yacht is to meet all the criteria specified in Table 6.1.1 for all plating areas indicated in Fig. 6.1.2.



h_s – height of rudder fin, [m]

Fig. 6.1.2

Table 6.1.2

Rule reinforcement mass for bottom and sides of a motor yacht, [g/m^2]

Plating area		Criterion			Other requirements
		Bending strength	Rigidity	Min. mass of reinforcement	
Keel	K	$6{,}0ak\sqrt{h}$	$7{,}2ak\sqrt[3]{h}$	$1350\sqrt{L}$	6.1.3
Stem and Stern	S	$6{,}0ak\sqrt{h}$	$7{,}2ak\sqrt[3]{h}$	$1100\sqrt{L}$	
Bottom	D	$4{,}6ak\sqrt{h}$	$5{,}5ak\sqrt[3]{h}$	$920\sqrt{L}$	6.1.6, 7
Sides	B	$4{,}6ak\sqrt{h}$	$4{,}8ak\sqrt[3]{h}$	$750\sqrt{L}$	6.1.6
Transom		$4{,}6ak\sqrt{h}$	$4{,}8ak\sqrt[3]{h}$	$750\sqrt{L}$	6.1.10

Marking according to Table 6.1.1.

6.1.3 If the hull plating is composed of halves, the keel strake reinforcement is to be increased by 100 per cent in respect of the bottom plating and its width is to be not less than 0,1 B or 70 x bottom thickness.

6.1.4 Plating of integral ballast fin or integral rudder fin if used, is to be made according to the following drawings, 6.1.4 –1 or 6.1.4 –2.

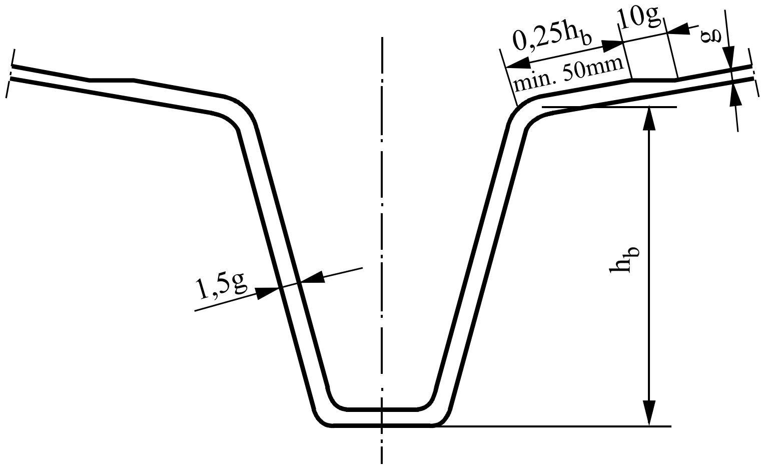


Fig. 6.1.4-1

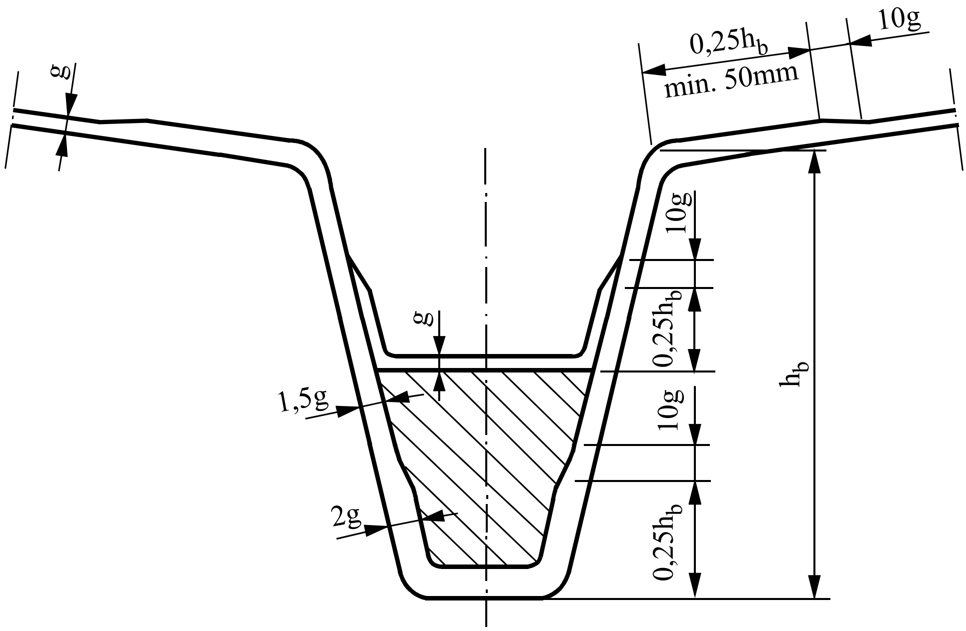


Fig. 6.1.4-2

6.1.5 Bottom plating in the area of contact with outer ballast or with built-in rudder fin is to be made according to the following drawings 6.1.5 –1 or 6.1.5 –2 or in any other equivalent way.

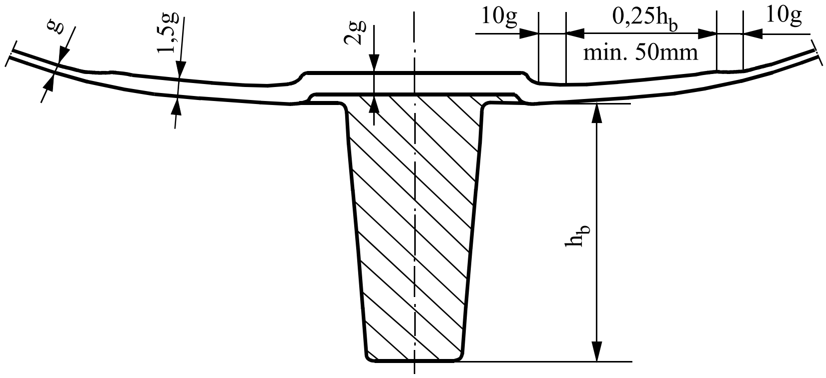


Fig. 6.1.5-1

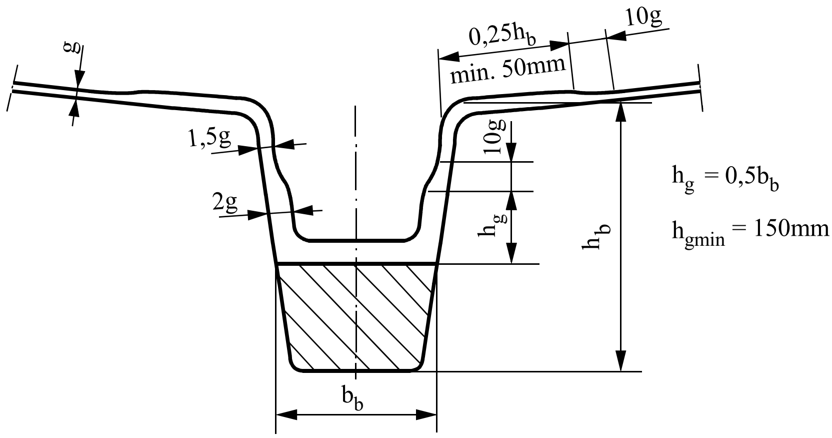


Fig. 6.1.5-2

6.1.6 Sharp plating edges, the so-called chines, which create shell plating stiffenings (1.4.2) or other sharp corners exposed to damage are to have reinforcement increased by 50 per cent at the width at least 0,025 B, as shown in Fig. 6.1.6.

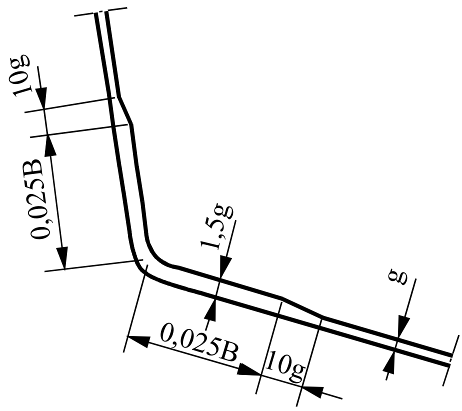


Fig. 6.1.6

6.1.7 Bottom plating is to be brought at least 150 mm above the designed water line.

6.1.8 For the minimum dimensions of the strengthened plating in the mast area, see the following drawings 6.1.8-1 and 6.1.8-2.

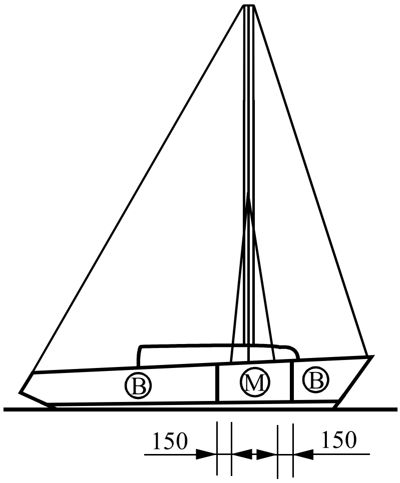


Fig. 6.1.8-1

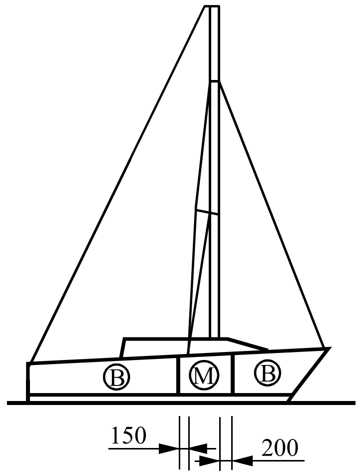


Fig. 6.1.8-2

6.1.9 If, on a two-mast yacht, the height of the lower mast does not exceed 0,7 of the main-mast height, then the sides in the area of the lower mast need not be strengthened.

6.1.10 Transom plating reinforcement is not to be less than the reinforcement of sides. If an outboard motor is used, then the transom is to be additionally strengthened by increasing the plating thickness, additional stiffenings or laminating a plywood plate into the transom plating. It is recommended that transom construction fulfil the requirements of International Council of Marine Industry Associations ICOMIA 13 – 83 standard “Motorwell Dimensions” or the recommendations of outboard engine manufacturer.

6.1.11 The transom plating thickness, on which an outboard engine is mounted should not be less than that given in Table 6.1.10 below.

Table 6.1.10

Minimum thickness of transom plating carrying an outboard motor

Outboard motor power [kW]	Plywood core thickness [mm]	Total transom thickness [mm]
Up to 7	–	15
7 – 18	15	25
18 – 30	20	30
30 – 40	25	35
40 – 90	30	40
over 90	Construction to be considered individually	

6.1.12 All other fragments of bottom and side plating subjected to increased load or abrasion are to be properly strengthened. Similar requirements are applied to the plating around bigger openings.

Plating with increased reinforcement (as in the ballast fin area, mast, etc.) is to be brought to the nearest longitudinal or transversal stiffenings.

6.2 Deck and Superstructure

6.2.1 Deck and superstructure plating is to meet the criteria specified in Table 6.2.1 for all plating areas indicated in Fig. 6.2.1.

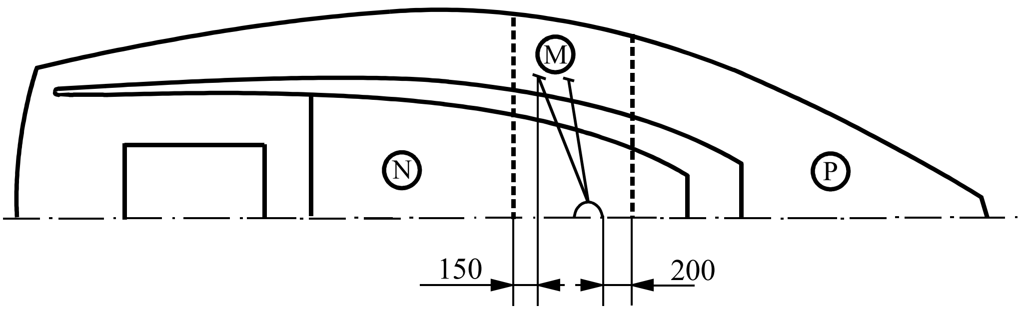


Fig. 6.2.1

Table 6.2.1

Rule reinforcement mass for deck and superstructure, [g/m^2]

Plating area		Criterion		
		Bending strength	Rigidity	Min. mass of reinforcement
Main deck	P	$5{,}0ak\sqrt{h}$	$5{,}4ak\sqrt[3]{h}$	$640\sqrt{L}$
Superstructure deck	P	$5{,}0ak\sqrt{h}$	$5{,}4ak\sqrt[3]{h}$	$640\sqrt{L}$
Superstructure walls		$4{,}6ak\sqrt{h}$	$4{,}8ak\sqrt[3]{h}$	$700\sqrt{L}$
Deckhouse deck	N	$4{,}8ak\sqrt{h}$	$5{,}0ak\sqrt[3]{h}$	$550\sqrt{L}$
Deckhouse walls		$4{,}6ak\sqrt{h}$	$4{,}8ak\sqrt[3]{h}$	$600\sqrt{L}$
Mast area	M	$5{,}0ak\sqrt{h}$	$6{,}3ak\sqrt[3]{h}$	$700\sqrt{L}$
Hatch covers		$4{,}6ak\sqrt{h}$	$6{,}3ak\sqrt[3]{h}$	$640\sqrt{L}$

a – plating shell breadth, [mm],
k = $k_k \cdot k_p$ acc. to 1.3.3 and 1.3.4,
h – load height acc. to 2.4 and 2.7.

6.2.2 It is recommended to increase the stiffness of deck end superstructure roof subjected to load of walking crew above the requirements specified in 6.2.1 to meet the condition:

$$M = 6{,}2ak \text{ , [g/m}^2\text{]} \qquad (6.2.2)$$

a, k – acc. to 6.2.1.

6.2.3 In the area where the equipment, such as quardrail sockets, cleats, is fastened to the plating, the plating is to be strengthened by plywood laminated between the plating layers and by increasing the reinforcement content in the plating.

6.2.4 All the openings in the deck and superstructure are to have rounded corners and edges stiffened with coamings.

In vicinity of big openings, particularly near the corners, the plating is to be adequately strong.

The strengthened plating with a closed opening is to have the strength and rigidity at least equal to those of the non-strengthened plating without openings.

6.3 Bulkheads and Tanks

6.3.1 Plating of bulkheads and tanks is to meet the following criteria:

Table 6.3.1
Rule mass of reinforcement for bulkheads and tanks, [g/m^2]

Plating area	Criterion		
	Bending strength	Rigidity	Min. mass of reinforcement
Bulkheads	$4{,}2ak\sqrt{h}$	$4{,}8ak\sqrt[3]{h}$	$550\sqrt{L}$
Side walls of tanks (or sides)	$5{,}4ak\sqrt{h}$	$6{,}3ak\sqrt[3]{h}$	2400
Deck above tank	$5{,}0ak\sqrt{h}$	$6{,}3ak\sqrt[3]{h}$	2400

a – plating shell breadth, [mm],
k = $k_k \cdot k_p$ acc. to 1.3.3 and 1.3.4,
h – load height acc. to 2.5, 2.6 and 2.7.

6.4 Sandwich Plating

6.4.1 Sandwich plating can be used for sides, deck, superstructures and bulkheads instead of massive plating. Sandwich plating can be used also for bottom, excluding the areas in vicinity of ballast - keel fin, skeg and engine bed, where the massive plating is to be applied. In areas subjected to increased loads, the sandwich plating should pass into a massive one or a proper filling is to be used (e.g. plywood).

6.4.2 Bending section modulus W for 1 mm wide plating bend, calculated for claddings should not be less than the following value:

– for bottom, sides, deck and tanks:

$$W = 19{,}5\ h \left(\frac{a}{1000}\right)^2, \ [\text{mm}^3] \qquad (6.4.2\text{-}1)$$

– for superstructures and bulkheads:

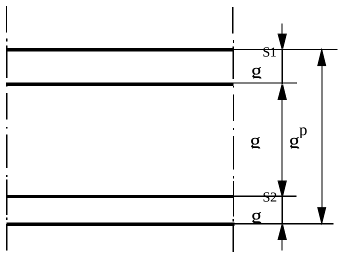
$$W = 15{,}6\ h \left(\frac{a}{1000}\right)^2, \ [\text{mm}^3] \qquad (6.4.2\text{-}2)$$

h – load height acc. 2.3 ÷ 2.7;
a – plating shell breadth, [mm].

6.4.3 Thickness g_p of sandwich plating should not be less than:

$$g_p = k_R\, h \frac{a}{100 R_t}\text{, [mm]} \tag{6.4.3}$$

k_R – core material coefficient:
$k_R = 0,89$ for balsa wood,
$k_R = 0,61 + \frac{0,35}{\sqrt{n}}$ for other core materials,
$k_{Rmin} = 0,7$,
n – coefficient of relative core thickness acc. to Fig. 6.4.3,
h, *a* – acc. to Fig. 6.4.2,
R_t – shear strength of core, [MPa].
g_r – core thickness, [mm],
g_{s1}, g_{s2} – cladding thickness, [mm],



$$n = \frac{g_r}{0,5\left(g_{s1} + g_{s2}\right)},$$

fig. 6.4.3

6.4.4 Designed relative sandwich plating shell deflection δ should not exceed the following value:

$$\delta = \frac{h\, a^3}{384\, E_p\, I_p} + \frac{h\, a}{8\, G_r\, g_r} \le \delta_d \tag{6.4.4}$$

h, *a* – acc. to 6.4.2,
E_p – bending Young's modulus of cladding, [MPa],
I_p – moment of inertia for 1 mm wide plating band, calculated for cladding, [mm^4],
G_r – modulus of rigidity of core, [MPa],
g_r – acc. to Fig. 6.4.3,
δ_d – permissible relative plating shell deflection:

δ_d = 1,5 for bottom, main deck, tank walls, fragments of sides with small curvature and for these parts of the superstructure which are subjected to direct load of walking crew,
δ_d = 3,0 for curved fragments of sides and for deckhouse decks.

6.4.5 External layer of the laminate is to have the reinforcement not less than:

- for bottom and sides $M = 360\sqrt{L}$, [g/m²],
- for main deck $M = 320\sqrt{L}$, [g/m²],
- for superstructure end bulkheads $M = 300\sqrt{L}$, [g/m²],
- for tanks walls $M = 900$, [g/m²],
- for plating with balsa wood core $M = 1200$, [g/m²].

7 GRP STIFFENERS

7.1 Required Stiffener Moduli

7.1.1 Section moduli W and moments of inertia I of the stiffeners with co-acting stripes of plate laminate are to be not less than the values given below and should meet additional criteria given below:

Tablica 7.1.1

Stiffeners	W [cm³]	I [cm⁴]	Other criteria
Bottom longitudinals	13,6 hsl^2	26,0 hsl^2	7.2.1 ÷ 3
Floors	13,6 hsl^2	22,8 hsl^2	7.2.3 ÷ 5
Side longitudinal	11,7 hsl^2	26,0 hsl^2	
Frames	10,3 hsl^2	22,8 hsl^2	
Deck longitudinal	10,3 hsl^2	26,0 hsl^2	
Beams	9,7 hsl^2	22,8 hsl^2	
Web frames	13,6 hsl^2	22,8 hsl^2	7.3.1
Bulkhead stiffeners	9,7 hsl^2	22,8 hsl^2	
Tank stiffeners	13,6 hsl^2	26,0 hsl^2	

h – load height acc. to 2.1 ÷ 2.7, [m],
s – supported breadth of the plating, [m],
l – unsupported breadth of the plating, [m].

7.1.2 The stiffeners are to be property strengthened in areas where parts of equipment are fastened, as well as in vicinity or masts end big openings.

7.2 Bottom Stiffeners

7.2.1 Yachts without ballast fin are to have central bottom longitudinal girder. If the yacht breadth at designed waterline exceeds 2,5 m, they are to have also two side bottom longitudinals. These longitudinals are to be extended fore and aft as far as practicable.

7.2.2 Yachts with ballast fin are to have at least two bottom longitudinals.

7.2.3 The bottom in the ballast area is to be stiffened according to the scheme given in Fig. 7.2.3.

Section modulus W_1 of the bottom longitudinal in the area of the ballast fin ends are to be not less than the following value:

$$W_1 = \frac{G_1\, l_w}{5\, n_w}\text{, [cm}^3\text{]}, \qquad (7.2.3\text{-}1)$$

G_1 – design mass of ballast acc. to Part III – "Equipment and Stability", [kg],
l_w – distance from a ballast end to the nearest partition (or web frame) supporting the bottom longitudinal, [m],
n_w – number of bottom longitudinals supporting the floors in the ballast area.

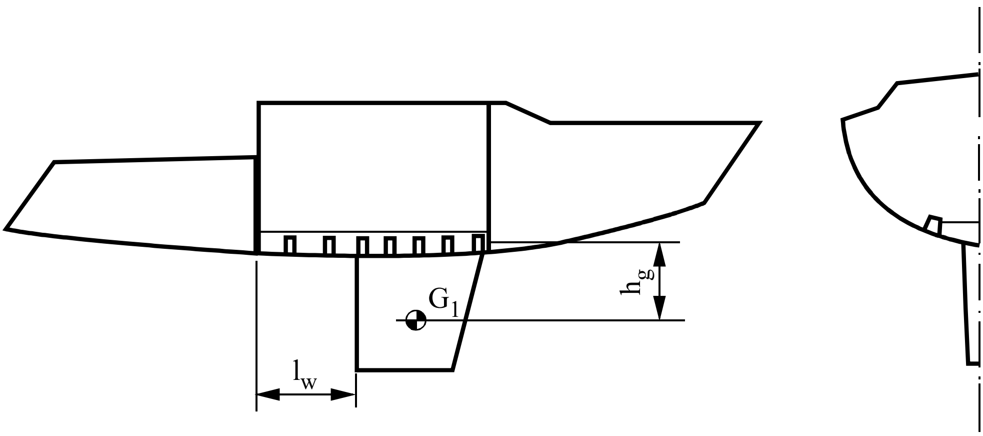


fig. 7.2.3

Moment of inertia of the bottom longitudinals I_1 should not be less than the following value:

$$I_1 = 2W_1 l_w\text{, [cm}^4\text{]}, \qquad (7.2.3\text{-}2)$$

Section modulus W_2 and moment of inertia I_2 of floors and ballast fins should not be less than the following values:

$$W_2 = 13{,}6\, hsl_d^2 + \frac{G_1\, h_g}{4{,}5\, n_d}\text{, [cm}^3\text{]} \qquad (7.2.3\text{-}3)$$

$$I_2 = 2W_2 l_d\text{, [cm}^4\text{]} \qquad (7.2.3\text{-}4)$$

h, s – acc. to 7.1.1,
l_d – unsupported length of floor, [m],
G_1 – acc. to 7.2.3-1,
h_g – vertical distance from the upper edge of the floors to the ballast gravity centre (however, not less than 0,4 T), [m],
n_d – number of stiffening floors in the rudder fin areas.

7.2.4 Section modulus W_s and moment of inertia I_s of floors above the rudder fin should not be less than the following values:

$$W_s = 13{,}6\, hsl_d^2 + \frac{R_1 h_s}{45\, n_s}, \text{ [cm}^3\text{]} \tag{7.2.4-1}$$

$$I_s = 2W_s l_d, \text{ [cm}^4\text{]} \tag{7.2.4-2}$$

h, s – acc. to 7.1.1,
l_d – unsupported length of floor, [m],
R_1 – force acting on lower bearing of rudder calculated acc. to Part III – "Equipment and Stability", [N],
h_s – height of rudder fin, [m],
n_s – number of stiffening floors in the rudder fin area.

7.2.5 Fore part of the bottom – from stem to ballast or from stem to midship section is to be stiffened with floors meeting the requirements specified in 7.1.1, assuming the unsupported length to be not less than 0,4 B. Such floors are also to be installed in the engine foundation area.

7.3 Web Frames

7.3.1 The web frames are to be a continuous construction connecting floors, frames and beams and should meet the 7.1.1 requirements, assuming that the values of unsupported lengths of the stiffeners are to be not less than:

- distance from the centre line of the bottom to the bilge (for bottom part of the web frame),
- distance from side-deck edge to the bilge (for the frame part),
- half of the deck breadth in the place under consideration (for the beam part),

If the pillars are used inside the web frame, then the design length *l* is to be reduced accordingly.

7.4 Design Requirements

7.4.1 Mass of reinforcement of trapezoidal stiffeners web is to be not less than:

$$M = 10d + 450, \text{ [g/m}^2\text{]} \tag{7.4.1-1}$$

d – height of stiffener, [mm].

Web or T-type or angle type stiffener is to have mass of reinforcement two times greater than that specified above.

Stiffener stringer reinforcement is to be not less than:

$$M = 15m + 450, \text{ [g/m}^2\text{]} \tag{7.4.1-2}$$

m – width of stringer, [mm].

7.4.2 If, due to design considerations, the stiffeners are considerably higher (bigger value d) than those required by the Rules, then the requirements specified in 7.4.1 can be dispensed with, provided that the stiffening surfaces are secured against buckling.

7.4.3 If fully prefabricated stiffeners are used, then their laminating to the plating is to meet the condition:

$$M = 10d + 450 \text{, [g/m}^2\text{]} \qquad (7.4.3)$$

7.4.4 Transversal and longitudinal partitions can be considered as stiffeners, provided that they are properly secured against buckling and are properly laminated to the plating.

7.4.5 Internal plating elements /inserted modules/ can be considered as stiffeners, provided that the requirements specified in 7.1 – 7.4.3 are complied with.

7.4.6 When using trapezoid and other closed profile stiffening, it is recommended to fill them with closed cell type foam. It is not recommended for stiffeners and it is not permitted for bottom stiffeners to be made of wood or plywood cladded fully with laminate. This requirement does not apply to laminated, decay resistant wood used as the mast step supported on the bottom.

7.4.7 For approximate values of stiffener section modulus, see Table 7.4.7.

Table 7.4.7

Approximate values of stiffener section modulus, [cm^3]

Height of stiffener, [mm]	Plating reinforcement, [g/m^2]	Stiffener web reinforcement x stringer width M_Z x m: [kg/m$^2 \times$ mm]								
		80	160	240	320	400	560	720	800	960
1	2	3	4	5	6	7	8	9	10	11
20	2000	5,3	10	15	20	24	32	–	–	–
	4000	6,6	12	17	23	28	38	48	54	66
	6000	–	15	21	27	33	44	55	62	75
	8000	–	–	26	31	38	51	63	71	85
40	2000	11	19	28	36	43	58	–	–	–
	4000	12	21	31	40	49	66	83	91	108
	6000	14	24	34	43	53	72	91	100	119
	8000	–	27	37	48	58	78	98	109	129
60	2000	19	31	43	54	66	87	–	–	–
	4000	21	34	48	59	71	96	120	132	155
	6000	23	36	50	63	78	103	129	142	167
	8000	25	40	53	67	81	110	137	151	178
80	2000	30	46	60	75	89	118	–	–	–
	4000	33	50	65	81	97	130	161	175	205
	6000	35	53	69	86	103	137	170	186	219
	8000	38	56	74	91	109	145	180	197	231
100	2000	41	60	78	95	114	150	–	–	–
	4000	44	65	84	103	123	163	201	219	254
	6000	47	69	89	109	130	171	212	231	270
	8000	50	75	93	114	136	179	222	242	283

1	2	3	4	5	6	7	8	9	10	11
120	2000	59	81	102	122	144	186	–	–	–
	4000	64	88	110	132	156	202	248	268	310
	6000	68	93	116	139	164	213	261	283	328
	8000	72	98	122	146	171	222	272	295	343
150	2000	91	118	143	167	194	246	–	–	–
	4000	89	129	155	181	210	267	323	348	398
	6000	105	136	163	191	221	281	340	366	421
	8000	110	142	170	199	230	292	363	380	438
180	2000	133	165	193	221	252	314	–	–	–
	4000	146	180	210	241	274	341	408	436	496
	6000	154	190	222	254	289	369	429	456	522
	8000	162	198	231	264	301	373	445	476	543
210	2000	202	238	269	300	336	407	–	–	–
	4000	221	260	294	327	366	442	518	549	617
	6000	235	276	311	346	386	466	545	578	550
	8000	247	288	325	361	402	485	567	602	677
240	2000	252	293	328	362	403	483	–	–	–
	4000	277	321	358	395	439	525	611	646	722
	6000	294	340	379	418	463	553	643	680	761
	8000	308	355	395	438	483	575	688	707	791
270	2000	332	378	415	453	498	597	–	–	–
	4000	364	413	453	494	542	637	732	770	854
	6000	387	437	480	522	572	672	771	812	901
	8000	405	457	501	545	597	699	802	844	937
300	2000	397	447	489	530	579	677	–	–	–
	4000	436	489	533	578	630	736	839	881	974
	6000	463	518	565	611	666	775	884	929	1047
	8000	484	541	590	638	694	807	919	966	1068
330	2000	503	558	602	646	700	807	–	–	–
	4000	551	608	656	703	760	874	987	1032	1131
	6000	585	645	696	744	803	922	1040	1087	1193
	8000	613	678	726	777	838	960	1082	1131	1241
360	2000	584	644	691	738	797	912	–	–	–
	4000	639	702	763	803	865	988	1101	1159	1267
	6000	680	744	798	851	915	1043	1171	1222	1335
	8000	712	778	833	889	955	1087	1218	1271	1389

8 GENERAL STRENGTH OF GRP HULL

8.1 General Remarks

8.1.1 The general strength of the structure of the hull is to be checked with respect to the following yachts:

- monolithic plating yachts $L > 20$ m,
- sandwich plating yachts $L > 10$ m.

8.1.2 The general strength is to be checked by calculating the hull bending section modulus at midship.

8.1.3 The general strength of the multi-hull yacht is to be individually considered by PRS.

8.2 Hull Bending Section Modulus

8.2.1 The Rule hull bending section modulus should not be less than:

$$W_k = 55L_W^2 B_W \left(C_b + 0{,}7\right), \text{ [cm}^3\text{]} \qquad (8.2.1)$$

B_w – breadth at waterline, [m];

C_b – block coefficient of the submerged part of the hull.

For yachts navigating in area III with fixed weather limitation or in area V waters, the hull section modulus can be reduced by 15%.

8.2.2 Hull section modulus in the transversal section passing by the mast should not be less than:

$$W_m = 45JV_{fs}\cos\beta_{fs}, \text{ [cm}^3\text{]} \qquad (8.2.2)$$

J – base of fore sail triangle as defined in VII – "Masting and Rigging", [m],

V_{fs} – forestay breaking force as defined in VII – "Masting and Rigging", [kN],

β_{fs} – angle between forestay and mast [degrees].

8.2.3 The above formulae given in 8.2.1 and 8.2.2 are valid for the Rule laminate (see 5.4.). The cross section areas of hulls made of other type of laminate are to be multiplied by the coefficient:

$$k = \frac{E_g}{7300} \qquad (8.2.3)$$

E_g – true Young's bending modulus, [MPa].

9 JOINTS IN GRP STRUCTURES

9.1 General Remarks

The examples given below are to be considered as recommended design solutions. Other solutions can be accepted after the equivalence of the joint strength has been stated.

9.2 Butt Joints

9.2.1 Step by step chamfered butt joints have better strength properties, as shown in Fig. 9.2.1.

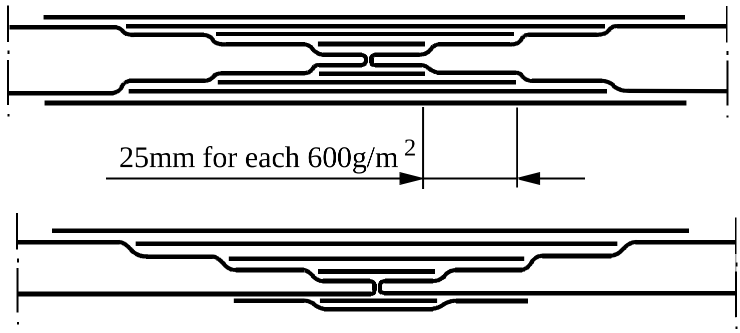


Fig. 9.2.1

9.2.2 Less loaded elements can be joined without chamfering, as shown in Fig. 9.2.2.

9.2.3 Number of layers of the joining laminate is to be not less than the number of layers of thinner of the joined elements.

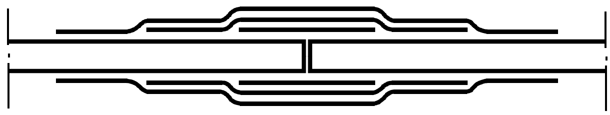


Fig. 9.2.2

9.2.4 When joining elements of different thickness, the thickness of the thicker element is to be gradually reduced before the joint area, as shown in Fig. 9.2.3.

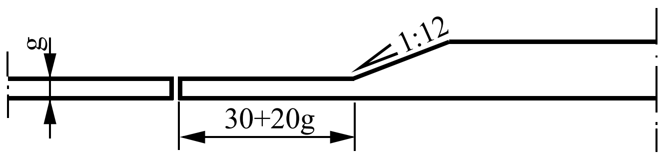


Fig. 9.2.3

9.2.5 The longitudinal joint of two halves of plating is to meet the requirements specified in 6.1.3. This joint can be made according to the following sketch or in any other agreed way:

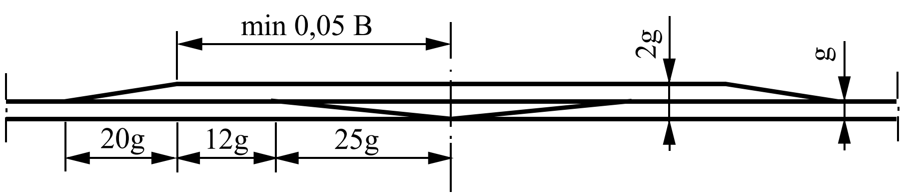


Fig. 9.2.4

9.3 Deck to Sides Joints

9.3.1 Joint of deck to sides should carry the bending load of deck and sides as well as the shear load due to yacht's hull torsion.

9.3.2 It is recommended to use lap joint strengthened with bolts or rivets.

9.3.3 For examples of correct joints, see Fig. 9.3.3 –1 ÷ 4. The reinforcement mass of the joint is to be not less than 40 per cent of the side plating reinforcement.

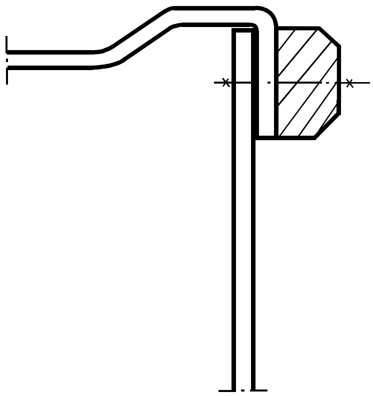


Fig. 9.3.3-1

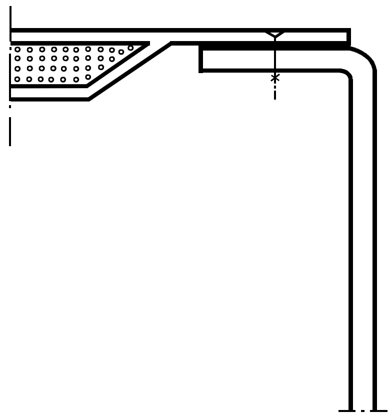


Fig. 9.3.3-2

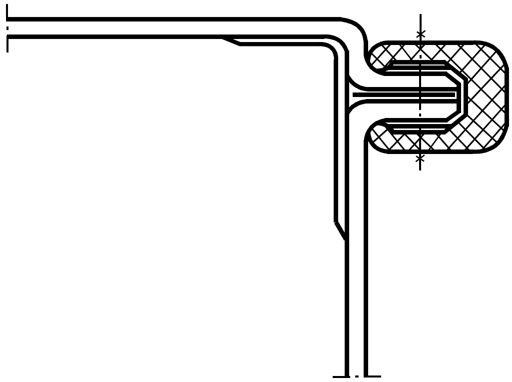


Fig. 9.3.3-3

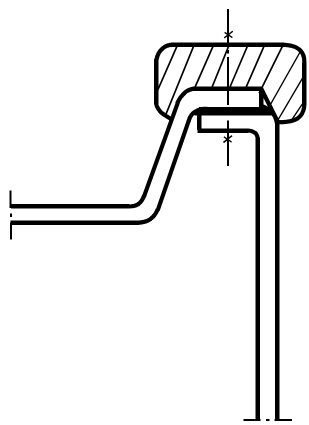


Fig. 9.3.3-4

9.4 Joints of Bulkheads to External Plating

9.4.1 When joining bulkheads with external plating, the thickness of laminated joint is to be not less than half the side thickness. Too rigid joints are to be avoided. For bigger yachts of 9 m of length and over, base laminate layer made of mat and resin of significant relative lengthening between the bulkhead and plating, or elastic inserts made of core foam, are recommended.

9.4.2 Recommended joints of bulkheads to external plating are shown in Fig. 9.4.2:

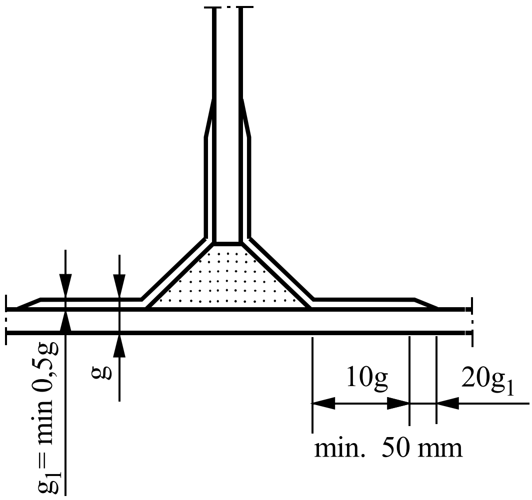


Fig. 9.4.2

9.4.3 Design solutions permissible for yachts of not more than 9 m of length are shown in Fig. 9.4.3 –1 ÷ 4:

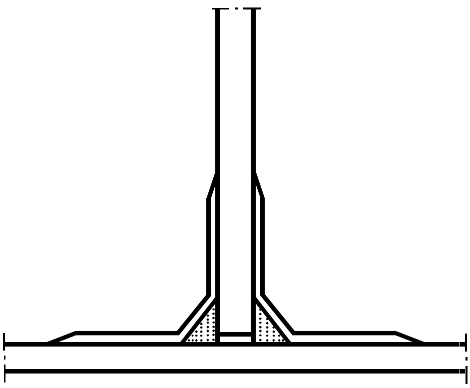


Fig. 9.4.3-1

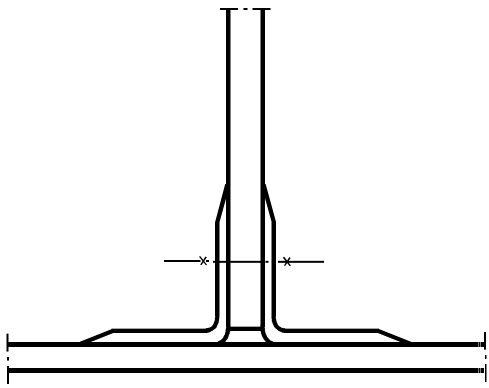


Fig. 9.4.3-2

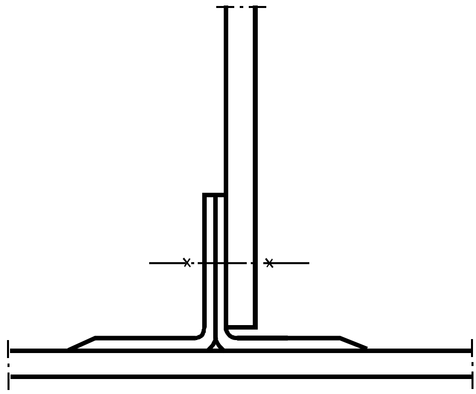


Fig. 9.4.3-3

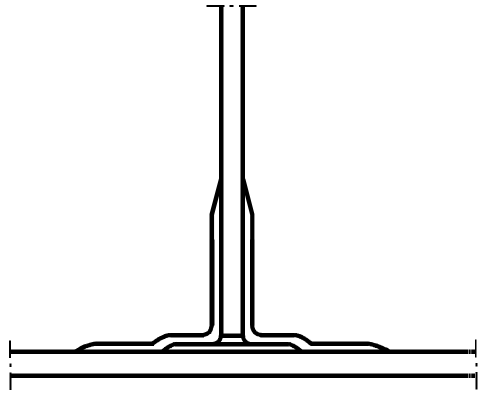


Fig. 9.4.3-4

9.5 Fastening of Internal Furniture

9.5.1 The following requirements concerning each of the two laminate reinforcements are to be observed when joining the internal furniture elements with the plating:

- for parts made of monolithic laminate – min. 50 per cent of the thinner part reinforcement,
- for parts of sandwich plating - min. 100 per cent of the thinner cladding reinforcement.

These requirements are valid for each of two sides laminating. For single side laminating, the above values are to be doubled.

9.5.2 The reinforcement of laminating joints is to be, in general, not less than:

- 1800 g/m^2 (or 2 × 900 g/m^2) for constructional parts strengthening directly the external plating,
- 1200 g/m^2 (or 2 × 600 g/m^2) for less loaded parts.

9.6 Fastening of Stiffeners

9.6.1 Shape laminated stiffeners can be joined with the plating in the following way shown in Fig. 9.6.1 –1 ÷ 2

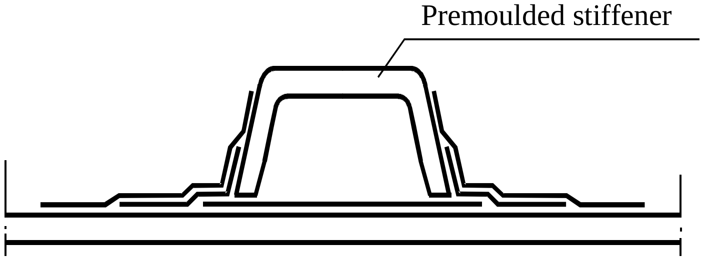


Fig. 9.6.1–1

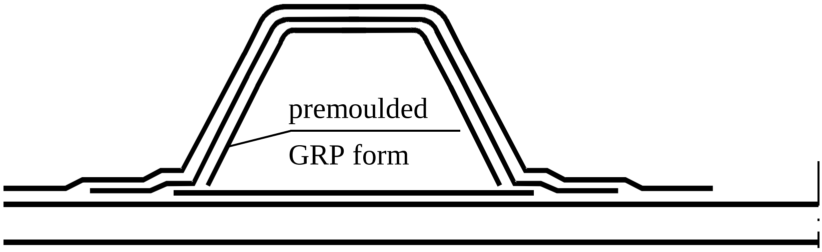


Fig. 9.6.1–2

In both solutions the reinforcement of laminated joint is to be not less than the reinforcement of the stiffeners.

9.6.2 For yachts of 9 m of length and over, the use of base laminate layer made of mat and resin of significant relative lengthening is recommended.

9.7 Sandwich Plating

9.7.1 Monolithic plating, instead of core foam, is to be used in the places of the equipment fastening as shown in Fig. 9.7.1. Plywood inserts laminated inside the sandwich plating in these places are allowed, the technology of which is to be agreed with PRS.

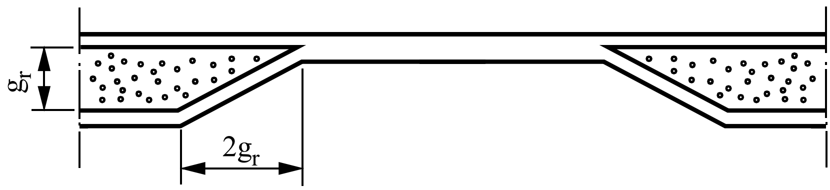


Fig. 9.7.1

9.7.2 Core foam is to be chamfered with 1:2 slope in all passages from the sandwich plating into the monolithic one.

10 METAL CONSTRUCTIONS

10.1 General Requirements

10.1.1 Metals used are to meet the requirements specified in Part VI – Materials.

10.1.2 For zinc sprayed steel hulls, the plating thickness and section moduli of stiffeners can be reduced by 10 per cent in respect of the values required by the Rules.

10.1.3 It is recommended that parts of plating and stiffeners exposed to increased corrosion as bilges, water and fuel tanks, scuppers, to be made of plate thicker than required and not thinner than 3 mm.

10.2 Conditions of Building

10.2.1 The welding site should be protected against frost and humidity. In the case of inert-gas arc welding, against wind and air currents.

If the welding is carried out in temperature below – 5°C, then the proper quality of welded joints is to be secured by covering or heating the welded parts of construction.

Quick cooling is to be avoided when welding thick plates.

10.2.2 The welding is to be made exclusively by a welder with PRS licence. There is a possibility for amateur builders of one yacht to be granted the licence during the yacht construction.

10.2.3 The electrodes are to be absolutely dry.

10.2.4 Preservation of the metal hull is to be made in a way recommended by the manufacturer of preservative materials.

10.3 Rule Metal

10.3.1 The requirements specified in the next Chapters apply to steel having the following mechanical properties:

tensile strength	R_m = 400 MPa;
yield strength	R_e = 235 MPa;
Young's modulus	E = 210 000 MPa,

10.3.2 When using steel of other properties or aluminium alloy, the plating thickness g_1 and stiffener section modulus W_1 are to be recalculated according to the following formulae:

– for bending strength criterion:

$$g_1 = g\sqrt{\frac{635}{R_m + R_e}}\ , \text{[mm]} \qquad (10.3.2\text{-}1)$$

– for criterion of rigidity:

$$g_1 = g\sqrt[3]{\frac{210\,000}{E}}\ , \text{[mm]} \qquad (10.3.2\text{-}2)$$

$$W_1 = W\frac{635}{R_m + R_e}\ , \text{[cm}^3\text{]} \qquad (10.3.2\text{-}3)$$

where:

g – required Rule plating thickness, according to 11;

W – required stiffener bending section modulus for Rule metal, according to 12;
R_m – tensile strength of the used material, not greater, however, than 600, [MPa];
R_e – yield strength of the used material, [MPa];
E – Young's modulus of the used material, [MPa].

11 STEEL PLATING

11.1 Rule Thickness

11.1.1 Steel plating thickness g is to be not less than that given in the Table 11.1.1 and is to meet additional criteria:

Table 11.1.1
Rule steel plating thickness, [mm]

Plating area	Criterion		Other criteria
	Bending strength	Minimum thickness	
Ballast fin area	$5{,}2ak\sqrt{h}$	$1{,}20\sqrt{L}$	
Keel, stem, stern	$5{,}2ak\sqrt{h}$	$1{,}10\sqrt{L}$	
Bottom	$5{,}0ak\sqrt{h}$	$0{,}90\sqrt{L}$	
Sides	$5{,}0ak\sqrt{h}$	$0{,}85\sqrt{L}$	
Integral ballast fin	$5{,}2ak\sqrt{h}$	$1{,}20\sqrt{L}$	
Integral skeg	$5{,}2ak\sqrt{h}$	$1{,}10\sqrt{L}$	
Main deck	$5{,}0ak\sqrt{h}$	$0{,}75\sqrt{L}$	11.1.2 ÷ 5
Deckhouses	$4{,}8ak\sqrt{h}$	$0{,}70\sqrt{L}$	11.1.2 ÷ 5
Bulkheads	$4{,}8ak\sqrt{h}$	$0{,}60\sqrt{L}$	
Wells of integral tanks	$5{,}2ak\sqrt{h}$	$0{,}80\sqrt{L}$	

a – breadth of plating shell, [m],
k = $k_k \cdot k_p$ acc. to 1.3.3 and 1.3.4,
h – load height acc. to 2.2 ÷ 2.7.

11.1.2 The thickness g of flat plating shells, shells of small curvature and parts subjected to load of walking crew due to rigidity criterion, is to be not less than that calculated from the formulae:

$$g = 5{,}3ak\sqrt[3]{h}\text{ , [mm]} \qquad (11.1.2)$$

a, k, h – acc. to 11.1.1
it is to be taken that $h \geq 0{,}5$ m.

11.1.3 Plating thickness of the inner bottom, if used, is to be not less than the side plating thickness; in the engine room area it is to be increased by 1 mm in respect of the side plating. The inner bottom plating is to be stiffened in a similar way as the outer bottom plating.

11.1.4 All openings in deck and superstructure are to have rounded comers, their edges being stiffened with coamings.

12 STEEL STIFFENERS

12.1 Required Stiffeners Moduli

12.1.1 The bending section moduli of the applied steel stiffenings are to be not less than those given in Table 12.1.1 and are to meet additional criteria given in the Table:

Table 12.1.1

Stiffeners	Bending section modulus [cm^3]	Other criteria
Bottom longitudinals	3,5 hsl^2	12.3
Floors	3,5 hsl^2	12.3
Side longitudinals	3,0 hsl^2	
Frames	2,6 hsl^2	12.4
Deck longitudinals	2,6 hsl^2	12.5.4
Beams	2,4 hsl^2	12.5.1 ÷ 12.5.3
Web frames	3,5 hsl^2	
Bulkhead stiffeners	2,4 hsl^2	
Tank stiffeners	3,5 hsl^2	

h – load height acc. to 2.1 ÷ 2.7,
s – supported breadth of plating, [m],
l – unsupported span of stiffener, [m].

12.2 Keel, Stem and Stern

12.2.1 Flat keel, as well as the stem and stern made of bent plates are to meet the requirements specified in 11.1.1.

The width *b* of these structural parts is to be not less than:
$b = 0,10\,B$ [mm] – for keel at midship, (12.2.1-1)
$b = 0,06\,B$ [mm] – for stem and stem of sailing yacht, (12.2.1-2)
$b = 0,08\,B$ [mm] – for stem of sailing yacht with the propeller shaft stern tube for auxiliary engine up to 40 kW. (12.2.1-3)

12.2.2 The thickness *g* of bar keel and its height *h* are to be not less than:

$$g = 0{,}4L + 8 \text{, [mm]} \qquad (12.2.2\text{-}1)$$

$$h = 2L + 60 \text{, [mm]} \qquad (12.2.2\text{-}2)$$

12.2.3 The thickness *g* and height *h* of bar stem and stern are to be not less than:

$$g = 0{,}5L + 3 \text{, [mm]} \qquad (12.2.3\text{-}1)$$

$$h = 2L + 50 \text{, [mm]} \qquad (12.2.3\text{-}2)$$

12.2.4 The thickness g and height h of bar stern with suspended rudder are to be not less than:

$$g = 0{,}7L + 5\text{ , [mm]} \qquad (12.2.4\text{-}1)$$

$$h = 1{,}2L + 80\text{ , [mm]} \qquad (12.2.4\text{-}2)$$

12.2.5 The thickness g and height h of bar stern with stern tube for engines above 40 kW are to be not less than:

$$g = L + 12\text{ , [mm]} \qquad (12.2.5\text{-}1)$$

$$h = L + 80\text{ , [mm]} \qquad (12.2.5\text{-}2)$$

The ruder spur of this stern is to meet the requirements specified in Part III – Equipment and Stability.

12.2.6 Welded stern of a motor yacht is to have the width b and thickness g near the propeller shaft boss not less than:

$$b = 18L + 110\text{, [mm]} \qquad (12.2.6\text{-}1)$$

$$g = 0{,}15L + 7\text{ , [mm]} \qquad (12.2.6\text{-}2)$$

The width b measured at a distance equal to 0,25 of stern span from the maximum section area is to be not less than 80 per cent of the values calculated according to the formulae 12.2.6-1.

12.3 Bottom Stiffeners

12.3.1 In transversal framing system, floors are to be installed for each frame. The floors are to be made of plate having the same thickness as the bottom plating.

12.3.2 Height h measured from flat keel or from transition of the inner contour or hull plating into the ballast fin plating to the upper edge of the floors is to be not less than:

$$h = (18L + 220)s\text{ , [mm]} \qquad (12.3.2)$$

s – supported breadth of the plating, [m].

12.3.3 If the floor span exceeds 75 times its thickness, then on its upper edge a reverse bar, the width of which is not to be less then 10 floor thicknesses, is to be installed.

12.3.4 Section modulus of floors above the ballast fin is to be not less than:

$$W_b = 3{,}5\, hsl_d^2 + \frac{G_1\, h_g}{17{,}5\, n_d}\text{ , [cm}^3\text{]} \qquad (12.3.4)$$

h – load height acc. to 2.2 and 2.7,
s – supported breadth of plating, [m],
l_d – unsupported length of floor, [m],
G_1 – design mass of ballast acc. to Part III – Equipment and Stability, [kg],
h_g – vertical distance from the ballast centre of gravity to the upper edge of the floors (not less, however, than 0,4 T), [m],

n_d – number of floors stiffening the bottom in the ballast area.

12.3.5 Section modulus W_s of floors above the rudder fin is to be not less than:

$$W_s = 3{,}5\, hsl_d^2 + \frac{R_1 h_s}{175\, n_s}\ , \text{[cm}^3\text{]} \qquad (12.3.5)$$

h, s, l_d – acc. to 12.3.4,
R_1 – the force acting on the lower rudder bearing, acc. to Part III – Equipment and Stability, [N],
h_s – height of the rudder fin, [m],
n_s – number of floors stiffening the bottom in the rudder fin area.

12.3.6 Floor supporting the mast or the mast pillar is to be connected with the neighbouring floors by means of a longitudinal structure.

12.3.7 If a double bottom is used, then the height of floors in the centre line is to be not less than 650 mm.

The plating of watertight double bottom floors is to meet the requirements set forth for integral tank walls.

12.4 Side Stiffeners

12.4.1 For transversal framing system, the frames in the mast area are to be strengthened by 50 per cent. The number of strengthened frames is to be not less than that given in Table 12.4.1.

Table 12.4.1

Depth H, [m]	Number of strengthened frames
$H \leq 3$	1
$3 < H \leq 4$	2
$H > 4$	3

12.4.2 The ends of the engine beds girders for engines of power greater than 200 kW are to be supported on the web floors or bulkheads.

12.5 Deck Stiffeners

12.5.1 For transversal framing system, beams are to be installed on each frame. For yachts, the length of which does not exceed 12 m, the beams in the half deck area longwise the deckhouse can be installed on every other frame.

12.5.2 The section modulus of transversal beams connected with the strengthened frames is to be doubled.

12.5.3 Properly strengthened or supported beams are to be installed in areas where bigger parts of equipment are fastened and also on edges of big openings.

12.5.4 The height of web of the longitudinal supporting the transversal beams is to be not less than 0,04 its unsupported span or 1,5 the height of the supported beams.

12.6 Web Frames

For longitudinal framing system, web frames are to be installed. The structure of web frames is to be of continuous type. It means that the floor, frames and beam are connected together.

The values of unsupported lengths of web frame parts are to be substituted into formulae 12.1.1. However, the values are to be not less than:

– distance between the centre line and turn of the bilge (for the bottom part of the web frame),
– distance between the deck-side edge and turn of the bilge (for the frame part of the web frame),
– half the breadth of deck in a given place (for the deck part of the web frame).

If pillars inside the web frame are installed, the unsupported length *1* of stiffener can be reduced accordingly.

13 WELDED JOINTS

13.1 General Requirements

13.1.1 The welding materials are to be approved by PRS according to the requirements specified in Part IX – Materials and Welding of the Rules for the Classification and Construction of Sea-going Ships.

13.2 Structural Details

13.2.1 Welded joints are to be designed in a way enabling easy access to them during manufacturing.

In order to reduce, as far as possible, the welding stresses and deformations, the welding is to be made in a proper succession. Where practicable, the welding is to be made in a downhand position.

13.2.2 Small spacing between the welded joints is to be avoided. Parallel butt joints are not to be nearer each other than 100 mm. Fillet welded joints are not to be nearer butt joints than 50 mm.

13.2.3 Continuous fillet welds are to be used for joining the following structural parts:

- plating,
- keel, stem and stern,
- floors to keel,
- engine and equipment foundations,
- brackets to stiffeners,
- stiffeners ends at the length equal to 1,5 times their height.

Interrupted fillet welds are to be used for joining the stiffeners to the plating. Stiffeners joined together without brackets are to be welded with continuous fillet welds.

13.3 Butt Joints

13.3.1 For the manual welding of plates up to 5 mm thick, the edge scarfing can be dispensed with. Plates thicker than 5 mm are to be V or X-scarfed. Butt joints are to be welded from both sides; for plates up to 3 mm in thickness, the weld can be laid on one side only, provided that the continuous root melting has been obtained.

13.3.2 If butt welded parts differ in thickness by more than 25 per cent of the smaller thickness or by more than 3 mm then the thicker part is to be scarfed in 1 : 3 ratio.

13.4 Fillet Welds

13.4.1 Thickness *a* of fillet welds is to be not less than that specified in Table 13.4.1:

Table 13.4.1

Thickness of welded part *g*, [mm]	Weld joint thickness *a*, [mm]
< 4	2,0
4 ÷ 6,5	2,5
6,5 ÷ 8	3,0
> 8	3,5

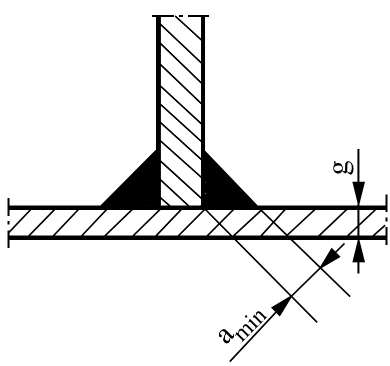


Fig. 13.4.1

13.4.2 For interrupted fillet welds, the dimensions according to Table 13.4.2 are recommended:

Table 13.4.2

Part thickness g, [mm]	Length of welded joint l, [mm]	Spacing t, [mm]
3 ÷ 4,5	25	100
5 ÷ 6,5	30	120
7 ÷ 8,5	40	160
> 9	55	220

13.5 Lap Welding

13.5.1 Lap welded joints are to be avoided where possible.

13.5.2 For lap welded joints, the lap width l is not to be less than:

$$l = 1{,}5g + 15 \text{, [mm]} \qquad (13.5.2)$$

g – thickness of the thinner part.

The fillet weld is to be continuous and closed around.

13.6 Hole Welding

13.6.1 The hole length l and pitch t are to be in compliance with Table 13.4.2. The thickness a of the fillet weld is to be in accordance with Table 13.4.1. The base for calculations is the thinner plate thickness.

The hole width is to be equal to two times the thickness of the plate and is to be not less than 12 mm. The hole ends are to be rounded.

13.6.2 Flat or shaped bar being the base for the hole welding is to have the width not less than four times the plate thickness but it need not exceed 20 mm.

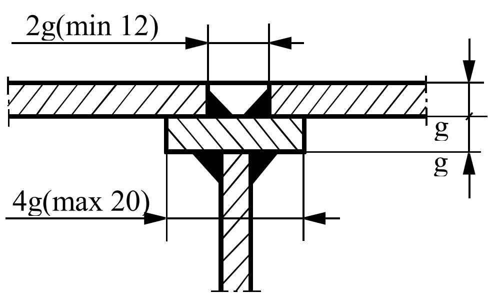


Fig. 13.6.2

13.6.3 The caving remaining after the hole welding can be filled with a proper material but it is not to be welded over.

13.6.4 Plug welding cannot be used for important structural parts joining.

13.7 Welded Joints of Stiffeners

13.7.1 If the stiffener is made of several sections of shape bar, the butt joint can be applied to a place subjected to small load.

13.7.2 Stringers of shape bars with different web heights are to be joined in a way shown in Fig. 13.7.2.

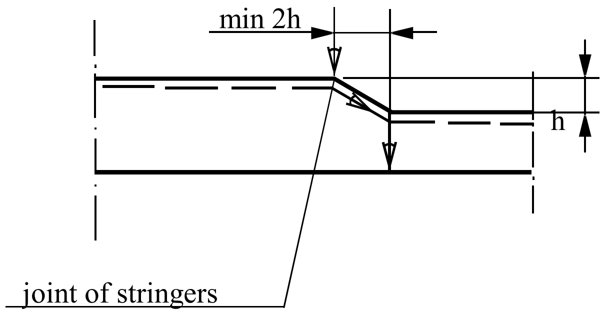


Fig. 13.7.2

13.7.3 For the recommended joints of frames to floors, see Figs. 13.7.3-1 and 13.7.3-2:

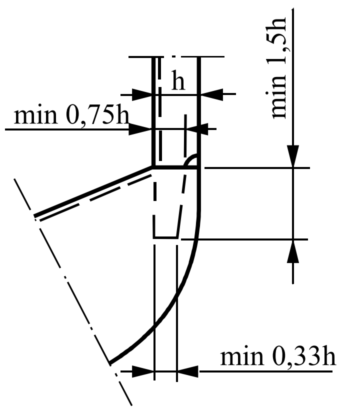


Fig. 13.7.3-1

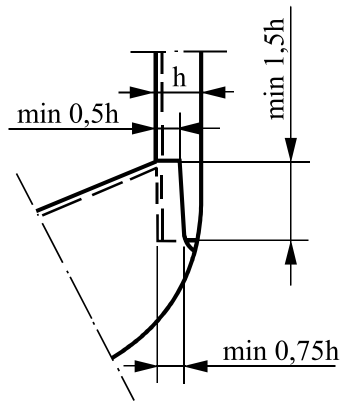
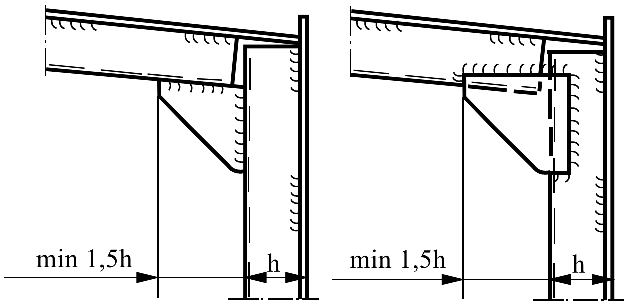
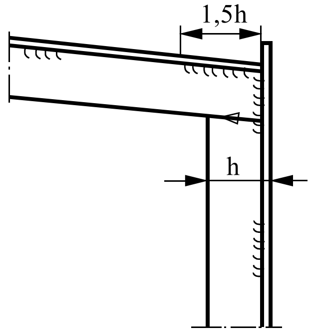


Fig. 13.7.3-2

13.7.4 For the recommended joints of frames to beams see the following drawings:





(for yachts with L < 10 m)

Fig. 13.7.4-1 Fig. 13.7.4-2

14 WOODEN STRUCTURES

14.1 General Requirements

14.1.1 Sorts of timber and glues are to meet the requirements specified in Part VI – Materials.

14.1.2 These Rules apply to the rounded planked hulls or hulls with diagonal glued of facing boards (moulded plywood), as well as to yachts with developable plywood plating. Other constructions of a wooden yacht need special agreement of PRS.

14.1.3 These Rules can also be applicable to the design of wooden decks and plywood bulkheads on metal or laminate plated yachts provided that the joints used meet the condition of carrying the shearing forces.

14.2 Conditions of Building

14.2.1 Prior to beginning the yacht construction, the Builder is obliged to receive from the PRS representative supervising the building the acceptance of the conditions of the building, including the material storage and place of the hull assembly. These conditional are to meet the requirements of PRS, as well as the requirements of the material suppliers or manufacturers, necessary for maintaining the full technological standard of the materials during the yacht construction.

14.2.2 Each material used for important structural parts is to be, prior to its usage, accepted by the PRS representative supervising the building.

14.2.3 Rule Timber

14.2.3.1 The requirements specified in the following Chapters refer to timber having the following properties:

R_g = 82 MPa,
E_g = 9500 MPa.

14.2.4 When using timber of other mechanical properties, the plating thickness g_1, section modulus W_1 and sectional area of stiffeners F_1 are to be recalculated according to the following formulae:

– for bending strength criterion: $g_1 = g\sqrt{\frac{82}{R_g}}$, [mm] (14.3.2-1)

– for criterion of rigidity: $g_1 = g\sqrt[3]{\frac{9500}{E_g}}$, [mm] (14.3.2-2)

$$W_1 = W\frac{82}{R_g}, \text{ [cm}^3\text{]} \quad (14.3.2\text{-}3)$$

$$F_1 = F\frac{82}{R_g}, \text{ [cm}^2\text{]} \quad (14.3.2\text{-}4)$$

g – required plating thickness acc. to 15,
W – required section modulus acc. to 16,
F – required sectional area of stiffener acc. to 16,
R_g – bending strength of used timber, [MPa],
E_g – Young's modulus of used timber, [MPa].

15 WOODEN PLATING

15.1 Rule Thickness

15.1.1 The wooden plating thickness *g* is to be not less than that specified in the Table 15.1.1 and additionally should meet other requirements given in the table:

Table 15.1.1
Rule thickness of wooden plating, [mm]

Type of plating	Criterion		Other requirements
	Bending strength	Minimum thickness	
Planking:			
– with bent frames only	–	$3 + 0{,}60\,L + 60\,s$	15.2.3
– with other frames	–	$5 + 0{,}88\,L + 40\,s$	15.2.3
Planked deck	–	$3 + 0{,}88\,L + 40\,s$	15.2
Deckhouse walls	–		
– solid wood		$9 + 1{,}3\,L$	
Developable plywood plating			
– bottom	$20{,}7\,ak\sqrt{h}$	$3{,}6\sqrt{L}$	15.4
– sides	$20{,}7\,ak\sqrt{h}$	$3{,}1\sqrt{L}$	15.4
– deck	$27{,}0\,ak\sqrt{h}$	$2{,}6\sqrt{L}$	15.4
– deckhouses	$27{,}0\,ak\sqrt{h}$	$2{,}3\sqrt{L}$	15.4
– collision bulkhead	$20{,}7\,ak\sqrt{h}$	$1{,}8\sqrt{L}$	15.4
– bulkhead	$14{,}6\,ak\sqrt{h}$	$1{,}8\sqrt{L}$	15.4
Strip-plywood deck			
– plywood	$20{,}7\,ak\sqrt{h}$	–	15.4
– stripes	–	min. 12 mm	15.2
Diagonal moulded plating	$29{,}3\,ak\sqrt{h}$	$4\sqrt{L}$	15.5

s – frame spacing, [m],
a – plate shell breadth, [m],
k = $k_k \cdot k_p$ acc. to 1.3.3 i 1.3.4,
h – load height acc. to 2.2 – 2.7.

15.1.2 For composite structures, the wood plating fastened to steel stiffeners is to be properly protected against a direct contact with steel.

15.2 Planking

15.2.1 The Rule thickness specified in Table 15.1.1 refers to a single smooth planking.

Clinker planking or double layer smooth planking may be by 10 per cent thinner.

15.2.2 The minimum thickness of hull planking is 12 mm. The minimum thickness of deck plating is 18 mm for a single layer of planks. If the deck is covered with laminate or fabric, then the minimum planking thickness is to be 12 mm. The minimum thickness does not depend on the kind of the timber used.

15.2.3 The recommended widths of planks b_k for a single layer planking are as follows:

hull planking – $b_k = 2{,}25g + 55 \pm 10\%$, [mm] (15.2.3-1)

deck planking – $b_k = 0{,}62g + 32 \pm 5\%$, [mm] (15.2.3-2)

g – plank thickness acc. to 15.1.

15.2.4 The planks are to be as long as practicable. The planks can be extended with the use of diagonally glued joints (in plank thickness) or with the use of butt straps.

Horizontal distances between the plank joints in adjacent belts are to be not lees than:

1,0 m – for plank thickness less than 20 mm,

1,2 m – for plank thickness 20 ÷ 32 mm,

1,5 m – for plank thickness above 32 mm.

Two plank joints in the same vertical plane are to be separated by three continuous planks, acc. to Fig. 15.2.4.

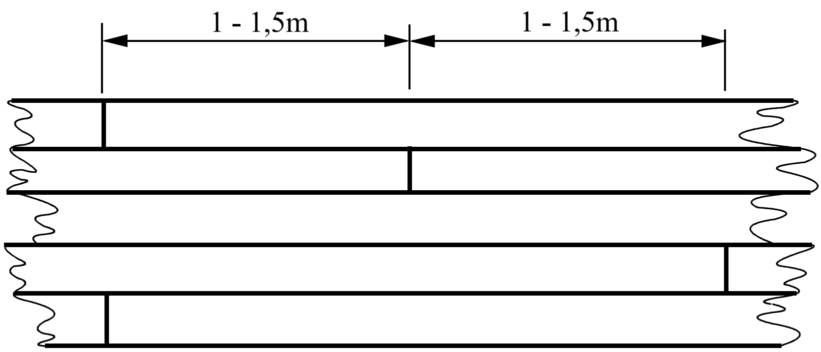
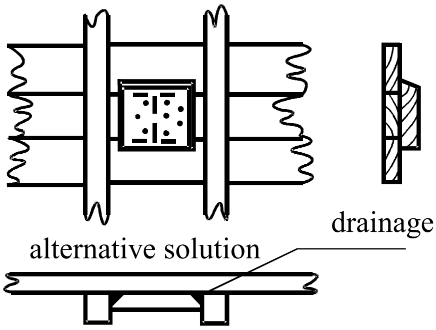


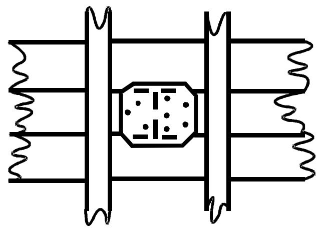
Fig. 15.2.4

15.2.5 The length of diagonally glued joint (in plank thickness) is to be at least 8 times greater than the plank thickness.

15.2.6 A butt strap joint is to be made acc. to Figs. 15.2.6-1 and 15.2.6-2.



Joint by wooden butt strap
Fig. 15.2.6-1



Joint by steel butt strap
Fig. 15.2.6-2

Wooden butt strap thickness is to be equal to the planking thickness. Steel butt strap thickness is to be equal to 15 - 18 per cent of the planking thickness. The minimum number of metal bolts or rivets for one side of the joint is:

3 pcs.for plank width up to 100 mm,
4 pcs. for plank width 100 ÷ 200 mm,
5 pcs. for plank width 200 ÷ 250 mm.

The diameters of bolts or rivets are to be as specified in 15.2.8.

15.2.7 Deck planks can be joined on the beams according to the Fig. 15.2.7:

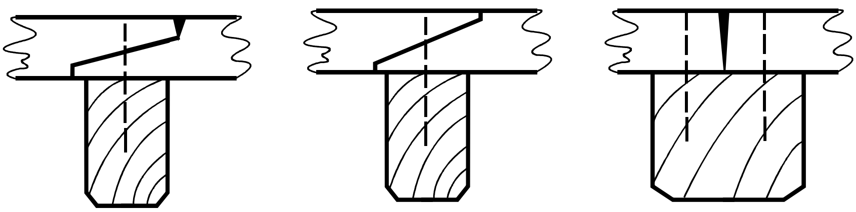


Fig. 15.2.7

15.2.8 Side planks are to be joined with the frames with the use of metal bolts or rivets. The number of bolts or rivets joining one plank to one frame is specified in Table 15.2.8.

Table 15.2.8

The number of bolts or rivets in a plank-frame joint

Plank thickness [mm]	Plank width [mm]				
	up to 100	100 ÷ 150	150 ÷ 180	180 ÷ 210	more than 210
up to 24	2	2	3	–	–
25 ÷ 36	1	2	2	3	–
more than 36	1	2	2	2	3

The diameter d of the bolts and rivets is to be not less than:

– copper rivets for bent frames:

$$d = 0{,}14g \text{ , [mm], however, not less than 2,5 mm,} \quad (15.2.8\text{-}1)$$

– copper rivets for other wooden frames:

$$d = 0{,}8 + 0{,}17g \text{ , [mm], however, not less than 3,5 mm,} \quad (15.2.8\text{-}2)$$

– bolts (carbon steel zinc coated, stainless steel or bronze):

$$d = 1{,}3 + 0{,}17g \text{ , [mm], however, not less than 5 mm.} \quad (15.2.8\text{-}3)$$

Lag screws of bronze or marine brass can be used in places where through holes cannot be made. The diameter d of lag screws is not to be less than:

$$d = 0{,}8 + 0{,}17g \text{ , [mm], however, not less than 5 mm} \quad (15.2.8\text{-}4)$$

g – plank thickness, [mm].

15.2.9 Side planks are to be joined with keel, stem and stern with the use of bolts, or lag screws where bolts cannot be used.

The diameters of bolts and screws are to be not less than those specified in 15.2.8, while their spacing is not to exceed twelve diameters.

15.2.10 Deck planks can be fastened to the beams with the use of rivets, bolts or lag screws. The diameters can be 10 per cent less than those specified in 15.2.8.

Deck planks can be also fastened by means of diagonally driven nails of zinc coated carbon steel or copper, of length l_g not less than that calculated from the formula:

$$l_g = 2{,}5g - 1{,}5 \text{ , [mm]} \quad (15.2.10)$$

g – plank thickness, [mm].

Fastening of deck planks by means of nails is shown in Fig. 15.2.10.

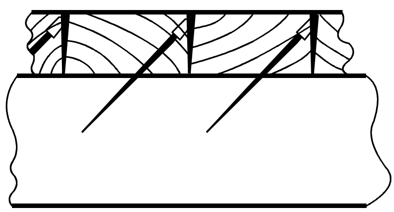


Fig. 15.2.10

15.2.11 Wooden hulls, the length L of which is greater than 9 m, with carvel planking (smooth planking), are to be provided with strengthenings in accordance with 16.12.5.

15.3 Double Planking

15.3.1 External layer of double planking is to have the thickness 0,5 ÷ 0,6 the thickness specified in Table 15.1.1.

15.3.2 Two layers of the double planking are to be interconnected and connected with frames in a way shown in Fig. 15.3.2.

15.3.3 The both layers are to be separated by canvas saturated with a preservative agent (for diagonal planking) or with resorcinol glue (for longitudinal system).

15.3.4 The typical design solutions of side planking-deck joining are shown in Fig. 15.3.4.

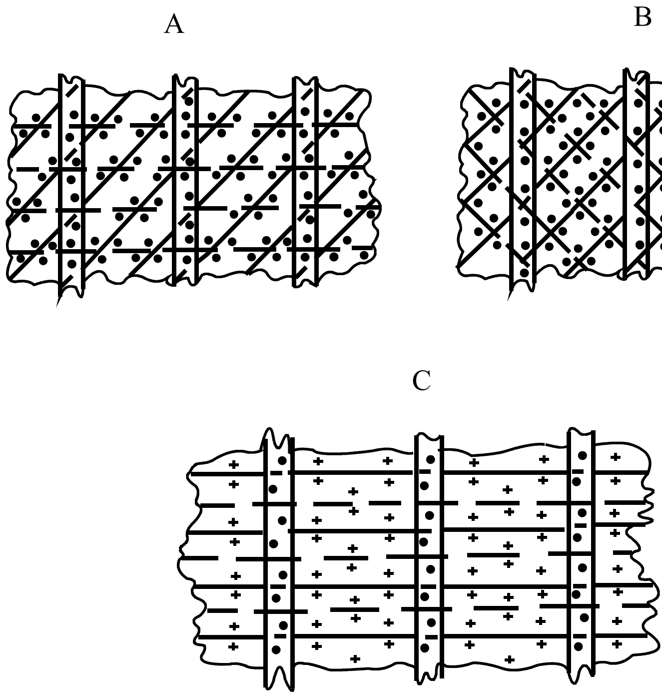


Fig. 15.3.2

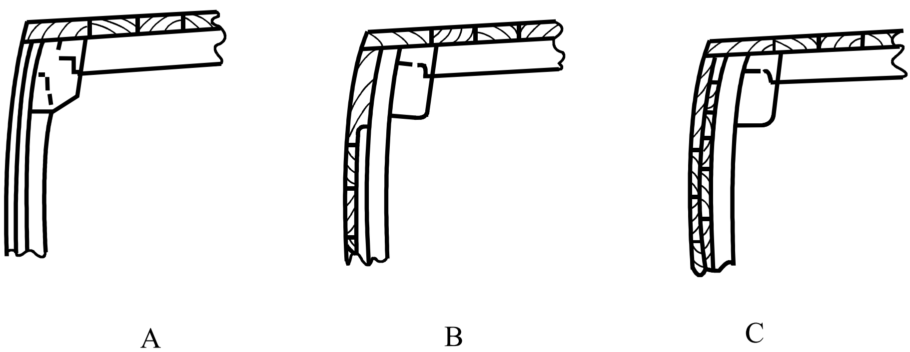


Fig. 15.3.4

15.4 Plywood Plating

15.4.1 Plywood plating is to be made of plywood sheets as large as practicable. The plating is to be joined longitudinally in such places as: keel, stem, stern, bilge longitudinals, deck longitudinals, etc.

Transversal joints are to be avoided in mast and engine foundation areas.

15.4.2 Transversal joints can be glued diagonally or joined with the use of glued–on strap.

15.4.3 The length of diagonally glued joint is to be at least 8 times greater than the plywood thickness, if glued in the workshop, or 10 times greater, if glued in situ on the hull skeleton. Joints on the skeleton are to be made at the floor or frame.

15.4.4 Joint with glued-on strap are to meet the conditions given in Table 15.4.4.

The strap is to be made of the same plywood as the shell plating. Lag screws may be used only in the case when the use of rivets is impossible.

Table 15.4.4

Butt strap joint of plywood sheet, [mm]

Plating thickness [mm]	Strap width [mm]	Fasteners		
		Number of rows	Diameter of copper rivets [mm]	Diameter of lag screws [mm]
6	150	two rows at each side	3	4
8	175	two rows at each side	3,5	4,5
10	200	two rows at each side	4	5
12	240	two rows at each side	4	5
15	280	three rows at each side	5	6
18	320	three rows at each side	5	6
20	350	three rows at each side	6	6

15.4.5 Plywood shell plating is to be connected with the hull stiffeners by means of glue and metal fasteners. The strap width and fasteners diameter are to be not less than those given in Table 15.4.5.

Table 15.4.5

Shell plating thickness [mm]	Minimum width of overlaps in connection to: [mm]		Fasteners diameter [mm]	
	keel or bilge stringer	other parts of skeleton	Copper nails	Lag screws
1	2	3	4	5
6	25 (1 row of fasteners)	25 (1 row of fasteners)	3	4
8	28 (1 row of fasteners)	28 (1 row of fasteners)	3,5	4,5
10	32 (1 row of fasteners)	32 (1 row of fasteners)	4	5
12	40 (2 rows of fasteners)	35 (1 row of fasteners)	4	5
15	48 (2 rows of fasteners)	42 (2 rows of fasteners)	5	6
18	55 (2 rows of fasteners)	48 (2 rows of fasteners)	5	6
20	60 (2 rows of fasteners)	52 (2 rows of fasteners)	6	6

15.4.6 The distance between rivets or screws is not, in general, to exceed 75 mm.

15.4.7 For thickness *g* of flat or little curved plywood shells and of parts of superstructure subjected to the load of walking crew, due to condition of rigidity, it is recommended that:

$$g = 22{,}8ak\sqrt[3]{h}\text{ , [mm]} \qquad (15.4.7)$$

a – plating shell breadth, [m],
k = $k_k \cdot k_p$ acc. to 1.3.3 and 1.3.4,
h – load height acc. to 2.4 and 2.7, but not less than 0,5 m.

15.5 Cold Moulded Plating

15.5.1 For cold moulded shell plating, made of facing boards, it is recommended to use such exotic timber as mahogany, cedar, makore and agba.

Facing boards made of other hardwood, used in general, for the production of waterproof plywood, can also be used, provided that they are properly preserved.

15.5.2 Plating stripes are in general not to exceed 3,5 mm in thickness and 125 mm in width.

15.5.3 Glued plating is to be made of at least four layers of facing boards.

16 WOODEN STIFFENERS

16.1 Required Stiffener Moduli

16.1.1 The bending section moduli *W* of wooden stiffeners are to be not less than those given in Table 16.1.1 and should meet other requirements specified in the Table.

Table 16.1.1

Stiffeners	Bending section modulus [cm^3]	Other requirements
Keel, stem and stern		16.2 ÷ 6
Glued floors	28,5 hsl^2	16.7
Cut-out floors	40,5 hsl^2	16.7
Steel floors	3,50 hsl^2	16.7
Glued frames	28,5 hsl^2	16.8
Cut-out frames	40,5 hsl^2	16.8
Bent frames	20,3 hsl^2	16.8
Steel frames	2,25 hsl^2	16.8
Side and bottom stringers	28,5 hsl^2	
Bilge stringers		16.9
Deck stringers	28,5 hsl^2	
Beam stringers		16.10
Glued beams	12 hsl^2	16.11
Cut-out beams	14 hsl^2	16.11
Steel beams	1,7 hsl^2	16.12
Web frames	35 hsl^2	16.13
Bulkhead stiffeners	15 hsl^2	

h – load height acc. to 2.1 ÷ 2.7;
s – supported breadth of plating, [m];
l – unsupported span of stiffener, [m].

16.2 Keel of Planked Yacht

16.2.1 The keel made of one piece of wood on sailing or motor-sailing yacht is to have the width *b* and the height *h* in the midship section not less than:

$$b = 60 + 20L \text{, [mm],} \qquad (16.2.1\text{-}1)$$

$$h = 24 + 10L \text{, [mm].} \qquad (16.2.1\text{-}2)$$

A similar keel of a motor yacht (without ballast fin, centreboard, etc.) is to have width *b* and cross section *F* not less than:

$$b = 42 + 7L \text{, [mm],} \qquad (16.2.1\text{-}3)$$

$$F = 3600(L - 4) \text{, [mm}^2\text{].} \qquad (16.2.1\text{-}4)$$

16.2.2 The width of the keel can be reduced fore and aft from the midship section to the dimensions required for stem or stern.

16.2.3 The keel of yacht of the length exceeding 10 m can be made of two pieces connected in a way shown in Fig. 16.2.3.

This joint is to be bolted together by means of bolts of the diameter not less than:

$$d = 3\sqrt{L} \text{, [mm]} \qquad (16.2.3)$$

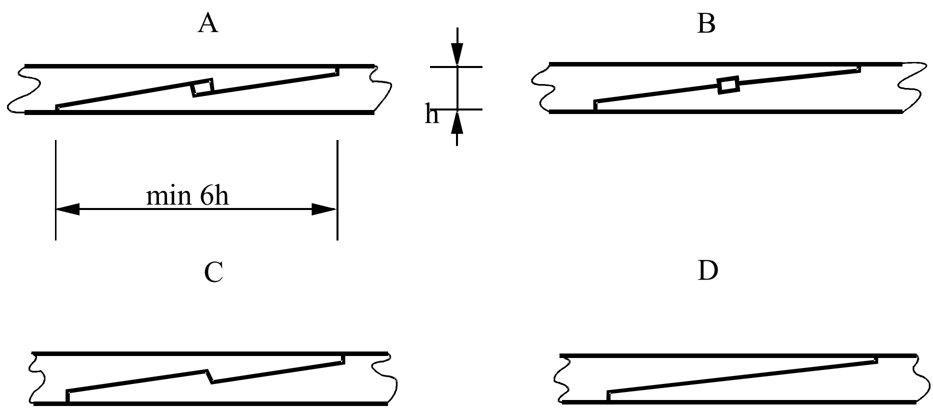


Fig. 16.2.3

16.2.4 Tightening pins made of soft wood are to be provided in the area of the plank groove cut in the keel, e.g. as shown in the drawing 16.2.4:

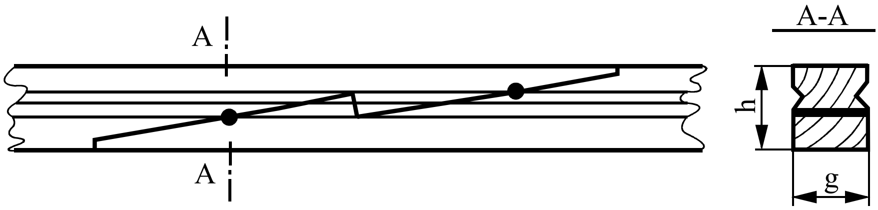


Fig. 16.2.4

16.2.5 Keel joints are not to be situated in the area of the mast or engine foundation.

16.2.6 Cross section of the keel is to be increased in the areas of increased load, e.g. under the mast step, when the ballast keel fin is slender, near centreboard case, etc.

16.2.7 Cross section of keel glued horizontally of planks can be 25 per cent less than the required in 16.2.1.

16.2.8 The wooden insert between ballast and keel (deadwood) is to be adequately strongly connected with the ballast and the keel.

16.3 Stem of Planked Yacht

16.3.1 The thickness *g* or the height *h* of the lower part of the stem are to be not less than:

– for sailing yacht and motor–sailing yacht g or $h = 42 + 9{,}0L$, [mm]
– for motor yacht g or $h = 21 + 9{,}5L$, [mm].

Cross section dimensions of the stem near the deck can be reduced by 20 per cent with regard to those given above.

16.3.2 The cross section area of glued stem can be 15 per cent less than that required in 16.3.1.

16.4 Stern of Planked Yacht

16.4.1 The thickness *g* or the height *h* of the stern are to be not less than:

– for sailing yacht and motor-sailing yacht g or $h = 42 + 6{,}8L$, [mm]
– for motor yacht g or $h = 48 + 5{,}7L$, [mm].

16.4.2 The cross section area of glued stem can be 15 per cent less than the required in 16.4.1.

16.5 Joints of Keel, Stem and Stern

16.5.1 Brackets connecting stem or stern to keel are to be designed in a way ensuring the cross section area in any place to be not less than the cross section of stem or stern acc. to 16.3 and 16.4.

16.5.2 Keel, stem and stern are to be connected together using bolts of the diameter d not less than:

$$d = 10 \text{ , [mm], for } L \le 10 \text{ m,} \qquad (16.5.2\text{-}1)$$
$$d = L \text{ , [mm], for } L > 10 \text{ m.} \qquad (16.5.2\text{-}2)$$

16.5.3 Transversal tightening pins made of soft wood are to be provided in the area of plank groove as in 16.2.4.

16.6 Keel, Stem and Stern of Yacht with Plywood or Cold Moulded Plating

16.6.1 Cross section areas of glued keel, stem or stern on a plywood or cold moulded plated yacht can be 20 per cent less than those specified in 16.2.1, 16.3.1 and 16.4.1.

16.7 Floors

16.7.1 Floors are to be, in general, installed at each frame as far forward and aftward as practicable. Outside the midship, the floors can be installed at every other frame. For yachts of length less than 10 m where bent frames are used exclusively, the floors can be installed at every third frame outside the midship area.

16.7.2 For longitudinal framing, the floor spacing is not to exceed the double spacing of bottom stringers.

16.7.3 Steel floors can be made of rolled bars or can be welded of plates.

The upper edge of floors made of plates is to be bent or secured against buckling in any other way (12.3.4).

16.7.4 The required section moduli of floors are to be kept along the whole width of the keel and can be gradually reduced towards the floor ends.

16.7.5 The length l of joint of a wooden floor with a wooden frame is to be not less than:

$$l = 0{,}15h \text{ , [m]} \qquad (16.7.5)$$

h – load height acc. to 2.2 and 2.7.

16.7.6 When calculating the required section modulus for floors in the area forward of the ballast or forward of the midship section (for motor yachts), the unsupported length of floors is to be taken not less than 0,4 B. Similar requirements apply to the floors in the engine area.

In no case is the floor section modulus to be less than the respective frame section modulus.

16.7.7 The bending section moduli W_b of the floors above the ballast fin are to be not less than:

for glued floors, $$W_b = 28{,}5\, hsl^2 + \frac{G_1\, h_g}{2{,}15\, n_d}, \quad [\text{cm}^3] \qquad (16.7.7\text{-}1)$$

for cut-out floors, $$W_b = 46\, hsl^2 + \frac{G_1\, h_g}{1{,}33\, n_d}, \quad [\text{cm}^3] \qquad (16.7.7\text{-}2)$$

for steel floors, $$W_b = 3{,}5\, hsl^2 + \frac{G_1\, h_g}{17{,}5\, n_d}, \quad [\text{cm}^3] \qquad (16.7.7\text{-}3)$$

h – load height acc. to 2.2 and 2.7,
s – supported breadth of plating, [m],
l – unsupported length of a floor, [m],
G_1 – design mass of ballast acc. to Part III – Equipment and Stability, [kg],
h_g – vertical distance from the upper edge of floors to the centre of gravity of the ballast (however, not less than 0,4 T), [m],
n_d – number of floors stiffening the bottom in the ballast area.

Joints of wooden frames with wooden floors in the ballast area are to be 100 mm longer than those specified in 16.7.5.

16.7.8 The bending section moduli W_s of the floors above the rudder skeg are to be not less than:

for glued floors, $$W_s = 28{,}5\, hsl^2 + \frac{R_1\, h_s}{21{,}5\, n_s}, \quad [\text{cm}^3] \qquad (16.7.8\text{-}1)$$

for cut-out floors, $$W_s = 46\, hsl^2 + \frac{R_1\, h_s}{13{,}3\, n_s}, \quad [\text{cm}^3] \qquad (16.7.8\text{-}2)$$

for steel floors, $$W_s = 3{,}5\, hsl^2 + \frac{R_1\, h_s}{175\, n_s}, \quad [\text{cm}^3] \qquad (16.7.8\text{-}3)$$

h, s, l – acc. to 16.7.7,
R_1 – force acting on the lower bearing of the rudder, calculated acc. to Part III – Equipment and Stability, [N],
h_s – height of rudder fin, [m],
n_s – number of floors stiffening the bottom in the rudder skeg area.

16.7.9 Steel floors in a separated engine room are to be 1 mm thicker than those required in 16.1.

16.7.10 Each floor is to be bolted to the keel by means of at least two bolts of the diameter *d* not less than 8mm and not less than:

$$d = 6{,}7H - 4\text{, [mm]} \qquad (16.7.10\text{-}1)$$

For bent frames, the bolts' diameter *d* is to be not less than 6mm, not greater than 12mm and not less than:

$$d = 4{,}5H - 2\text{, [mm]} \qquad (16.7.10\text{-}2)$$

16.7.11 Floors are to be bolted to the frames by means of bolts of diameter *d* not less than 6mm and not less than:

$$d = 4{,}5H - 2\text{, [mm]} \qquad (16.7.11\text{-}1)$$

For bent frames connections, the bolts' diameter is to be not less than 6mm and not less than:

$$d = 3{,}3H - 1\text{, [mm]} \qquad (16.7.11\text{–}2)$$

If frame–floor joint length does not exceed 250 mm, 3 bolts are to be used; for longer joints lengths – 4 bolts.

16.7.12 If ballast bolts passing through keel and wooden floor are used, then the thickness of these floors is to be not less than 3,5 times the diameter of the ballast bolts.

16.8 Frames

16.8.1 Provision has been made for the following types of frames:

- bent frames for sailing and motor-sailing yachts of depth *H* not greater than 3 m and for motor yachts of depth not greater than 2.7 m,
- glued or steel frames,
- glued or steel frames alternated with bent frames – up to three bent frames can be used between two glued or steel frames for sailing yachts and motor-sailing yachts of depth *H* not greater than 3,6 m and for motor yachts of depth *H* not greater than 3 m,
- cut-out frames for plywood plated yachts.

Other types of frames will be considered individually by PRS.

16.8.2 Strengthened frames are to be installed in the mast area:

- for bent frames, the section modulus of the three frames is to be increased by 60 per cent or glued or steel frames are to be installed instead the bent ones,
- for glued, steel or cut-out frames, the section modulus of three glued, or steel frames is to be increased by 50 per cent,
- for glued or steel frames alternated with bent frames, the section modulus of three glued or steel frames is to be increased by 50 per cent.

16.8.3 Joints of cut-out frame parts (for plywood type plating) are to be stronger than the frame itself.

16.9 Bilge Stringers

16.9.1 Bilge stringers for transversally framed yachts are required if:

– bent frames are used exclusively or glued frames alternated with groups of three bent frames are used,
– other wooden frames are used on yachts longer than 10 m,
– steel frames are used and the distance between floors and deck at the midship exceeds 2.4 m.

16.9.2 The cross-sectional area *F* of the bilge stringers in the midship area is to be not less than:

$F = 4L$, [cm^2] – for yachts of length $L \leq 12$ m,
$F = 7L - 36$, [cm^2] – for sailing and motor-sailing yachts of length $L > 12$ m,
$F = 6L - 24$, [cm^2] – for motor yachts of length $L > 12$ m.

Cross sections of the stringers can be reduced outside the midship area down to 70 per cent of the required area at stem and stern.

16.9.3 Two stringers having cross section area equal to 0,6 *F* of the value required in 16.3.2 can be installed instead of the single one.

16.9.4 For steel framing, bilge stringers made of shaped bar are to have the bending section modulus *W* not less than:

$$W = 0{,}6L - 4\ , \text{[cm}^3\text{]} \qquad (16.9.4)$$

16.9.5 Bilge stringers are to have properly strong connections to all the frames.

Steel or wooden brackets are to be installed as joints between stringers and stem, stern or transom. The joints are to be bolted together using the bolts of the diameter *d* not less than:

$$d = 3\sqrt{L}\ , \text{[mm]} \qquad (16.9.5)$$

16.9.6 Bilge stringers on yachts with developable plating are to be designed according to 15.4.5.

If the angle between adjacent plating sheets along the stringer exceeds 150°, then this stringer should also meet the requirements specified in 16.1.

16.10 Deck Stringers

16.10.1 For yachts with transversely stiffened deck, the required deck stringers (shelves) are to have the total cross section area *F* (including the beam cut-out) in the midship area not less than:

$F = 5L$, [cm^2] – for sailing and motor-sailing yachts of length $L \leq 10$m,
$F = 10L - 50$, [cm^2] – for sailing and motor–sailing yachts of length $L > 10$m,
$F = 5L$, [cm^2] – for motor yachts of length $L \leq 12$ m,
$F = 10L - 60$, [cm^2] – for motor yachts of length $L > 12$ m.

The cross section area of deck stringers may be reduced by 25 per cent, when the deck and sides plating is made of plywood, or cold moulded.

Outside the midship area the cross sections of stringers can be reduced at stem and stem or transom down to 75 per cent of the value required above.

16.10.2 Deck stringers are to have properly strong, bolted connections with all the frames. The bolt diameters *d* are to be not less than:

$$d = 2\sqrt{L} \text{, [mm]} \qquad (16.10.2\text{-}1)$$

Steel or wooden brackets are to be installed as joints between shelves and stem or stern. The joints are to be bolted together using the bolts of the diameter *d* not less than:

$$d = 3\sqrt{L} \text{, [mm]} \qquad (16.10.2\text{-}2)$$

16.10.3 For yachts with longitudinal deck structure, deck stringers meeting the requirements of the minimum width according to 15.4.5 are to be installed between the deck and side.

16.10.4 Shroud girders having the cross section area equal to about 75 per cent of cross section of the shelf are to be installed additionally in the mast area. At the ends, the girder cross section can be reduced to 50 per cent of its value in the centre.

The length of the girder is to be not less than the deck breadth in the mast area.

16.10.5 If chain plates are fastened to properly strong structural partitions, then the shroud girders can be dispensed with.

16.11 Beams

16.11.1 The section modulus of beams required in 16.1 should be kept applied in the centre of the stiffening span. At the ends of the beams, the modulus can be reduced to 50 per cent of the required value.

16.11.2 Two beams in the mast area, as well as end beams of the hatches or beams situated at ends of superstructures are to be strengthened as follows:

- if the beam is a part of the partition, its section modulus is to be increased by 50 per cent,
- if the beam is not connected with the partition or has no other support, its section modulus is to be doubled.

For planking deck, the strengthened beams are also to be connected with deck stringers by means of the horizontal brackets (knees).

16.11.3 The distance between deck stringers or distance between deck stringers and hatch coamings or side walls of deckhouse are to be substituted in to formula 16.1 as unsupported length. The distance is to be, however, not less than:

$l = 0{,}7B$ –   for midship area,

$l = 0,5B$ – for fore and aft end, for deckhouse half beams and beams in the midship area.

16.11.4 If the deck is covered exclusively with planks, then strong joints between the beams and shelves are required, e.g. dovetail or pinned joints.

For yachts of L greater than 9 m, also steel diagonals are to be installed as required in 16.12.5.

16.11.5 Regardless of the kind of deck plating, the strengthened beams are to be connected to the frames by means of vertical brackets (knees). The number of pairs n of such brackets is to be not less than:

$$n = 1,5B \qquad (16.11.5\text{-}1)$$

The brackets can be made of forged steel with the cross section area F in the middle of the span not less than:

$$F = 4,4B - 7 \text{ , [cm}^2\text{]} \qquad (16.11.5\text{-}2)$$

or can be made of steel rolled or welded bars with the section modulus W not less than:

$$W = 1,6B - 2,2 \text{ , [cm}^3\text{]} \qquad (16.11.5\text{-}3)$$

The required length l of the bracket arms is to be not less than:

$$l = 0,09B + 0,120 \text{ , [m] – in the midship area,} \qquad (16.11.5\text{-}4)$$

$$l = 0,07B + 0,090 \text{ , [m] – outside the midship area.} \qquad (16.11.5\text{-}5)$$

16.11.6 The vertical brackets (knees) can be dispensed with if structural partitions connected with the beams and frames are installed.

16.12 Steel Stiffeners of Wooden Hull

16.12.1 Steel beams are to meet the requirements specified in 16.1, 16.11.2 and 16.11.3.

The beams are to be connected to steel frames with the use of brackets of the minimum height equal to 2,5 the beam height.

16.12.2 Steel sheerstrake is to be installed on steel beams along the sides. The width b of the sheerstrake is to be not less than:

$$b = 0,020L \text{ , [m] – in the midship area,} \qquad (16.12.2\text{-}1)$$

$$b = 0,016L \text{ , [m] – in the hull end area.} \qquad (16.12.2\text{-}2)$$

Steel plating is to be provided around deckhouses, superstructures and deck hatch coamings. The plating width b is to be not less than:

$$b = 0,06 + 0,004L \text{ , [m]} \qquad (16.12.2\text{-}3)$$

The wooden plating is to be fastened to the beams and to the above mentioned steel plates.

16.12.3 The thickness g of the steel stiffeners and brackets is to be not less than:

$$g = 0{,}9\sqrt{L}\text{, [mm]} \qquad (16.12.3\text{-}1)$$

If zinc coated steel has been used, then:

$$g = 0{,}81\sqrt{L}\text{, [mm]} \qquad (16.12.3\text{-}2)$$

16.12.4 For decks covered exclusively with planks on sailing and motor–sailing yachts of length greater than 9 m, steel diagonal tie plates are required. These plates are to cross in vicinity of masts and are to interconnect the sheerstrakes or/and steel plating around the deckhouses.

When the structure of such deck is exclusively wooden one, the steel diagonal tie plates are to be connected with bolts to the shelves and coaming stringers. The width b of diagonal tie plates is to be not less than:

$$b = 7(L - 5)\text{, [mm], but not less than 40 mm} \qquad (16.12.4)$$

The thickness of steel diagonal tie plates is to be determined according to 16.12.3.

16.12.5 For the yachts specified in 16.12.4, with carvel type planking (smooth planking), the side diagonal strakes, running from chain plates in the bow and stem direction, are required (see as well 15.2.10). The dimensions of strakes cross section are to meet the requirements of 16.12.4.

16.13 Web Frames

16.13.1 For longitudinal framing system of the hull made of plywood or cold moulded, the web frames are to be installed. The recommended web frame spacing s is to be not more than:

$$s = 0{,}05L + 0{,}2\text{, [m]} \qquad (16.13.1)$$

In no case the spacing s is to be greater than:

s = 1,5 m for yachts of $L \le 9$ m,
s = 2,0 m for yachts of $L > 9$ m.

16.13.2 The web frames are to be continuous structures connecting floors, frames and beams. The unsupported lengths l are to be substituted into the formula 16.1. The values, however, are to be not less than:

– distance between bottom axis and bilge turn (for the bottom part of the web frame),
– distance between deck-side edge and bilge turn (for frame part of the web frame),
– half the breadth of deck in the considered place (for deck part of the web frame),

If pillars are installed inside the web frame, then the value l can be reduced accordingly.

17 GENERAL STRENGTH OF WOODEN HULL

17.1 General Remarks

17.1.1 For single–hull, diagonally plated yacht, of length *l* greater than 9 m and plywood plated yacht, of length *l* greater than 15 m the general strength of the hull is to be checked.

17.1.2 The general strength is checked by calculating the hull bending section modulus at the midship.

17.1.3 Checking the general strength of the multi-hull yachts is subject to special agreements.

17.2 Hull Bending Section Modulus

17.2.1 The hull bending section modulus W_k is to be not less than:

$$W_k = 125 L_w^2 B_w \left(C_b + 0{,}7 \right), \text{ [cm}^3\text{]} \qquad (17.2.1)$$

B_w – breadth on waterline, [m],
C_b – block coefficient of the submerged part of the hull.

The value of the bending section modulus W_k may be reduced by 15 per cent for yachts with navigation area **III** or **V**.

17.2.2 The hull section modulus W_m in the transversal section passing by the mast is to be not less then:

$$W_m = 102 J V_{fs} \cos \beta_{fs}, \text{ [cm}^3\text{]} \qquad (17.2.2)$$

J – base of fore sail triangle as defined in Part VII – Masting and Rigging, [m],
V_{fs} – forestay breaking force as defined in Part VII – Masting and Rigging, [kN],
β_{fs} – angle between forestay and mast [degrees].

17.2.3 The formulae given in 17.2.1 and 17.2.2 are valid for the Rule timber (14.3) with fibres laid along the hull.

The cross section areas of structural members made of other sorts of timber or for other arrangement of fibre in wood are to be multiplied by the factor *k*:

$$k = k_s \frac{E_g}{9500} \qquad (17.2.3)$$

k_s – material factor:
- $k_s = 1{,}0$ for solid wood with fibres along the hull,
- $k_s = 0{,}4 \div 0{,}6$ for plywoods (depending on the ratio of layers laid along the hull to the total number of layers);
- $k_s = 0{,}25$ for diagonal plating,

E_g –bending Young's modulus of the timber used, [MPa].

18 PILLARS

18.1 Design Load of Pillars

18.1.1 The design load of a pillar supporting fragment of the deck is to be assumed as force P_p not less than:

$$P_p = 7abh \text{, [kN]} \qquad (18.1.1)$$

a, b – average length and breadth of the supported fragment of the deck, [m],
h – load height acc. to 2.4 and 2.7.

If above the considered pillar there is another pillar and another deck, then the loads of both pillars are to be added.

18.1.2 If above the deck pillar a mast base is installed, then the design load is to be increased by value P_m not less than:

$$P_m = 1{,}8 P_t \text{, [kN]} \qquad (18.1.2)$$

P_t – mast compressing force acc. to Part VII – Masting and Rigging, [kN].

18.2 Strength of Pillars

18.2.1 Under the design load P_p (according to 18.1), the permissible strength of pillars P_N is not to be exceeded:

$$P_N = 10^{-3} \delta_N A \text{, [kN]} \qquad (18.2.1)$$

δ_N – permissible compression stress acc. to the Table 18.2.1.

Table 18.2.1
δ_N values [N/mm^2]

Material of pillars	δ_N [MPa]	
	$\lambda \le 100$	$\lambda > 100$
Carbon steel, stainless steel	$121 - 0{,}44\,\lambda$	$\frac{770\,000}{\lambda^2}$
Aluminium alloy used for masts	$68 - 0{,}396\,\lambda$	$\frac{285\,000}{\lambda^2}$
Hard wood (E_{min} = 12000)	$14{,}05 - 0{,}093\,\lambda$	$\frac{47\,500}{\lambda^2}$
Soft wood (E_{min} = 9000)	$10{,}55 - 0{,}07\,\lambda$	$\frac{35\,500}{\lambda^2}$

λ – slenderness ratio of the pillar,

$$\lambda = \frac{l_p}{i}$$

l_p – pillar span, [mm],
i – radius of inertia, [mm],

$$i = \sqrt{\frac{I}{A}}$$

I – cross section moment of inertia, [mm^4],
A – cross section area, [mm^2].

The wall thickness of tubular and shaped pillars is to be sufficient to prevent local buckling.

18.3 General Remarks

18.3.1 Structural parts of pillar cap and footing are to be made appropriately to the carried load.

The joints are to be designed in a way preventing excessive pressures in steel parts (ie not more than 100 MPa).

18.3.2 Pillars are to be mounted on continuous stiffeners. Heavy loaded pillars are to be mounted on stringers distributing the load to several transversal stiffeners.

18.3.3 The use of laminate pillars is not recommended. If they cannnot be avoided, the pillars strength is not to be greater than the strength of wooden pillars of similar dimensions.