# RULES
# FOR THE CLASSIFICATION AND CONSTRUCTION OF HIGH-SPEED CRAFT

## PART II
## Hull

January
2024

**TEMPORARY RULES**

GDAŃSK

**RULES FOR THE CLASSIFICATION AND CONSTRUCTION OF HIGH SPEED CRAFT**
developed and issued by Polski Rejestr Statków S.A., further referred to as PRS, consist of the following parts:

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

With respect to materials and welding, the requirements specified in the *Rules for the Classification and Construction of Sea-Going Ships*, *Part IX – Materials and Welding*, apply.

*Part II – Hull – January 2024* was approved by the PRS Board on 21 December 2024 and enters into force on 1 January 2014.



* *Polish Register of Shipping means Polski Rejestr Statków S.A., seated in Gdańsk, al. gen. Józefa Hallera 126, 80-416 Gdańsk, Poland,* registered in the Register of Entrepreneurs of the National Court Register, under entry number 0000019880. Polish Register of Shipping, its affiliates and subsidiaries, their respective officers, employees or agents are, individually and collectively, referred to as Polish Register of Shipping or as PRS for short.

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# 1 GENERAL

## 1.1 Application

**1.1.1** These *Hull Construction Rules for High Speed Craft* (hereinafter referred to as the *Rules*) apply to monohull and catamaran high speed crafts, i.e. craft capable of a maximum speed [knots] equal to or exceeding $v_0 = 7.19\ V^{0.1667}$, where $V$ represents displacement corresponding to the design waterline, in [m$^3$].

Typical hull shape for such craft is shown in Fig. 1.1.1.

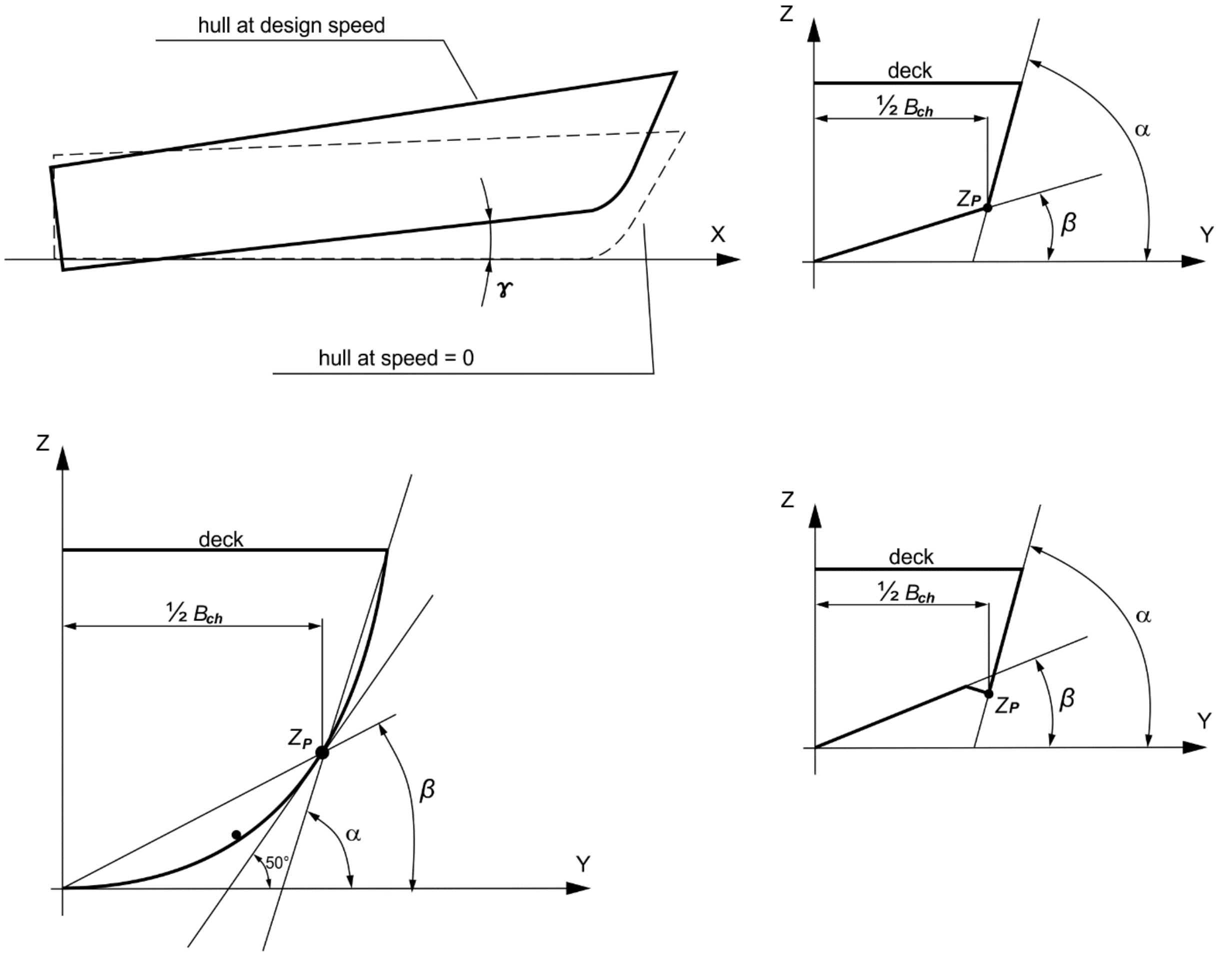



Fig. 1.1.1 Typical hull shapes of high speed craft

**1.1.2** The requirements specified in these *Rules* apply to craft with steel or aluminium-alloy hulls of typical shapes and dimensional proportions.

Craft having atypical shapes or dimensional proportions are subject to PRS consideration in each particular case.

**1.1.3** Craft service with the speed exceeding or equal to $v_0$ in ice conditions is not permitted (for $v_0$ see paragraph 1.1.1).

Where the craft is intended for service in the ice conditions with a speed less than $v_0$, ice strengthening is required to be applied in accordance with Chapter 26 of *Part II – Hull* of the *Rules for the Classification and Construction of Sea-going Ships* or Chapter 21 of *Part II – Hull* of the *Rules for the Classification and Construction of Small Sea-going Ships* (see Chapter 8 hereto). Ice strengthening shall be designed having regard, to the applicable extent, to the requirements of Chapter 7 so that safe craft service be ensured at a speed not less than $v_0$ in no ice conditions.

**1.1.4** Construction elements not included in this part of the rules will be considered by PRS individually.

## 1.2 Symbols and Definitions

### 1.2.1 General

In sub-chapters from 1.2.2 to 1.2.4, symbols and definitions are given associated with the craft hull applied in these *Rules*.

### 1.2.2 General Symbols

*B* – moulded breadth of the craft, [m] - the greatest breadth measured between the outer edges of frames.

$B_1$ – breadth of individual hull of catamaran, [m] – maximum breadth measured between the outer edges of frames of the individual hull outer side and inner side (i.e. the side closer to the catamaran centre plane) – see Fig. 1.2.2.

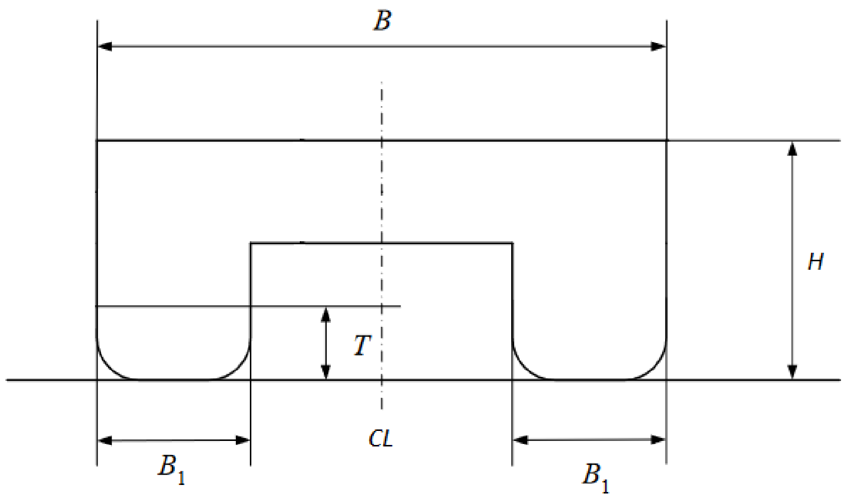



Fig. 1.2.2 Definition of some dimensions of catamaran hull

*D* – displacement of craft, [t] – mass of water, in tonnes, of the volume equal to the volume of the submerged part of hull. Unless specified otherwise, the sea water mass density shall be taken as 1.025 t/m$^3$.

*E* – elasticity (Young) modulus, [MPa] – for steel, E = $2.06 \cdot 10^5$ [MPa], for aluminium alloys, E = 69000 [MPa] shall be taken.

*g* – standard gravitational acceleration, [m/s$^2$] – may be taken as 9.81 m/s$^2$.

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

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

$k$ – material factor – factor dependent on the material yield point – see Chapter 2

$L$ – length of craft – means 96% of the overall length of hull measured on the waterline at 85% of the least moulded depth measured from the top of the keel, or the length from the fore side of the stem to the axis of the rudder stock on that waterline, whichever is greater.

In ships designed with a rake of keel, the waterline on which this length is measured shall be parallel to the design waterline.

$L_{PP}$ – length between perpendiculars, [m] – distance measured between the forward perpendicular and after perpendicular

$LCG$ – longitudinal centre of gravity,

$L_W$ – length of ship measured on waterline corresponding to draught $T$, [m]

$L_0$ – design length of craft, [m] – distance measured on summer load waterline from the fore side of the stem to the rudder stock axis. The adopted value of $L_0$, shall not be taken less than 96% of the overall length of hull measured on the summer load waterline, however need not exceed 97% of that length.

$F.P.$ – forward perpendicular – the perpendicular at the intersection of the summer load waterline with the fore side of the stem.

$B.P.$ – base plane – horizontal plane which crosses amidships the top of a flat keel or the intersection of the inner surface of the plating with the bar keel.

$A.P.$ – after perpendicular – the perpendicular at the centre plane, at distance $L_0$ from $FP$ afterwards.

$C.P.$ – centre plane of craft.

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

$R_e$ – material yield point, [MPa] – see explanation in the Chapter 2.

$V$ – volume of moulded displacement, [m$^3$] – volume of craft body defined by the outer edges of frames at draught $T$.

$x$, $y$, $z$ – co-ordinates of a point in the craft [m] – see Fig. 1.2.3.1.

$\delta$ – block coefficient, [-] - the moulded block coefficient corresponding to the load waterline at the scantling draught:

$$\delta = \frac{V}{L_W B T}$$

*for catamaran* $B=2B_1$.

$v$ – design craft speed, [knot].

$v_0$ – threshold speed value above which the craft is considered as a high speed craft (see paragraph 1.1.1), [m/s].

### 1.2.3 Co-ordinate System

**1.2.3.1** In these *Rules*, the co-ordinate system shown in Fig. 1.2.3.1 has been assumed for craft; the following reference planes have been assumed for the system: base plane, centre plane and midship section.

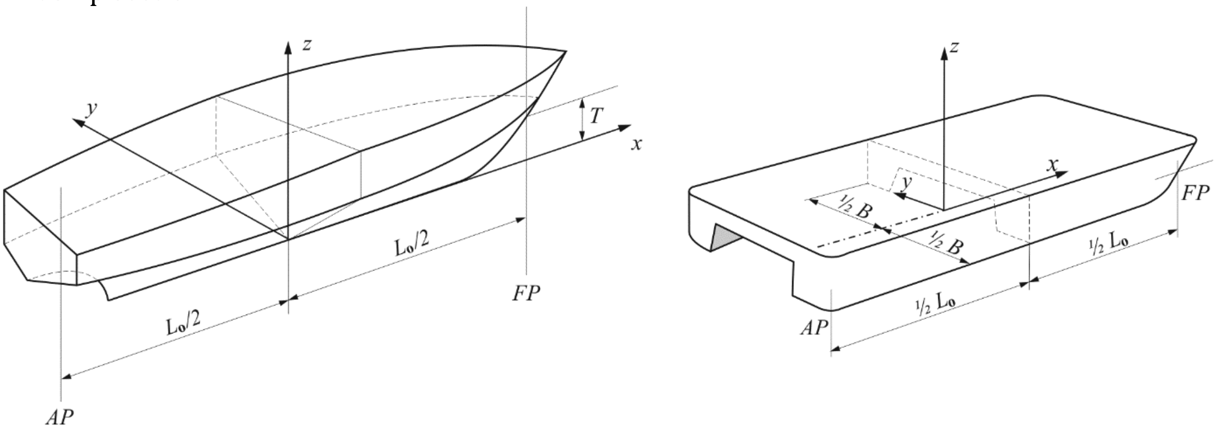



Fig. 1.2.3.1 Co-ordinate system

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

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

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

### 1.2.4 General Definitions and Definitions of Structural Elements

Provisions of sub-chapters 1.2.4 and 1.2.5 of *Part II – Hull* of the *Rules for the Classification and Construction of Sea-going Ships* apply within the scope applicable to high speed craft.

The following supplementary definitions have been introduced:

*Non-displacement mode* – craft motion with a speed sufficient to make the craft weight fully or partially equilibrated by the dynamic pressure on the craft bottom. Thus, in particular it applies for crafts operating in planning or semi-planing modes and typically considers Froude number $F_N \geq 0.5$.

*Displacement mode* – craft motion with a speed lesser than in planing state; the craft weight is fully or predominantly equilibrated by the craft bouyancy. It applies to all crafts designed for operating in that mode, and crafts that are not operating in non-displacement mode.

*Patrol craft* – a patrol craft which may be operated by the harbour, police, customs, military authorities, search and rescue or similar organisations.

*Wind Farm Service Vessel* – a craft which is designed for duties specific to the maintenance and support of offshore wind farms.

*Workboat* – a general service craft which may be adapted for duties such as line handling, towing, tender, survey, fishing, oil spill recovery, or diving support.

*Pilot launch* – a craft designed to come alongside ship whilst at sea to embark or disembark pilots.

*Cargo craft* – unassisted high speed cargo craft which do not proceed in the course of their voyage more than eight hours at operational speed from a place of refuge when fully laden.

*Passenger Category A and B* – the definition as given in Part I of Rules for the Classification and Construction of High Speed Craft.

## 1.3 Survey and Classification

**1.3.1** Survey and classification are performed in accordance with the regulations specified in *Part II – Hull* of the *Rules for the Classification and Construction of Sea-going Ships* within the scope applicable to high speed craft.

**1.3.2** The Owner of craft under design shall determine the design allowable value of vertical acceleration in its centre of gravity (not less than the value specified in paragraph 5.2) or maximum design speed and the significant wave height that those values are obtained.

This relation forms an *Annex* to the *Certificate of Class* and is also entered in the *Loading Manual*.

**1.3.3** More stringent limitations than those applicable to operating areas I, II or III are subject to PRS consideration in each particular case and are entered in the *Annex* to the *Certificate of Class*.

## 1.4 Technical Documentation

**1.4.1** The requirements for technical documentation specified in *Part II – Hull* of the *Rules for the Classification and Construction of Sea-going Ships* apply within the scope applicable to high speed craft.

# 2 METALLIC MATERIALS AND CORROSION PROTECTION

## 2.1 General

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

## 2.2 Hull Structural Steel

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

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

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

**Table 2.2.2**
**Hull steel characteristics**

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

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

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

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

$$k = \frac{R_e}{235} \tag{2.2.4}$$

## 2.3 Aluminium Alloys

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

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

$$k_{al} = \frac{R_{mal} + R_{eal}}{635} \tag{2.3.2}$$

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

The symbols have the following meaning:

$R_{eal}$ – aluminium alloy yield point, considered as 0.2% offset yield stress [MPa];
$R_{mal}$ – aluminium alloy tensile strength, [MPa].

For welded aluminum structures, the expected strength characteristics of aluminium alloys after welding shall be assumed, i.e. for series 5000 alloys – in soft condition (without strain hardening), and for series 6000 alloys – in the condition after natural ageing irrespective of their supply condition.

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

**2.3.4** When determining material factor $k_{al}$ for the post-weld values of $R_{eal}$ and $R_{mal}$ , their values shall not be taken greater than specified in Table 2.3.4-1 – for rolled products and in Table 2.3.4-2 – for extruded products of both open and closed sections. The symbols are consistent with those used in *Part IX – Materials and Welding*.

**Table 2.3.4-1**
**Minimum mechanical properties**
**of post-weld aluminium alloy rolled products**

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

**Table 2.3.4-2**
**Minimum mechanical properties of post-weld aluminium alloy extruded products (sections)**

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

## 2.4 Corrosion protection

**2.4.1** Corrosion additions for hull structural steel elements shall be determined in accordance with the requirements specified in sub-chapter 2.5 of *Part II – Hull* of the *Rules for the Classification and Construction of Small Sea-going Ships* or sub-chapter of *Part II – Hull* of the *Rules for the Classification and Construction of Sea-going Ships,* whichever is applicable.

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

# 3 STRUCTURE PARTICULARS

## 3.1 General

As regards such issues as:
– rounding of member scantlings,
– span of primary supporting members and stiffeners,
– effective flange of stiffeners or girders,
– effective cross-sectional area of stiffener web or of girder web,
– calculation of section modulus of stiffener or girder,
– details of welded structures,
– ensuring structure continuity,
– openings in structural members,
– construction of T-section primary supporting members,
the requirements of Chapter 3 of *Part II – Hull* of the *Rules for the Classification and Construction of Sea-going Ships* apply.
The requirements specified in Chapter 7 shall also be fulfilled.

# 4 JOINTS OF STRUCTURAL ELEMENTS

## 4.1 General

Requirements concerning the types and sizes of welds, welded joints of some structural elements, riveted joints as well as steel/aluminium alloy joints are specified in this Chapter.

**4.1.1** The requirements of Chapter 4 in *Part II – Hull* of the *Rules for the Classification and Construction of Sea-going Ships* within the scope applicable to high speed craft, supplemented by the requirements specified in the following sub-chapters from 4.2 to 4.6 as well as Chapter 7, shall apply.

## 4.2 Butt Joints

All butt joints shall be made with full penetration.

Other requirements are identical with those specified in sub-chapter 4.2.1 of *Part II – Hull* of the *Rules for the Classification and Construction of Sea-going Ships.*

## 4.3 Fillet Welds

### 4.3.1 Fillet Weld Thickness

**1.1.1.1** Fillet weld thickness shall be determined in accordance with the requirements specified in 4.2.3.1 of *Part II – Hull* of the *Rules for the Classification and Construction of Sea-going Ships* within the scope applicable to high speed craft.

### 4.3.2 Application of Double Continuous Welds

**4.3.2.1** It is recommended that in any joints of structural elements where fillet welds are permitted double continuous welds be applied.

**4.3.2.2** Double continuous welds are required for welding the system of stiffeners and girders to the bottom and sides in those areas where impact pressure defined in sub-chapters 5.3.2 and 5.3.3 occur.

Other cases where double continuous welds are required are specified in sub-chapter 4.2.3 of *Part II – Hull* of the *Rules for the Classification and Construction of Sea-going Ships*.

### 4.3.3 Other Welds than Double Continuous

**4.3.3.1** Other welds than double continuous, e.g. double staggered welds, chain welds, scallop welds, single continuous welds or single intermittent welds are permitted in other cases than those specified in paragraph 4.3.2.2.

## 4.4 End Connections of Structural Members

### 4.4.1 General

**4.4.1.1** The requirements specified in sub-chapter 4.3 of *Part II – Hull* of the *Rules for the Classification and Construction of Sea-going Ships* and paragraph 7.2.3 of this Publication shall be fulfilled.

Lap welds shall, however, be avoided. The possibility for application of such joints is subject to PRS consideration in each particular case.

### 4.4.2 End Connections of Primary Members

**4.4.2.1** Primary member ends shall be so connected to their supporting structures that the cross-section area of the welds be not less than the cross-section area of such a member (irrespective of brackets).

The cross-section area of fillet welds shall be calculated as the product of the weld length and its thickness.

### 4.4.3 Connections of Plating Stiffeners to Primary Members

**4.4.3.1** Cross-section areas of welds (see paragraph 4.4.2.1) connecting plating stiffeners to girders shall not be less than the value determined in accordance with formula 6.3.1.1-2.

To fulfil this condition, it may be reasonable to reinforce the connections by means of connection lugs (see paragraph 4.3.7 in *Part II – Hull* of the *Rules for the Classification and Construction of Sea-going Ships*).

### 4.5 Riveted or Screw Joints

Particulars concerning riveted joints shall be included in the technical documentation submitted to PRS for approval.

**4.5.1** PRS may require that the strength of proposed riveted joints be verified by laboratory tests whose scope is subject to PRS agreement in each particular case.

**4.5.2** Riveted or screw joints of structural elements made of different materials shall be so effected that the possibility for galvanic corrosion occurrence be precluded.

Riveted or screw joints are subject to PRS consideration in each particular case.

### 4.6 Bonded Joints Steel/Aluminium Alloy

Joints made by means of special fasteners (made using e.g. explosion method) shall fulfil the requirements specified in paragraph 4.4.1 of *Part II – Hull* of the *Rules for the Classification and Construction of Small Sea-going Ships*.

## 5 DESIGN LOADS FOR MONO-HULL AND CATAMARAN

### 5.1 Vertical motions

#### 5.1.1 Parameters to determine the design loads

**5.1.1.1** The Froude number $F_N$ is to be calculated as follows:

$$F_N = \frac{0.507v}{\sqrt{gL_0}} \qquad (5.1.1.1)$$

**5.1.1.2** The wave coefficient $C_w$ in meters, should be calculated according to the following equation:

$$C_w = 0.0795L_0(\delta + 0.2)^{0.3}e^{-0.0045L_0} \qquad (5.1.1.2)$$

#### 5.1.2 Relative vertical motion

**5.1.2.1** The relative vertical motion is to be calculated according to the following equation:

$$S_A = C_{W,min}\left(1 + \frac{k_r}{\delta + 0.2}\left(0.97\frac{x}{L_0} + 0.515 - x_m\right)^2\right) \qquad (5.1.2.1.)$$

where:

$k_r$ – factor dependent on the hull form equal to:

2.25 for mono-hull crafts in the non-displacement mode,

1.95 for mono-hull crafts in the displacement mode,

2.55 for catamarans, [-];

$$C_{W,min} = \frac{C_w}{k_m}$$

$$k_m = 1 + \frac{k_r(0.5 - x_m)^2}{\delta + 0.2}$$

$x$ – longitudinal coordinate of a point in the craft, [m] – see Fig. 1.2.3.1;

$L_0$ – rule length, as defined in 1.2.2;

$x_m = 0.45 - 0.6\,F_n$, but not less than 0.2;

$F_N$ – Froude number as defined in 5.1.1.1 calculated for $v_m = 2/3\,v$, where $v$ is the design speed.

## 5.2 Vertical acceleration

For Froude number $F_N$ values higher than 1.75, the accelerations are to be specially considered with consultation with PRS.

### 5.2.1 Vertical acceleration in the non-displacement mode for mono-hull craft

The vertical acceleration in the non-displacement mode for mono-hull craft at the LCG in  is to be taken as:

$$a_v = 55.58\,\gamma L_1 \left(\frac{h_{1/3}}{B_W} + 0.084\right)(5 - 0.1\beta)F_N^2 g 10^{-3}, \qquad \left[\frac{m}{s^2}\right] \qquad (5.2.1)$$

where:

$h_{1/3}$ – significant wave height, [m], depends on the area of navigation (see 3.4.3.2 of *Part I of Rules for the Classification and Construction of High Speed Crafts*), at the same time $h_{1/3}/B_W$ should but not taken as less than 0.2 (see Table 5.2.1);

**Table 5.2.1**
**Significant wave height**

| Area of navigation | $h_{1/3}$ [m] |
|---|---|
| I | 3.0 |
| II | 1.4 |
| III | 1.0 |

$\beta$ – deadrise angle [$^0$], but not to be taken greater than $30^0$;

$\gamma$ – running trim angle [$^0$], but not to be taken less than $3^0$;

$B_W$ – breath of the hull at the LCG measured at the waterline [m];

$L_1 = \frac{1.031 L_0 B_c^3}{B_W D}$, on the same time $\frac{L_0}{B_W}$ should be considered not less than 2.91;

$B_{ch}$ – breadth of hull between the chines or bilge tangential points at LCG, as appropriate, [m] (see Figure 1.1.1).

### 5.2.2 Vertical acceleration in the non-displacement mode for catamaran

The vertical acceleration in the non-displacement mode for catamaran at the LCG in  is to be taken as:

$$a_v = \frac{171.9 L_0}{D}\left(B_M h_{\frac{1}{3}} + 0.084 B_M^2\right)(5 - 0.1\beta)F_N^2 g 10^{-3}, \qquad \left[\frac{m}{s^2}\right] \qquad (5.2.2)$$

where:

$h_{1/3}, \beta$ - parameters as defined in 5.2.1;

$B_M$ – total breadth of hulls at LCG at the waterline, equal to sum of breadths of hulls [m].

### 5.2.3 Vertical acceleration in the displacement mode

The vertical acceleration in the displacement mode for all type of crafts at the LCG in is to be taken as:

$$a_v = \left(1.217F_N + \frac{33}{L_0}\right)g, \qquad \left[\frac{m}{s^2}\right] \tag{5.2.3}$$

### 5.2.4 Vertical acceleration at any given location

The vertical acceleration at distance $x_W$ from the aft end along the hull should be calculated as follows:

$$a_{v,x} = a_v\left(1 - 0.31\frac{x - x_{LCG}}{L_0} + 1.656\left[\left(\frac{x}{L_0}\right)^2 + 1.062\frac{x - x_{LCG}}{L_0} - \left(\frac{x_{LCG}}{L_0}\right)^2\right]\right) \tag{5.2.4}$$

where:

$x$ – longitudinal coordinate of a point in the craft, [m] – see Fig. 1.2.3.1;

$x_{LCG}$ – the position of LCG in the coordinate system given in the Fig. 1.2.3.1;

$a_v$ – vertical acceleration at LCG as calculated according to 5.2.1 – 5.2.3.

## 5.3 Pressure Acting on Shell Envelope for mono-hull and catamaran

### 5.3.1 General

In sub-chapter 5.3 are provided formulae for determining design pressures acting on the craft hull and superstructures for craft in displacement and non-displacement modes.

The example of pressure distribution is presented in Figure 5.3.1, where pressures $p_1$ - $p_5$ should be determined according to 5.3.2 – 5.3.4.

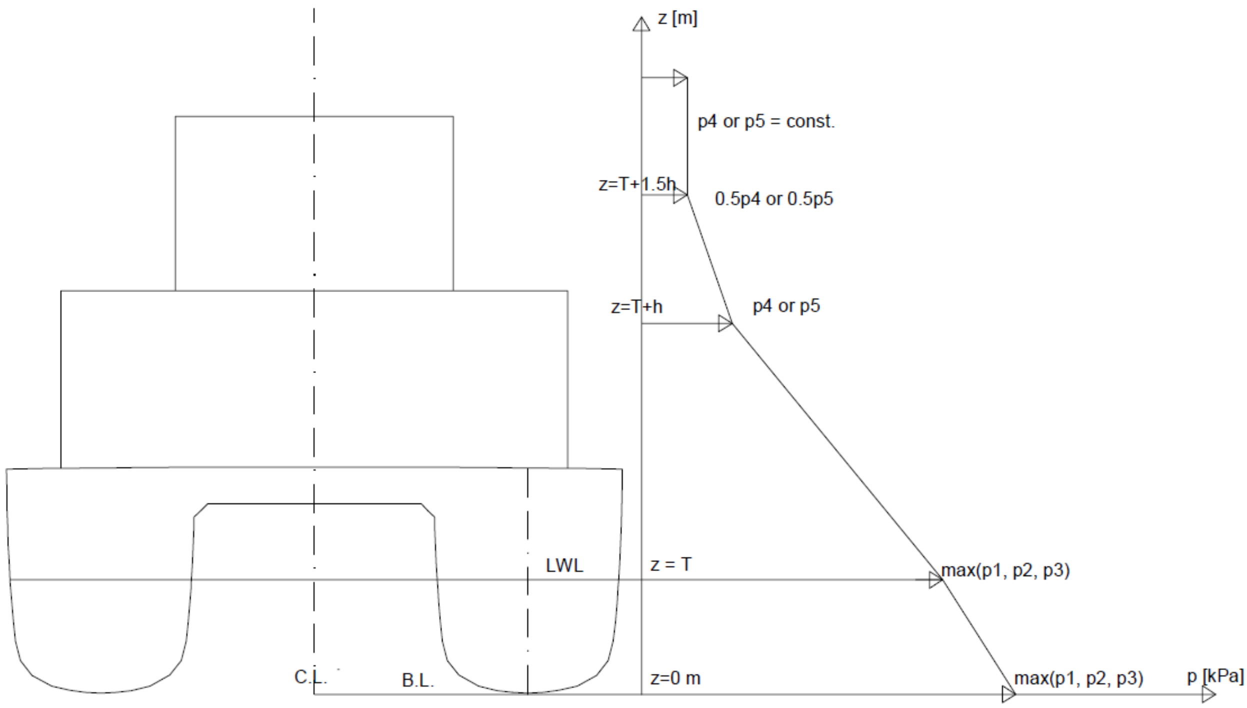



Fig. 5.3.1 Example of pressure distribution on the cross-section of a catamaran hull.

### 5.3.2 Pressure acting on the shell plating up to the operating waterline for displacement and non-displacement mode

**5.3.2.1** Pressure acting on the shell plating up to the operating waterline should be determined as greater from the following $p_1$, $p_2$ and $p_3$:

$$p_1 = 10\left[(T_a - (z - z_k)) + \left(k_z + \frac{(1-k_z)(z-z_k)}{T_a}\right)S_A\right], \qquad [kPa] \qquad (5.3.2.1)$$

$$p_2 = 10\left[(T_a - (z - z_k)) + 1.083\left(\frac{2x}{L_0} + 0.031\right)\sqrt{L_0}\right], \qquad [kPa] \qquad (5.3.2.2)$$

$$p_3 = 10\left[(T_a - (z - z_k)) + 1.015 f_L \sqrt{L_0}\right], \qquad [kPa] \qquad (5.3.2.3)$$

where:

$z$ – vertical distance from the baseline to the point where pressure is calculated, [m];

$T_a$ – local draught measured from the underside of the keel to the operating waterline at the position of consideration, [m];

$z_k$ – vertical distance from the baseline to the underside of the keel, [m];

$k_z = e^{-6.094\frac{T_a}{L_0}}$

$S_A$ – relative vertical motion as defined in 5.1.2.1;

$x$ – longitudinal coordinate of a point in the craft, [m] – see Fig. 1.2.3.1;

$f_L$ – factor equal to:

0.6 for $L_0 < 58m$,

$1.5 - 0.0155L_0$ for $58m \le L_0 \le 78m$,

0.3 for $L_0 > 78m$.

**5.3.2.2** The pressure determined according to 5.3.2.1 should be multiplied by factor equal to 1.0 for passenger CATEGORY A and cargo crafts, 1.1 for passenger CATEGOTY B, 1.2 for patrol ships and 1.25 for pilot ships.

### 5.3.3 Pressure acting on the exposed decks in the displacement mode

**5.3.3.1** Pressure acting on the exposed decks in the displacement mode should be determined as follows:

$$p_4 = k_t k_L (6 + 0.0103L_0)(1 + 0.304F_N) + p_0, \qquad [kPa] \qquad (5.3.3.1)$$

where:

$k_L$ – is the location coefficient equal to:

1.0 for $-0.5L_0 \le x \le 0.38L_0$,

1.25 for $0.38L_0 < x \le 0.425L_0$,

1.5 for $0.425L_0 < x \le 0.5L_0$.

$k_t$ – factor equal to:

1.0 for passenger CATEGORY A and cargo crafts, 1.1 for passenger CATEGORY B,

1.2 for patrol ships and

1.25 for pilot ships.

$$p_0 = \frac{0.7 + 0.0825L_0}{H - T}$$

$p_0$ should not be taken greater than 3 kPa.

### 5.3.4 Pressure acting on the exposed decks in the non-displacement mode

**5.3.4.1** Pressure acting on the exposed decks in the non-displacement mode should be determined as follows:

$$p_5 = k_t k_L (5 + 0.0103L_0)\left(1 + \frac{0.5a_v}{g}\right) + p_0, \qquad [kPa] \qquad (5.3.4.1)$$

where:

$k_L, p_0$ – are defined in 5.3.3.1;

$a_v$ – vertical acceleration as defined in 5.2, taken no less than $g$ but not be taken greater than $4g$;

$k_t$ – parameters as specified in 5.3.3.1.

### 5.3.5 Pressure acting on the shell plating above the operating waterline

**5.3.5.1** The pressure on the waterline should be determined as given in 5.3.2.1.

**5.3.5.2** The pressure on the distance $h$ above the waterline should be taken as $p_4$ or $p_5$, as defined in 5.3.3 and 5.3.4, whatever is applicable.

**5.3.5.3** The pressure on the distance $1.5h$ above the waterline should be taken as $0.5p_4$ or $0.5p_5$, as defined in 5.3.3 and 5.3.4, whatever is applicable.

**5.3.5.4** The pressures between waterline and distance $h$ above the waterline should be determined as linear interpolation between pressures determined according to 5.3.5.1 and 5.3.5.2.

**5.3.5.5** The pressures between distance $h$ above the waterline and distance $1.5h$ above the waterline should be determined as linear interpolation between pressures determined according to 5.3.5.2 and 5.3.5.3. The pressure above the distance $1.5h$ above the waterline should be taken equal to value obtained according to 5.3.5.3.

**5.3.5.6** The distance $h$ related to points 5.3.5.2-5.3.5.5 should be calculated as follows:

$$h = 2S_A, \qquad [m] \qquad (5.3.5.6)$$

where:

$S_A$ – relative vertical motion as defined in 5.1.2.1.

## 5.4 Impact pressures due to bottom slamming for mono-hull and catamaran

### 5.4.1 Impact pressures for the displacement mode

**5.4.1.1** The bottom impact pressure for the crafts in displacement mode should be determined according to the following:

$$p_{i1} = 1.015 k_t k_i \left(19 - 2559 \left(\frac{T_i}{L_0}\right)^2\right) \sqrt{L_0 v}, \qquad [kPa] \qquad (5.4.1.1)$$

where:
$k_i$ – coefficient, see Fig. 5.4.1.1, equal to 0.09 at $x \geq 0.5L_0$, 0.18 for $x = 0.40L_0$, 0.18 for $x = 0.29L_0$ and 0.0 for $x \leq -0.02L_0$, intermediate values shall be determined by linear interpolation;

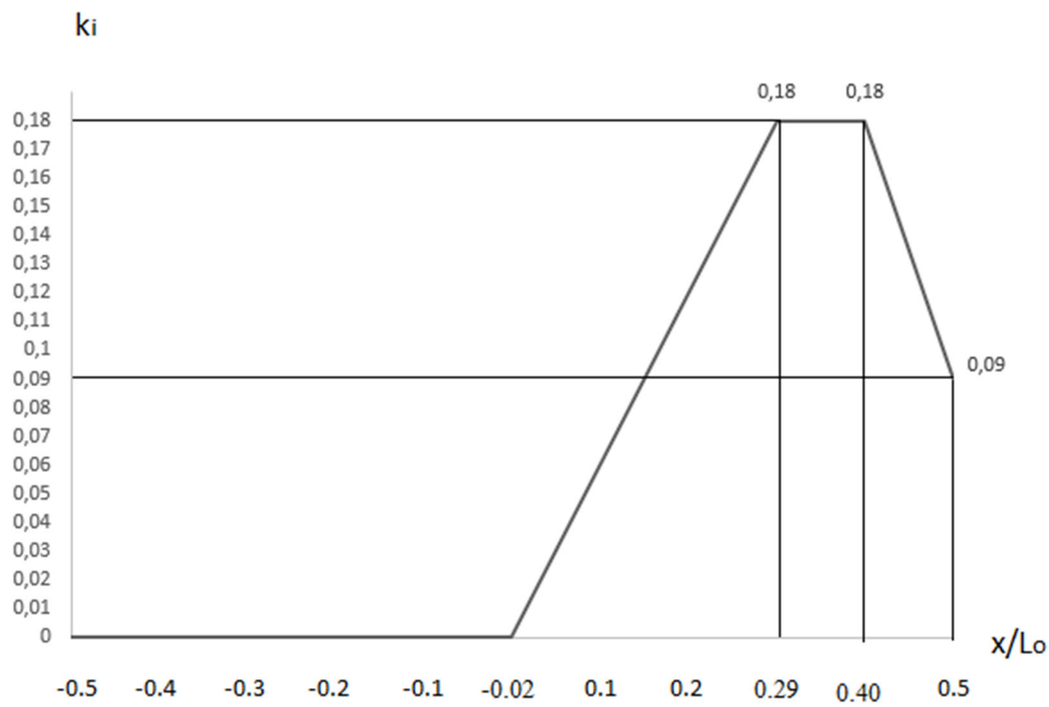



Fig. 5.4.1.1 Coefficient $k_i$

$T_i$ – draught of the ship equal to $T_a$ as specified in 5.3.2.1, but not greater than $0.0825L_0$;

$k_t$ – parameter as specified in 5.3.3.1.

The calculated pressure should be taken not less than $p_{i5}$ calculated according to 5.4.3.3.

**5.4.1.2** The impact pressure for $0.29L_0 \leq x \leq 0.40L_0$ determined according to 5.4.1.1, not need to be taken greater than $p_{i4}$ determined according to 5.4.3.1.

**5.4.1.3** The side shell impact pressure shall be taken equal to $p_{i1}$ at the operating waterline, reducing to $0.4p_{i1}$ on the exposed deck. The intermediate values are to be calculated using linear interpolation.

### 5.4.2 Impact pressures for the non-displacement mode

**5.4.2.1** The bottom impact pressure for the crafts in non-displacement mode should be determined according to the following:

$$p_{i2} = 0.97k_t \frac{k_d D k_{i2}\left(1+\frac{a_v}{g}\right)}{L_0 d_g}, \qquad [kPa] \qquad (5.4.2.1)$$

where:
$k_{i2}$ – coefficient, see Fig. 5.4.2.1, equal to 0.5 at $x \geq 0.5L_0$, 1.0 for $x = 0.24L_0$, 1.0 for $x = -0.02L_0$ and 0.5 for $x \leq -0.53L_0$, intermediate values shall be determined by linear interpolation

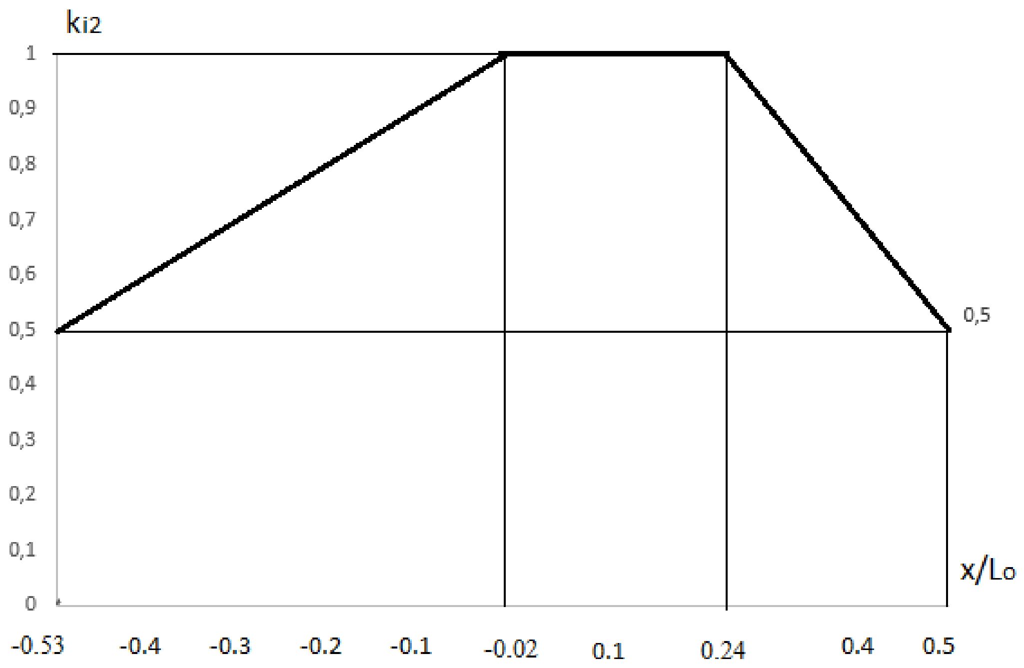



Fig. 5.4.2.1 Coefficient $k_{i2}$

$k_d$ – hull form factor equal to 54 for mono-hull crafts and 40.5 for catamarans;

$a_v$ – vertical acceleration as defined in 5.2;

$d_g$ – for crafts with chines equal to support grith between chines; for crafts without chines equal to support girth between tangential points (see Figure 5.4.2.1) in points within that area and girth distance between waterlines for points between tangential points and design waterline [m];

$k_t$ – parameter as specified in 5.3.3.1.

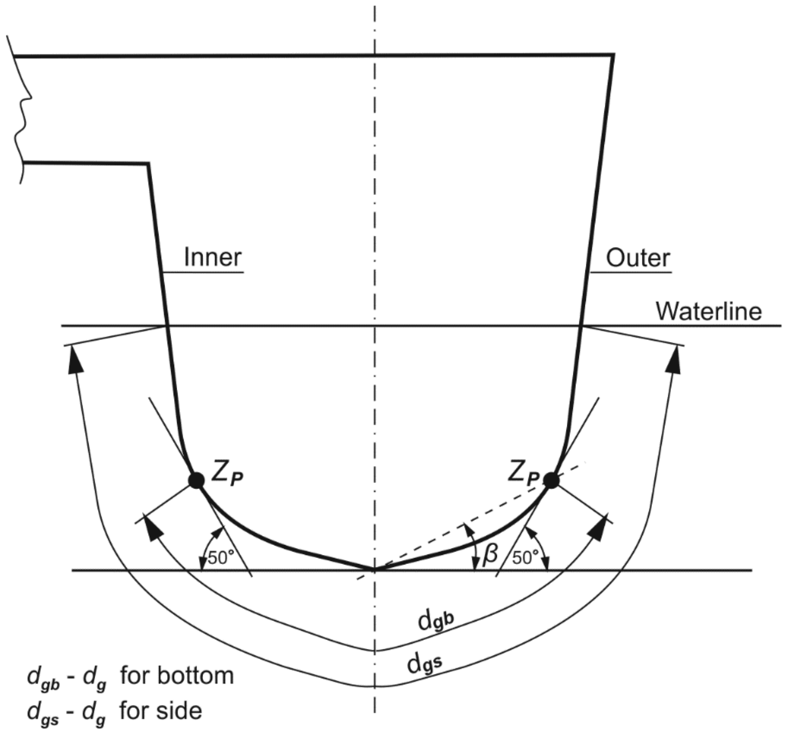



Figure 5.4.2.1 Definition of support grith.

**5.4.2.2** The side impact pressure for the crafts in non-displacement mode should be determined according to the following:

$$p_{i3} = p_{i2}\frac{\tan(40-\beta)}{\tan(\alpha-40)}, \qquad [kPa] \tag{5.4.2.2}$$

where:

$\alpha$ – mean deadrise angle of side plating at local section [$^0$], $\alpha - 40$ should not be less than $10^0$ (see Figure 1.1.1);

$\beta$ – mean deadrise angle of bottom plating at local section [$^0$], $40 - \beta$ should not be less than $10^0$ (see Figure 1.1.1);

$p_{i2}$ – pressure as determined by 5.4.2.1.

The calculated $p_{i3}$ should not be taken greater than $p_{i2}$ and is to be taken constant from the chine to a point on a half distance between the chine and waterline, or exposed deck if is reached first.

### 5.4.3 Bow slamming and fore part impact pressure

**5.4.3.1** Bow slamming and fore part impact pressure for displacement mode at x=0.5$L_0$ should be taken as:

$$p_{i4} = 1.031k_t k_f L_0(0.8+0.913F_N)^2, \qquad [kPa] \tag{5.4.3.1}$$

where:

$k_f$ – forebody impact pressure factor, for mono-hull crafts equal to 0.89 and for catamarans equal to 1.0;

$k_t$ – parameter as specified in 5.3.3.1.

**5.4.3.2** Bow slamming and fore part impact pressure for displacement mode at $x = 0.40L_0$ should be taken equal to $p_{i1}$ calculated according to 5.4.1.1.

**5.4.3.3** Bow slamming and fore part impact pressure for displacement mode at $x = 0.24L_0$ should be taken equal to:

$$p_{i5} = k_t 10\left[\left(k_z + \frac{(1-k_z)(z-z_k)}{T_a}\right)S_A\right], \qquad [kPa] \qquad (5.4.3.3)$$

where $z, z_k, k_z$ and $T_a$ are defined as given in 5.3.2.1, whereas $k_t$ is parameter as specified in 5.3.3.1.

**5.4.3.4** Bow slamming and fore part impact pressure for displacement mode between x=-0.53$L_0$ and $x = 0.24L_0$ should be taken equal to 0.

**5.4.3.5** Bow slamming and fore part impact pressure for displacement mode for intermediate values are to be considered based on the linear interpolation considering values calculated according to 5.4.3.1 – 5.4.3.3.

**5.4.3.6** The side shell impact pressure for displacement model should be taken as determined according to 5.4.3.1 – 5.4.3.5 on the chine or the operating waterline for rounded hull form, reducing linearly to 40% of that value for weather deck.

**5.4.3.7** Bow slamming and fore part impact pressure for non-displacement mode at FP should be taken as greater from $p_{i3}$ as determined according to 5.4.2.2 and $p_{i4}$ determined according to 5.4.3.1, where $k_f$ should be taken equal to 0.94 for mono-hull crafts and 1.0 for catamarans.

**5.4.3.8** Bow slamming and fore part impact pressure for non-displacement mode at $x = 0.24L_0$ should be taken equal to $p_{i3}$ determined according to 5.4.2.2, where $k_f$ should be taken equal to 0.94 for mono-hull crafts and 1.0 for catamarans.

**5.4.3.9** Bow slamming and fore part impact pressure for non-displacement mode at $x = -0.02L_0$ should be taken equal to $p_{i5}$ determined according to 5.4.3.3.

**5.4.3.10** Bow slamming and fore part impact pressure for non-displacement mode between x=-0.53$L_0$and $x = -0.02L_0$ should be taken equal to 0.0.

**5.4.3.11** Bow slamming and fore part impact pressure for non-displacement mode for intermediate values are to be considered based on the linear interpolation considering values calculated according to 5.4.3.7 – 5.4.3.9.

**5.4.3.12** The side shell impact pressure for non-displacement model should be taken as determined according to 5.4.3.7 – 5.4.3.11 on the chine or the operating waterline for rounded hull form, reducing linearly to 30% of that value for weather deck.

### 5.4.4 Impact loads acting on the cross-deck structure of catamarans

**5.4.4.1** The sufficient clearance should be provided between cross-deck structure of catamaran and water level to avoid excessive impact loads.

**5.4.4.2** In the determination of clearance the following variables should be considered: relative motion in waves, the wave height and the bow sinkage.

**5.4.4.3** The clearance submitted by the designer must be validated using calculations based on the accepted theories, model tests or full scale measurements for similar structures in operation. The clearance value will be considered by PRS in case by case matter.

**5.4.4.4** If sufficient clearance will be not provided, the impact loads due to cross-deck slamming should be calculated according to the following equation (but not less than 0):

$$p_{ic} = k_t k_{ic} k_{cd} v_R v \left(1 - \frac{d_{ag}}{1.29\, h_{1/3}}\right), \qquad [kPa] \qquad (5.4.4.4)$$

where:
$k_{ic}$ – is the longitudinal distribution factor, see Fig. 5.4.4.4-1, taken as 1.0 for $x \leq 0.24L_0$ and 2.0 for $x \geq 0.5L_0$, whereas intermediate values to be determined by linear interpolation;

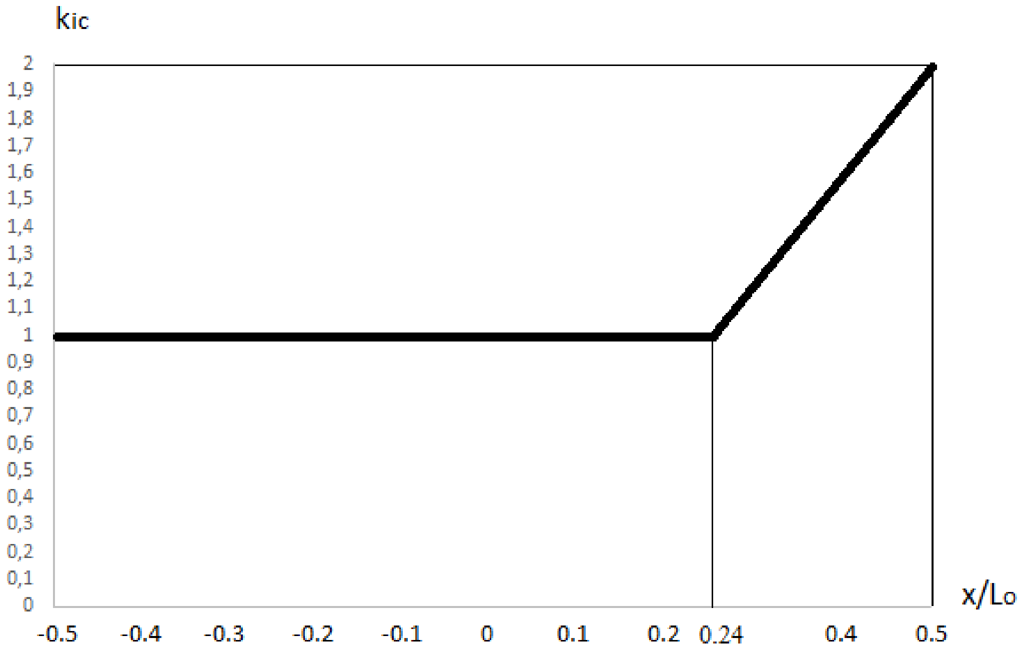



Fig. 5.4.4.4-1 Coefficient $k_{ic}$

$k_{cd}$ – coefficient equal to 0.17 in region where cross-deck structure is supported by structure of portside and starboard side hulls and 0.33 in region where cross-deck structure is not supported by structure of portside and starboard side hulls;

$k_t$ – parameter as specified in 5.3.3.1;

$v_R$ – relative vertical speed of the craft in the moment of wave impact on cross-deck structure, if unknown, to be determined as given in 5.4.4.5;

$d_{ag}$ – air gap distance defined as distance between cross-deck structure and operational waterline (see Figure 5.4.4.4-2);

$h_{1/3}$ – significant wave height as defined in 5.2.1.

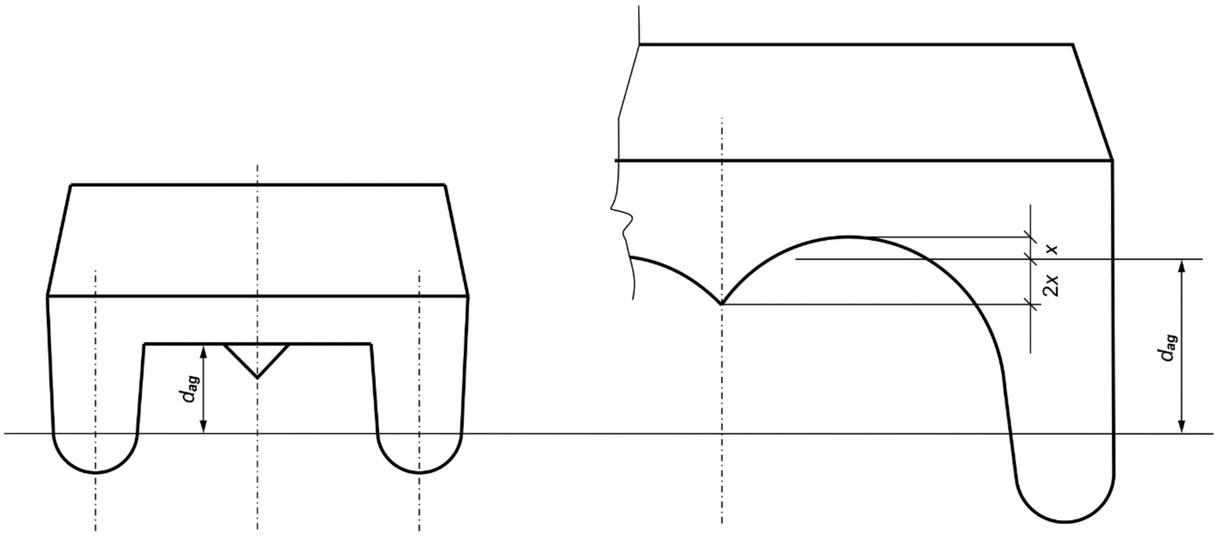



Fig. 5.4.4.4-2 Air gap distance definition.

**5.4.4.5** If unknown, the relative vertical speed of the craft in the moment of wave impact on cross-deck structure is to be determined according to the following equation:

$$v_R = \frac{7.88h_{\frac{1}{3}}}{\sqrt{L_0}} + 2, \qquad [knots] \qquad (5.4.4.5)$$

where:

$h_{1/3}$ – significant wave height as defined in 5.2.1.

### 5.4.5 Pressures acting on superstructures

**5.4.5.1** The design pressure for plating for deckhouses, bulwarks and superstructures to be determined as follows:

$$p_{ds} = k_1 p_d, \qquad [kPa] \qquad (5.4.5.1)$$

where:

$p_d$ – $p_4$ or $p_5$, whatever is applicable, according to 5.3.3.1 or 5.3.4.1;

$k_1$ – coefficient equal to:

1.25 for deckhouse and superstructure fronts on upper deck for $0.5L_0 \geq x \geq 0.15L_0$;
1.15 for deckhouse and superstructure fronts on upper deck for $0.15L_0 > x \geq -0.53L_0$;
1.0 for deckhouse and superstructure fronts above the lowest tier;
0.8 for superstructure sides;
0.5 elsewhere.

**5.4.5.2** The design pressure for windows toughened by safety glass to be determined as maximum from the following:

$$p_{dw1} = k_2 k_3 k_4 p_d, \qquad [kPa] \qquad (5.4.5.2-1)$$

$$p_{dw2} = k_2 k_t (10 + 0.0412L_0), \qquad [kPa] \qquad (5.4.5.2-2)$$

$p_d$ – $p_4$ or $p_5$, whatever is applicable, according to 5.3.3.1 or 5.3.4.1;

$k_2$ – factor equal to:

2.0 for the lowest tier of unprotected front,
1.5 for superstructure fronts above the lowest tier,
1.0 for superstructure sides,
0.67 elsewhere;

$k_3$ – factor equal to:

$0.67 + 0.32\left(\frac{x}{L_0} - 0.5\right)$ for $-0.5L_0 \leq x \leq 0.01L_0$,
0.67 elsewhere.

$k_4 = 1 - (d - (H - T))/d$;

$k_t$ – parameter as specified in 5.3.3.1.

### 5.4.6 Pressures acting on bulkheads

**5.4.6.1** The design pressure for watertight bulkheads and tank bulkheads should be determined as given in 14.3.2 of *Part 2 of Rules for the Classification and Construction of Small Sea-going Ships* and in 16.2.4.1 of *Part II of the Rules for the Classification and Construction of Sea-going Ships.*

### 5.4.7 Pressures acting on deck area assigned for cargo

**5.4.7.1** The pressures acting on cargo deck should be calculated as follows:

$$p_{cd} = p_c\left(1 + 0.5a_{v,x}/g\right), \qquad [kPa] \tag{5.4.7.1}$$

where:

$a_{v,x}$ – vertical acceleration calculated according to 5.2.4;

$p_c$ – pressure due to cargo as specified by the designer.

## 6 HULL STRUCTURE STRENGTH AND BUCKLING CONTROL

Design load point and its determination for structural elements should be determined as given in 13.1.3 of *Part II of the Rules for the Classification and Construction of Sea-going Ships.*

Effective flange width of the stiffeners and simple primary supporting members should be determined as given in 3.2.2 of *Part II of the Rules for the Classification and Construction of Sea-going Ships.*

The spacing of stiffeners and effective span of stiffeners, for purpose of calculation of strength characteristics, should be determined as required by Chapter 3 of *Part II – Hull* of the *Rules for the Classification and Construction of Sea-going Ships.*

### 6.1 Minimum Thickness of Structural Elements

**6.1.1** The minimum thickness requirements should be determined according to the following formula:

$$t = \frac{t_0 + k_1\sqrt{L_0}}{\sqrt{k}} + t_k\,, [mm] \tag{6.1.1}$$

where:

$t_0$ and $k_1$ are factors determined according to Table 6.1.1;

the corrosion addition $t_k$, $[mm]$, should be determined according to 2.4;

material parameter $k$ should be determined according to chapter 2.

**Table 6.1.1.**
**Parameters to calculate minimum thickness of structural elements.**

| Material type | Steel | Aluminium |
|---|---|---|
| Hull envelope | | |
| Bottom shell plating | $t_0 = 2.0$, $k_1 = 0.4$ | $t_0 = 0.8$, $k_1 = 0.55$ |
| Side shell plating | $t_0 = 1.2$, $k_1 = 0.38$ | $t_0 = 1.1$, $k_1 = 0.39$ |
| Main deck plating | $t_0 = 1.2$, $k_1 = 0.38$ | $t_0 = 1.1$, $k_1 = 0.39$ |
| Wet deck for catamarans | $t_0 = 1.2$, $k_1 = 0.38$ | $t_0 = 1.1$, $k_1 = 0.39$ |
| Single bottom structure | | |
| Centre girder web | $t_0 = 1.0$, $k_1 = 0.8$ | $t_0 = 1.1$, $k_1 = 0.86$ |
| Floor webs | $t_0 = 0.8$, $k_1 = 0.6$ | $t_0 = 0.9$, $k_1 = 0.62$ |
| Side girder webs | $t_0 = 0.8$, $k_1 = 0.6$ | $t_0 = 0.9$, $k_1 = 0.62$ |
| Double bottom structure | | |
| Centre girder within $0.4L_0$ amidships | $t_0 = 1.0$, $k_1 = 0.8$ | $t_0 = 1.1$, $k_1 = 0.86$ |
| Centre girder outside $0.4L_0$ amidships | $t_0 = 1.0$, $k_1 = 0.7$ | $t_0 = 1.1$, $k_1 = 0.74$ |
| Floors and side girders | $t_0 = 0.8$, $k_1 = 0.6$ | $t_0 = 0.9$, $k_1 = 0.62$ |
| Inner bottom plating | $t_0 = 1.0$, $k_1 = 0.5$ | $t_0 = 1.0$, $k_1 = 0.55$ |
| Deck plating | | |
| Lower decks | $t_0 = 1.7$, $k_1 = 0.2$ | $t_0 = 1.0$, $k_1 = 0.23$ |
| Bulkheads | | |
| Watertight bulkhead plating | $t_0 = 1.0$, $k_1 = 0.33$ | $t_0 = 1.0$, $k_1 = 0.33$ |
| Deep tank bulkhead plating | $t_0 = 1.2$, $k_1 = 0.38$ | $t_0 = 1.1$, $k_1 = 0.39$ |
| Superstructures and deckhouses | | |
| Superstructure side plating | $t_0 = 1.0$, $k_1 = 0.3$ | $t_0 = 0.9$, $k_1 = 0.31$ |
| Deckhouse front 1st tier | $t_0 = 1.5$, $k_1 = 0.47$ | $t_0 = 1.4$, $k_1 = 0.48$ |
| Deckhouse front upper tiers | $t_0 = 1.3$, $k_1 = 0.42$ | $t_0 = 1.2$, $k_1 = 0.43$ |
| Deckhouse aft | $t_0 = 0.6$, $k_1 = 0.2$ | $t_0 = 0.6$, $k_1 = 0.19$ |

**6.1.2** For catamaran aluminium crafts, the minimum thicknesses calculated according to 6.1.1 for the following elements:

– Shell envelope: bottom shell plating, side shell plating, main deck plating;
– Single bottom structure: centre girder web, floor webs, side girder webs;
– Deck plating: lower decks;
– Superstructures and deckhouses: superstructure side plating, deckhouse front,

may be reduced by multiplying calculated thickness with the factor equal to:

$$t_r = \frac{0.6s}{105 + L_0}, [-] \qquad (6.1.2)$$

where:

$s$ – stiffener spacing in mm.

The reduction factor $t_r$ should not be taken greater than 1.0 and lower than 0.5.

**6.1.3** Regardless of the results of calculations according to 6.1.1 and 6.1.2, the minimum thickness of structural elements should be not less that specified in Table 6.1.3.

**Table 6.1.3**
**Required minimum thickness of structural elements in mm.**

| Material type | Steel | Aluminium |
|---|---|---|
| Hull envelope | | |
| Bottom shell plating | 3.5 | 4.0 |
| Side shell plating | 3.0 | 3.5 |
| Main deck plating | 3.0 | 3.5 |
| Wet deck for catamarans | 3.0 | 3.5 |
| Single bottom structure | | |
| Centre girder web | 4.0 | 5.0 |
| Floor webs | 3.5 | 4.0 |
| Side girder webs | 3.5 | 4.0 |
| Double bottom structure | | |
| Centre girder within $0.4L_0$ amidships | 4.0 | 5.0 |
| Centre girder outside $0.4L_0$ amidships | 4.0 | 5.0 |
| Floors and side girders | 3.5 | 4.0 |
| Inner bottom plating | 2.5 | 3.5 |
| Deck plating | | |
| Lower decks | 2.0 | 3.0 |
| Bulkheads | | |
| Watertight bulkhead plating | 2.5 | 3.0 |
| Deep tank bulkhead plating | 3.0 | 3.5 |
| Superstructures and deckhouses | | |
| Superstructure side plating | 2.0 | 3.0 |
| Deckhouse front 1st tier | 3.0 | 3.5 |
| Deckhouse front upper tiers | 3.0 | 3.0 |
| Deckhouse aft | 2.0 | 2.5 |

**6.1.4** For cargo and pilot ships, the minimum thickness calculated according to 6.1.1 - 6.1.3, should be additionally multiplied by factor 1.1.

**6.1.5** The minimum thickness of wall thickness of pillars should be determined according to the following equation:

$$t = 0.05\sqrt{k} \cdot a, [mm] \qquad (6.1.5)$$

where $a$ is the outside diameter of tubular pillar or minimum breadth of cross-section of rectangular pillar.

## 6.2 Plating Strength

### 6.2.1 Required Plating Thickness

**6.2.1.1** Plating thickness of the bottom, sides, open deck, first tier of superstructure-deckhouse front wall and tank walls shall not be lesser than the value obtained in accordance with the following formula:

$$t = 22.4 k_a k_r s \sqrt{\frac{p}{\sigma}} + t_k, \qquad [mm] \qquad (6.2.1.1)$$

where:

$s$ – spacing of stiffeners measured along the plating, [m];

$k_a = \begin{cases} \frac{l}{s}\left(1 - \frac{0.25l}{s}\right), & \text{for } \frac{l}{s} \le 2, \\ 1, & \text{for } \frac{l}{s} > 2; \end{cases}$ $l$ - plating panel length, [m];

$k_r = 1 - \frac{h}{s}$, taken not less than 0.7;

$h$ – the distance, measured perpendicularly from the midpoint of the chord spanned between stiffeners to the highest point of the curved plating arc between stiffeners, [m] (see Fig. 6.2.1.1);

$p$ – design pressure, [kPa], to be determined in accordance with sub-chapter 5.3 and 5.4;

$\sigma$ - allowable stresses as determined according to 6.2.1.2, [MPa];

$t_k$ – corrosion addition, [mm] (see sub-chapter 2.4).

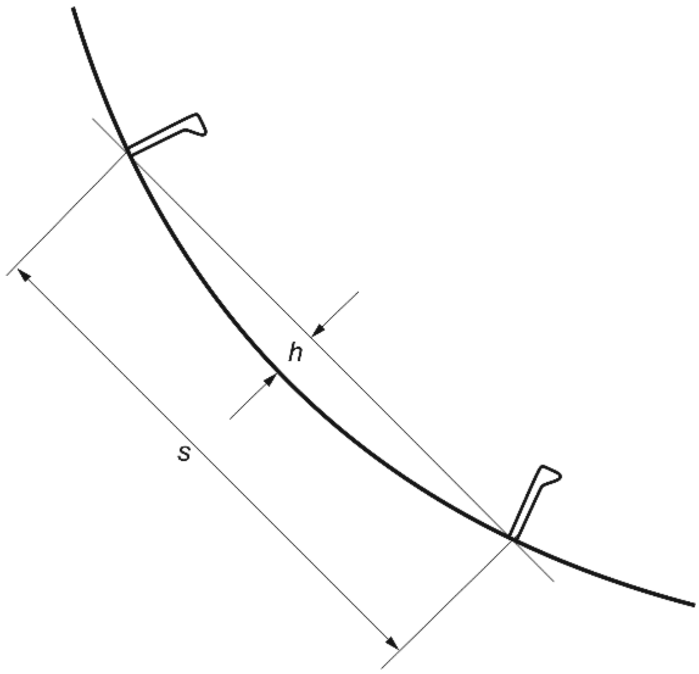



Fig. 6.2.1.1 Definition of *h*.

**6.2.1.2** The allowable stresses $\sigma$ for the determination of required plating thickness should be determined as given in Table 6.2.1.2.

**Table 6.2.1.2**
**Allowable stresses $\sigma$ for the determination of required plating thickness, [MPa]**

| Type of applied loading | Impact pressure | Other pressure types |
|---|---|---|
| Hull envelope | | |
| Bottom shell plating | $0.85R_e$ | $0.75R_e$ |
| Side shell plating | $0.85R_e$ | $0.75R_e$ |
| Main deck plating | - | $0.75R_e$ |
| Keel | - | $0.75R_e$ |
| Wet deck for catamarans | $0.85R_e$ | $0.75R_e$ |
| Bulkheads | | |
| Watertight bulkhead plating | - | $R_e$ |
| Deep tank and minor bulkhead plating | - | $0.65R_e$ |
| Superstructures and deckhouses | | |
| Superstructure side plating | - | $0.75R_e$ |
| Deckhouse front 1st tier | - | $0.65R_e$ |
| Deckhouse front upper tiers | - | $0.75R_e$ |
| Deckhouse aft | - | $0.75R_e$ |

Note: $R_e$ is the minimum yield strength for steel or aluminium, as specified in 2.2.2 and 2.3.4, respectively.

**6.2.1.3** Plating thickness of deck subjected to loads from vehicle wheels shall be determined in accordance with the requirements specified in Chapter 19 of *Part II – Hull* of the *Rules for the Classification and Construction of Sea-going Ships*, taking the design load value which shall be determined in accordance with the requirements specified in sub-chapter 19.6 of *the Rules for the Classification and Construction of Sea-going Ships*, taking the value of $a_v$, determined in accordance with paragraph 5.2.4.

## 6.3 Strength of Plating Stiffeners

### 6.3.1 Required Sectional Modulus and Effective Cross-section Area

**6.3.1.1** Required net moment of inertia, $I$, net sectional modulus, $W$, and effective net cross-section area, $A_s$, of stiffeners of the plating of bottom, sides, open deck, first tier of superstructure-deckhouse front wall and tank walls shall be determined in accordance with the following formulae:

$$I = 1000\, d_l \frac{psl^3}{nE}, [cm^4] \qquad (6.3.1.1-1)$$

$$W = 1000 \frac{psl^2}{m\sigma}, [cm^3] \qquad (6.3.1.1-2)$$

$$A_s = 5 \frac{psl}{\tau}, [cm^2] \qquad (6.3.1.1-3)$$

where:

$s$ – spacing of stiffeners, [m];

$l$ – effective span of stiffener, [m];

$p$ – design pressure, [kPa], to be determined in accordance with sub-chapters 5.3 and 5.4;

$m$ = 12 – for stiffeners, where fixed boundary conditions could be considered;

$m$ = 10 – for stiffeners, where partially fixed boundary conditions could be considered;
$m$ = 8 – for stiffeners, where simply supported boundary conditions could be considered;
$n$ = 3.84 – for stiffeners, where fixed boundary conditions could be considered;
$n$ = 2.88 – for stiffeners, where partially fixed boundary conditions could be considered;
$n$ = 1.85 – for stiffeners, where simply supported boundary conditions could be considered;
$s$ = allowable stresses as determined according to 6.3.1.2, [MPa];
$t$ = $\sigma/\sqrt{3}$, [MPa];
$d_l$ – deflection limiting factor, equal to:
400 for watertight bulkhead, deckhouse and superstructure stiffeners;
475 for bottom, side shell, lower decks, catamaran wet deck stiffeners;
625 for main deck and deep tank stiffeners;
$E$ – elastic modulus, as given in 1.2.2.

**6.3.1.2** The allowable stresses $\sigma$ for the determination of required sectional modulus and cross-section area of stiffeners should be determined as given in Table 6.3.1.2.

**Table 6.3.1.2**
**Allowable stresses $\sigma$ for the determination of required section modulus and cross-section area of stiffeners, [MPa]**

| Type of applied loading | Impact pressure | Other pressure types |
|---|---|---|
| Hull envelope | | |
| Bottom stiffeners | $0.94R_e$ | $0.81R_e$ |
| Side shell stiffeners | $0.94R_e$ | $0.81R_e$ |
| Main deck stiffeners | - | $0.81R_e$ |
| Wet deck stiffeners for catamarans | $0.94R_e$ | $0.81R_e$ |
| Bulkheads | | |
| Watertight bulkhead stiffeners | - | $1.19R_e$ |
| Deep tank and minor bulkhead stiffeners | - | $0.81R_e$ |
| Superstructures and deckhouses | | |
| Superstructure side stiffeners | - | $0.94R_e$ |
| Deckhouse front 1st tier stiffeners | - | $0.75R_e$ |
| Deckhouse front upper tiers stiffeners | - | $0.81R_e$ |
| Deckhouse aft stiffeners | - | $0.94R_e$ |

Note: $R_e$ is the minimum yield strength for steel or aluminium, as specified in 2.2.2 and 2.3.4, respectively.

**6.3.1.3** The required value of net sectional modulus of longitudinals and beams of deck subjected to loads from vehicle wheels shall be determined in accordance with the requirements of Chapter 19 of *Part II – Hull* of the *Rules for the Classification and Construction of Sea-going Ships*, taking the design load value which shall be determined in accordance with the requirements specified in sub-chapter 19.6 of *the Rules for the Classification and Construction of Sea-going Ships*, taking the value of $a_v$, determined in accordance with paragraph 5.2.4.

**6.3.1.4** The required dimensions of brackets at the stiffener span ends shall be determined in accordance with the requirements specified in sub-chapter 13.8 of *Part II – Hull* of the *Rules for the Classification and Construction of Sea-going Ships*.

## 6.4 Strength of Primary Supporting Members

### 6.4.1 Scope and Method of Calculations

**6.4.1.1** Strength of the hull primary supporting members system of bottom and sides shall be checked using FEM calculations obligatory for crafts having length higher than 60m. For crafts of lower length, especially with unordinary shape of Primary Supporting Members, the decision should be made by PRS on case-by-case basis.

It is recommended that the FEM model cover the entire bottom and sides as well as associated transverse and longitudinal bulkheads/divisions.

Application of FEM models covering smaller portions of hull stiffeners is subject to PRS consideration in each particular case.

**6.4.1.2** The FEM model shall fulfil general requirements specified in Chapter 14 of the *Rules for the Classification and Construction of Sea-going Ships*.

It is recommended that the model where the plating and webs of primary supporting members be divided into shell finite elements, is applied.

Application of a three-dimensional frame model is subject to PRS consideration in each particular case.

**6.4.1.3** If calculations according to 6.4.1.1 and 6.4.1.2 will be not required, the strength of Primary Supporting Members should be determined according to 6.3.1.1, considering allowable stresses as defined in Table 6.3.1.2 for other pressure types and pressures as required by 6.4.2.3. However, for calculation of required net moment of inertia, the following values of limiting deflection factor, $d_l$, should be considered:

– 475 for watertight bulkhead, deckhouse and superstructure primary supporting members;
– 625 for bottom, side shell, lower decks and catamaran wet deck primary supporting members;
– 775 for main deck and deep tank primary supporting members.

### 6.4.2 Calculation Variants and Design Pressures

**6.4.2.1** In the calculations, two variants of loads defined in paragraphs 6.4.2.2 and 6.4.2.3 shall be applied.

**6.4.2.2** In the first variant, the pressure acting on the shell envelope determined according to 5.3 or 5.4 (whichever is greater) shall be applied to the hull fragment of 0.3 $L_0$ in length, but the impact pressures values in the non-displacement mode are to be multiplied by factor 0.2.

Other parts of the structure of bottom and sides are subjected to no load.

Hull fragments in several positions along the craft hull shall be considered, so that the FEM analysis takes account of the loads on all the bottom primary members.

**6.4.2.3** In the second variant, the strength of representative individual spans of bottom, side and bow primary supporting members shall be checked by means of FEM model defined in sub-chapter 6.4.1.

Bottom plating, side shell plating or bow plating in the area of length equal to *l* and width equal to *b* is subjected to the pressure determined according to 5.3 or 5.4 (whichever is greater), but the impact pressures values in the non-displacement mode are to be multiplied by factor:

$$c = \left(\frac{lb}{0.3B_{ref}L_0}\right)^{-0.285} \qquad (6.4.2.3)$$

where:
$b$ – width of plating strake supported by girder, [m];

$l$ – girder span (distance between adjacent members perpendicular to girder under consideration, distance between member perpendicular to girder under consideration and side or longitudinal bulkhead, etc.);

$B_{ref}$ – considered as $B_W$ for mono-hull craft (see 5.2.1) and $B_M$ for catamaran (see 5.2.2).

Other parts of the plating are subjected to no load.

**6.4.2.4** If in the calculations in accordance with the requirements specified in paragraph 6.4.2.1 any fragment of hull segment subjected to any load is located within the region of co-ordinates – 0.15 $L_0 \leq x \leq 0.15$ $L_0$ , then the normal stresses in longitudinal primary members (calculated by means of FEM) shall be combined with the stresses due to general bending determined in accordance with the requirements specified in paragraph 6.5.9.1 for bending moment defined in paragraph 6.5.5.

These requirements do not apply to the craft mentioned in paragraph 6.5.1.1.

### 6.4.3 Boundary Conditions

**6.4.3.1** The requirements given in 14.4.4 of *Part II – Hull* of the *Rules for the Classification and Construction of Sea-going Ships* shall be used to determine boundary conditions.

### 6.4.4 Allowable Stress

**6.4.4.1** Allowable stress values specified in Table 6.4.4.1 should be applied to the variants of calculations defined in paragraphs 6.4.2.2 and 6.4.2.3.

**Table 6.4.4.1**
**Allowable stresses norma, shear and equivalent stresses for PSM, [MPa]**

| Normal stresses $\sigma$, [MPa] | Shear stresses $\tau$, [MPa] | Equivalent stresses $\sigma_{eq}$, [MPa] |
|---|---|---|
| $0.65R_e$ | $0.65R_e/\sqrt{3}$ | $0.75R_e$ |

Note: $R_e$ is the minimum yield strength for steel or aluminium, as specified in 2.2.2 and 2.3.4, respectively.

**6.4.4.2** Allowable normal stress values in longitudinal primary members determined in accordance with the requirements specified in paragraph 6.4.2.4 is $0.80R_e$, [MPa].

## 6.5 Longitudinal Strength

### 6.5.1 General

**6.5.1.1** PRS may not require hull longitudinal strength analysis for craft whose length of craft $L$ is less than 45 m for mono-hull crafts and 40 m for catamarans.

**6.5.1.2** For catamaran crafts, the requirements given in 6.5.10 are to be considered, regardless of the craft length.

### 6.5.2 Still Water Bending Moments and Shear Forces for Mono-hull Crafts

**6.5.2.1** The still water bending moments, $M_S$, should be determined as the maximum moment obtained from the longitudinal strength calculations, considering both sagging and hogging.

**6.5.2.2** The still water shear force, $Q_S$, should be determined as the maximum positive and negative value obtained from the longitudinal strength calculations.

### 6.5.3 Vertical Wave Bending Moments for Mono-hull and Catamaran

**6.5.3.1** The minimum wave bending moment $M_W$ for monohull craft should be taken not less than:

$$M_W = 0.1 k_f k_{wm} k_s C_W L_0^2 B(\delta + 0.7), [kNm] \qquad (6.5.3.1)$$

where:

$k_f$ – factor equal to -1.1 for sagging and $1.9\delta/(\delta + 0.7)$ for hogging conditions;

$k_{wm}$ – factor dependent on the location, see Fig. 6.5.3.1, equal to 0 for $x \leq -0.5L_0$ and $x \geq -0.5L_0$ and 1.0 for sections between x≥-0.1$L_0$ and x≤0.15$L_0$, the intermediate values are to be determined by linear interpolation;

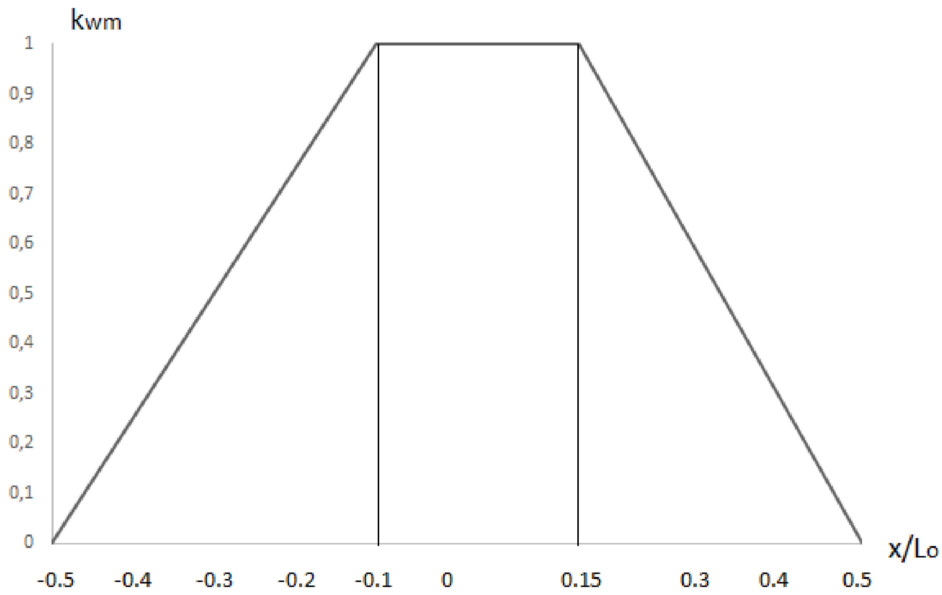



Fig. 6.5.3.1 Coefficient $k_{wm}$

$k_s$ – service area factor, see Table 6.5.3.1;

**Table 6.5.3.1**
**Service area factor**

| Area of navigation | $k_s$[-] |
|---|---|
| I | 0.75 |
| II | 0.64 |
| III | 0.6 |

$$C_W = \begin{cases} 0.0412L_0 + 4.0, & for\ L_0 < 90m \\ 10.75 - (3 - 0.01L_0)^{1.5}, & for\ L_0 \geq 90m \end{cases}$$

**6.5.3.2** The minimum wave bending moment $M_W$ for catamaran craft should be taken not less than:

$$M_W = \delta_W k_f k_{wm} k_t k_s L_0^{2.5} B_M, [kNm] \qquad (6.5.3.2)$$

where:

$k_f$ – factor equal to -0.125 for sagging and 0.2 for hogging conditions;

$\delta_w$ – the waterplane area coefficient and shall not be taken less than 0.5;

$k_{wm}$ – factor dependent on the location, see Fig. 6.5.3.1, equal to 0 for x=-0.5$L_0$ and x=0.5$L_0$ and 1.0 for sections between x≥-0.1$L_0$ and x≤0.15$L_0$, the intermediate values are to be determined by linear interpolation;

$k_t$ – factor related to the type of craft, equal to 1.1 for passenger and cargo crafts and 1.15 for other types of crafts;

$k_s$ – service area factor, see Table 6.5.3.1;

$B_M$ – total breadth of hulls at LCG at the waterline (see 5.2.2), [m].

### 6.5.4 Vertical Wave Shear Forces for Mono-hull and Catamaran

**6.5.4.1** The vertical shear force $Q_W$ should be calculated as follows for both monohull crafts and catamarans:

$$Q_W = \frac{3k_{ws}|M_W|}{L_0}, \qquad [kN] \qquad (6.5.4.1)$$

where:

$M_W$ – vertical wave bending moment calculated according to 6.5.3.1 or 6.5.3.2;

$k_{ws}$ – factor calculated as (see Fig. 6.5.4.1):

$$k_{ws} = \begin{cases} 0, \ for\ x \le -0.5L_0 \\ 1.59\frac{\delta}{\delta+0.7}, \ for\ x \ge -0.3L_0\ and\ x \le -0.2L_0 \\ 0.7, \ for\ x \ge -0.1L_0\ and\ x \le 0.1L_0 \\ 1.0, \ for\ x \ge 0.2L_0\ and\ x \le 0.35L_0 \\ 0, \ for\ x \ge 0.5L_0 \end{cases}, \text{ for positive shear force}$$

$$k_{ws} = \begin{cases} 0, \ for\ x \le -0.5L_0 \\ -0.92, \ for\ x \ge -0.3L_0\ and\ x \le -0.2L_0 \\ -0.7, \ for\ x \ge -0.1L_0\ and\ x \le 0.1L_0 \\ -1.73\frac{\delta}{\delta+0.7}, \ for\ x \ge 0.2L_0\ and\ x \le 0.35L_0 \\ 0, \ for\ x \ge 0.5L_0 \end{cases}, \text{ for negative shear force}$$

The intermediate values of $k_{ws}$ distribution factor are to be calculated by linear interpolation.

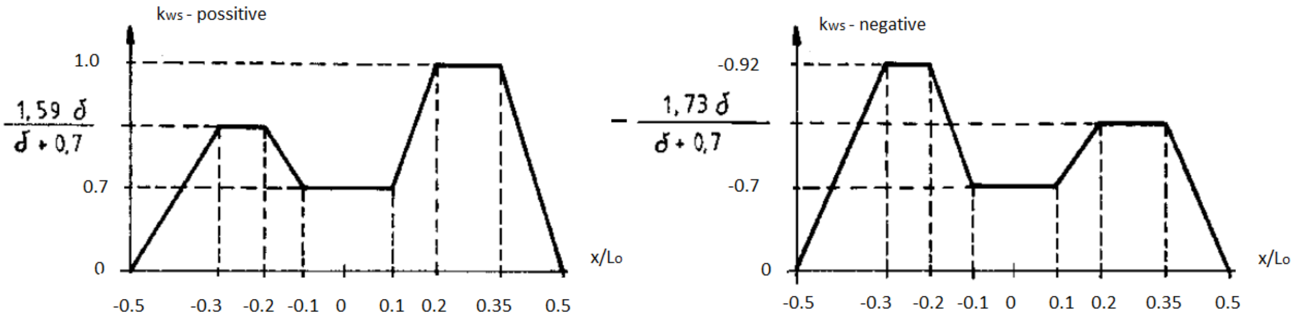



Fig. 6.5.4.1 Coefficients $k_{ws}$

### 6.5.5 Bending Moments Due to Impact Loads for Mono-hull and Catamaran

**6.5.5.1** Consideration shall be given to the hull bending moment due to the hull middle portion impact against water surface which causes hull hogging and also due to simultaneous impact of the craft forebody and afterbody of the bottom which causes hull sagging. Those requirements are taken into consideration for crafts operating in non-displacement mode.

**6.5.5.2** The value of the bending moment due to the impact against water $M_{WI}$ for monohull crafts shall be determined in accordance with the following formula:

$$M_{WI} = k_f k_{wm} \left|0.05DL_0\left(1.66a_v - 0.42a_{v,FP} - 1.76a_{v,AP} - 5.2\right)\right|, \qquad [kNm] \qquad (6.5.5.2)$$

where:

$k_f$ – factor equal to -1.0 for sagging and 1.0 for hogging conditions;

$k_{wm}$ – factor as defined in 6.5.3.1;

$a_v$ – vertical acceleration at the LCG, as defined in 5.2.2;

$a_{v,FP}$ – vertical acceleration at the x=0.5$L_0$, determined according to 5.2.4;

$a_{v,AP}$ – vertical acceleration at the x=-0.5$L_0$ determined according to 5.2.4.

**6.5.5.3** The value of the bending moment due to the impact against water $M_{WI}$ for catamaran crafts shall be determined in accordance with the following formula:

$$M_{WI} = k_f k_{wm} |0.05DL_0(2.12a_v - 5.2)|, \qquad [kNm] \qquad (6.5.5.3)$$

$k_f$ – factor equal to -1.0 for sagging and 1.0 for hogging conditions;

$k_{wm}$ – factor as defined in 6.5.3.2;

$a_v$ – vertical acceleration at the LCG, as defined in 5.2.2.

### 6.5.6 Shear Forces Due to Impact Loads for Mono-hull and Catamaran

**6.5.6.1** The value of shear force $Q_{WI}$ due to impact against the water surface shall be determined in accordance with the following formula:

$$Q_{WI} = \frac{4k_{ws}|M_{WI}|}{L_0} \qquad (6.5.6.1)$$

where:

$M_{WI}$ – vertical bending moment due to impact loads determined according to 6.5.5.2 or 6.5.5.3;

$k_{ws}$ – distribution factor as given in 6.5.4.1.

### 6.5.7 Total Bending Moments and Shear Forces for Monohull Craft

**6.5.7.1** The total bending moment for non-displacement mode should be considered as greater from the $(M_S + M_W)$ determined according to 6.5.2 and 6.5.3 and $M_{WI}$ determined according to 6.5.5, considering both sagging and hogging conditions.

**6.5.7.2** The total shear force for non-displacement mode should be considered as greater from the $(Q_S + Q_W)$ determined according to 6.5.2 and 6.5.4 and $Q_{WI}$ determined according to 6.5.6, considering both positive and negative values.

**6.5.7.3** The total bending moment for displacement mode should be considered as $(M_S + M_W)$ determined according to 6.5.2 and 6.5.3, considering both sagging and hogging conditions.

**6.5.7.4** The total shear force for non-displacement mode should be considered as $(Q_S + Q_W)$ determined according to 6.5.2 and 6.5.4, considering both positive and negative values.

### 6.5.8 Total Bending Moments and Shear Forces for Catamaran

**6.5.8.1** The total bending moment for non-displacement mode should be considered as greater from the $M_W$ determined according to 6.5.3 and $M_{WI}$ determined according to 6.5.5, considering both sagging and hogging conditions.

**6.5.8.2** The total shear force for non-displacement mode should be considered as greater from the $Q_W$ determined according to 6.5.4 and $Q_{WI}$ determined according to 6.5.6, considering both positive and negative values.

**6.5.8.3** The total bending moment for displacement mode should be considered as $M_W$ determined according to 6.5.3, considering both sagging and hogging conditions.

**6.5.8.4** The total shear force for non-displacement mode should be considered as $Q_W$ determined according to 6.5.4, considering both positive and negative values.

### 6.5.9 Allowable Stress

**6.5.9.1** Normal and shear stress in hull due to global loads be determined as required in Chapter 15 of *Part II – Hull* of the *Rules for the Classification and Construction of Sea-going Ships*, taking the values of bending moment and shear force defined in 6.5.7 or 6.5.8.

**6.5.9.2** Allowable values of those stresses are given in Table 6.5.9.2.

**Table 6.5.9.2**
**Allowable stresses normal and shear stresses due to global loads, [MPa]**

| Operational mode of craft | Normal stresses $\sigma$, [MPa] | Shear stresses $\tau$, [MPa] |
|---|---|---|
| Displacement mode | $0.72R_e$ | $0.72R_e/\sqrt{3}$ |
| Non-displacement mode | $0.80R_e$ | $0.80R_e/\sqrt{3}$ |

Note: $R_e$ is the minimum yield strength for steel or aluminium, as specified in 2.2.2 and 2.3.4, respectively.

### 6.5.10 Additional Requirements for Cross-Deck Structure for Catamarans

**6.5.10.1** The catamaran transverse bending moment should be calculated according to the following equation:

$$M_{BT} = 2k_s bDa_v/g, \qquad [kNm] \qquad (6.5.10.1)$$

where:

$k_s$ – service area factor, see Table 6.5.10.1;

**Table 6.5.10.1**
**Service area factor**

| Area of navigation | $k_s$[-] |
|---|---|
| I | 0.88 |
| II | 0.68 |
| III | 0.63 |

$b$ – transverse distance between the hulls centre, [m];

$a_v$ – vertical acceleration at the LCG, as defined in 5.2.2.

**6.5.10.2** The catamaran hull torsional moment $M_T$ should be calculated as follows:

$$M_T = k_s L_0 D a_v / g, \qquad [kNm] \qquad (6.5.10.2)$$

where:

$k_s$ – service area factor as specified in 6.5.10.1;

$a_v$ – vertical acceleration at the LCG, as defined in 5.2.2.

**6.5.10.3** The catamaran shear force acting at the centreline between both hulls should be calculated as follows:

$$Q_T = 2 k_s D a_v / g, \qquad [kN] \qquad (6.5.10.3)$$

where:

$k_s$ – service area factor as specified in 6.5.10.1;

$a_v$ – vertical acceleration at the LCG, as defined in 5.2.2.

**6.5.10.4** The verification of the strength of the cross-deck structure should be determined using FE simulations according to requirements given in Chapter 25 of the *Part II – Hull* of the *Rules for the Classification and Construction of Sea-going Ships*, taking into account values of transverse bending moment, torsional moment and shear force given in 6.5.10.1 – 6.5.10.3. However, the considered allowable stresses should be determined as given in Table 6.5.10.4.

**Table 6.5.10.4**
**Allowable stresses normal, shear and equivalent stresses for strength determination of cross-deck structure, [MPa]**

| Operational mode of craft | Normal stresses $\sigma$, [MPa] | Shear stresses $\tau$, [MPa] | Equivalent stresses $\sigma_{eq}$, [MPa] |
|---|---|---|---|
| Displacement mode | $0.72R_e$ | $0.72R_e/\sqrt{3}$ | $0.75R_e$ |
| Non-displacement mode | $0.80R_e$ | $0.80R_e/\sqrt{3}$ | $0.82R_e$ |

Note: $R_e$ is the minimum yield strength for steel or aluminium, as specified in 2.2.2 and 2.3.4, respectively.

### 6.6 Buckling Control of Structure

Buckling strength of the hull structural elements shall be checked using the methods and criteria specified in Chapter 13 of *Part II – Hull* of the *Rules for the Classification and Construction of Sea-going Ships*.

# 7 HULL STRUCTURE

## 7.1 General

### 7.1.1 Application

**7.1.1.1** General requirements regarding the construction of hull, superstructures or deckhouses, bulwark, etc., are specified in this Chapter. Those requirements apply also for particular hulls in case of catamarans.

The required scantlings of structural elements (plating thickness, sectional modulus of plating stiffeners, bracket scantlings) shall be determined in accordance with the requirements of Chapter 6.

## 7.2 Continuity of Structural Members

### 7.2.1 Primary Supporting Members and their Endings

**7.2.1.1** Primary supporting members shall be so arranged and designed as to avoid abrupt changes of their height or cross-sectional area.

Where primary member segments are connected to both sides of the bulkhead or other hull structure element, they shall be aligned.

It is recommended that primary members in tanks form frame systems in transverse planes (i.e. frame planes) or longitudinal planes.

**7.2.1.2** Buckling strength of primary members shall be ensured by effective stiffening of their webs and application of tripping brackets. Detailed requirements in respect of the above mentioned issues are specified in sub-chapter 3.6 of *Part II – Hull* of the *Rules for the Classification and Construction of Sea-going Ships*.

Openings in primary member webs shall have respectively rounded corners and shall not be arranged in the regions where extreme stress is expected and their presence may not significantly reduce the buckling strength of such a member.

**7.2.1.3** Primary member terminating on a structural element (e.g. bulkhead) which does not form a significant constrainment on rotation shall be extended beyond such a structural element for at least two frame spacings – e.g. in the form of bracket with gradually reduced height.

**7.2.1.4** Segments of primary members forming planar frames shall be so connected as to avoid excess stress concentration.

It is recommended that integral brackets or smooth-ended brackets be applied.

The bracket arm lengths shall not be less than the lesser height of the connected segments of primary members.

### 7.2.2 General Requirements for Continuity of Structural Members

**7.2.2.1** Abrupt changes of cross section shapes and size of structural members, sharp endings and other types of stress raisers shall be avoided.

**7.2.2.2** Deck pillars shall, generally, be situated coaxially and supporting bulkheads – in the same vertical planes.

Unless meeting theses conditions is possible, adequate design solutions shall be applied to ensure safe transmission of vertical loads on the structural elements of lower tiers.

Structural elements adjacent to pillars or primary supporting members shall provide for suitable load distribution in the form of axial forces in pillars.

**7.2.2.3** In places of intersection of primary member webs of the same height, diamond plates or brackets shall be applied (Fig. 7.2.2.3).

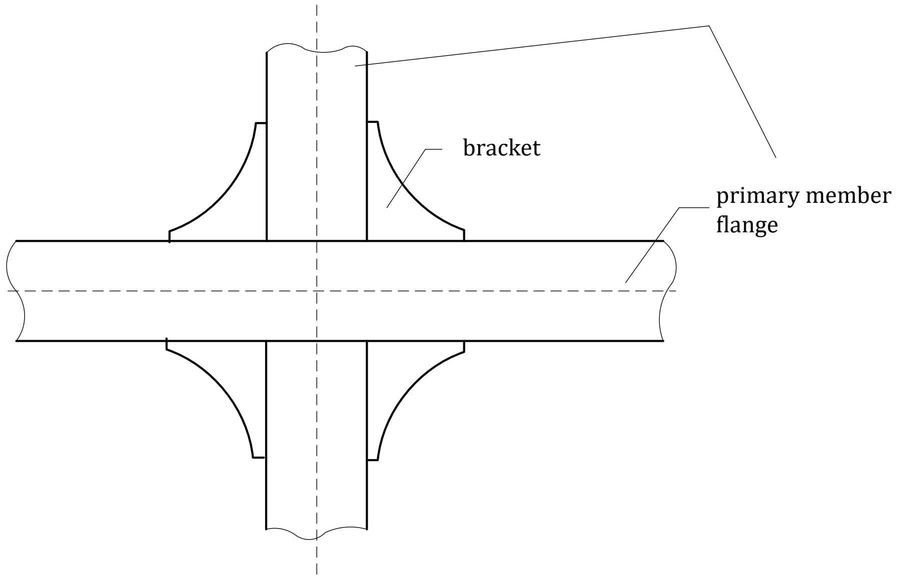



Fig. 7.2.2.3 Brackets at primary member flanges

**7.2.2.4** At primary member ends, smooth-ended brackets shall be applied.

Bracket ends shall be effectively supported, i.e. they shall not be connected to unstiffened plating panels.

Bracket flange ends shall be snipped.

Where bracket flange is welded to its side surface, the bracket end shall be so shaped that the following condition is fulfilled (see Fig. 7.2.2.4):

$$h_w t_w \geq 0.6 h_m t_m \tag{7.2.2.4}$$

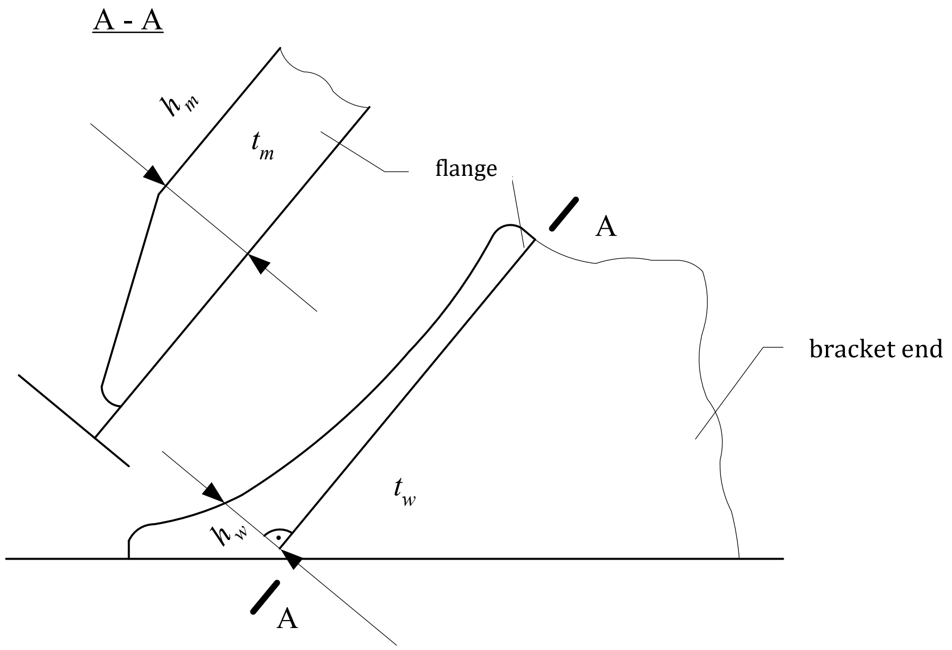



Fig. 7.2.2.4 Bracket end

### 7.2.3 Connection of Plating Stiffeners to Primary Members

**7.2.3.1** The requirements specified in paragraph 4.3.7 of Part II – Hull of the Rules for the Classification and Construction of Sea-going Ships apply.

The requirements specified below apply to heavy loaded connections of the bottom and side stiffeners to primary members, subjected to impact pressures defined in sub-chapters 5.3.2 and 5.3.3.

**7.2.3.2** Plating stiffeners of the bottom, sides, decks and bulkheads shall, generally, pass continuously through their primary supporting members, bulkheads or other divisions.

Cut-outs in primary member webs (or in the plating of bulkheads or other divisions) shall be so shaped that the stress concentration on their whole perimeter and in the hull shell plating in their immediate vicinity be as low as possible.

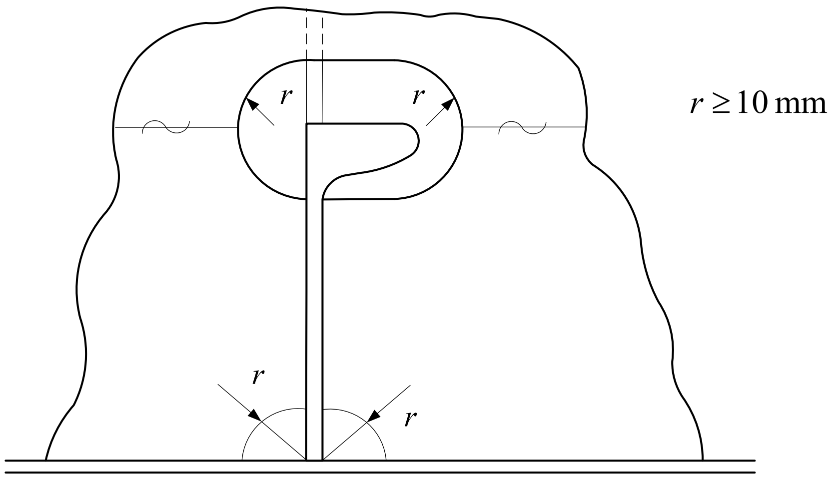
If a plating stiffener web is not directly connected to the primary member web, doubling plates shall be applied on both sides of such a stiffener.

**7.2.3.3** Cut-outs for stiffeners shall be as narrow as practicable and their corners shall be rounded to a radius as large as practicable.

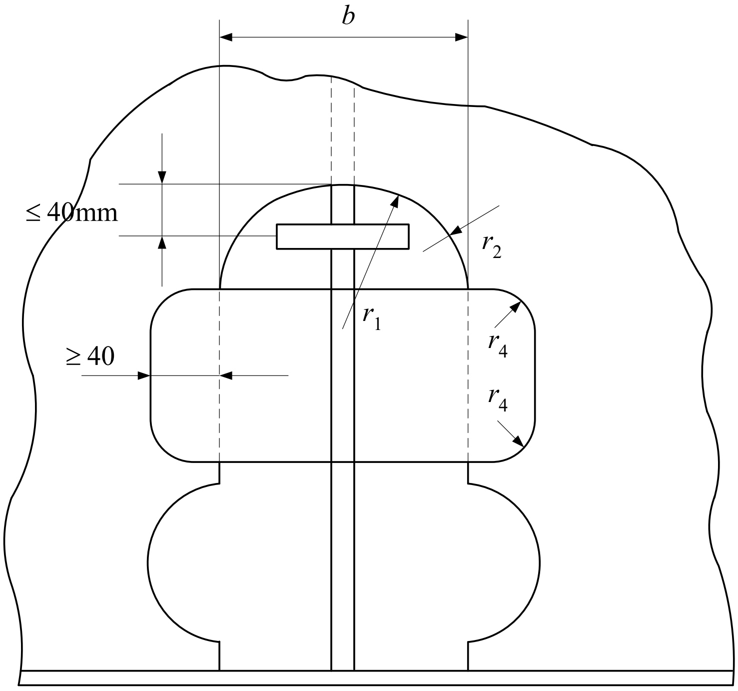
Recommended patterns of connection of plating stiffeners to primary members are shown in Fig. 7.2.3.3.

Rounding radius $r_2$ at the cut-out upper edge shall not be less than 20% of the cut-out width and not be less than 10 mm – for craft of a length not exceeding 24 m and 20 mm – for craft more than 24 m in length.

a)



b)

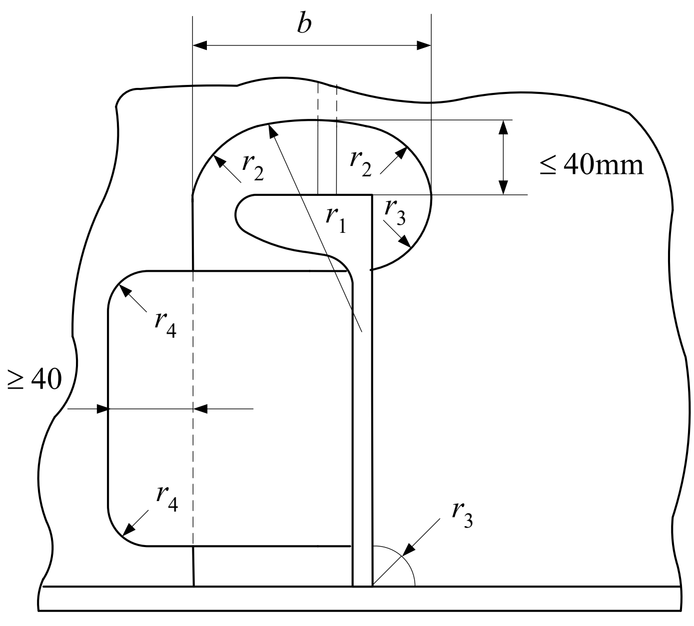



$r_1 \approx b$

$r_2 = Min(02b; 10mm)$

$r_4 \geq 15mm$

c)




$r_1 \approx b$

$r_2 = Min(02b; 10mm)$

$r_3 \geq 10mm$

$r_4 \geq 15mm$

Fig. 7.2.3.3 Recommended patterns of connection of plating stiffeners to primary members

**7.2.3.4** Application of primary member web stiffeners which are staggered in relation to the plating stiffener is permitted. An example of such solution is shown in Fig. 7.2.3.4.

An opening for plating stiffener and doubling plate shall fulfil the requirements specified in paragraph 7.2.3.3.

Doubling plate shall be connected by means of fillet welds of thickness determined in accordance with paragraph 4.3.1.1 using $\alpha = 0.45$.

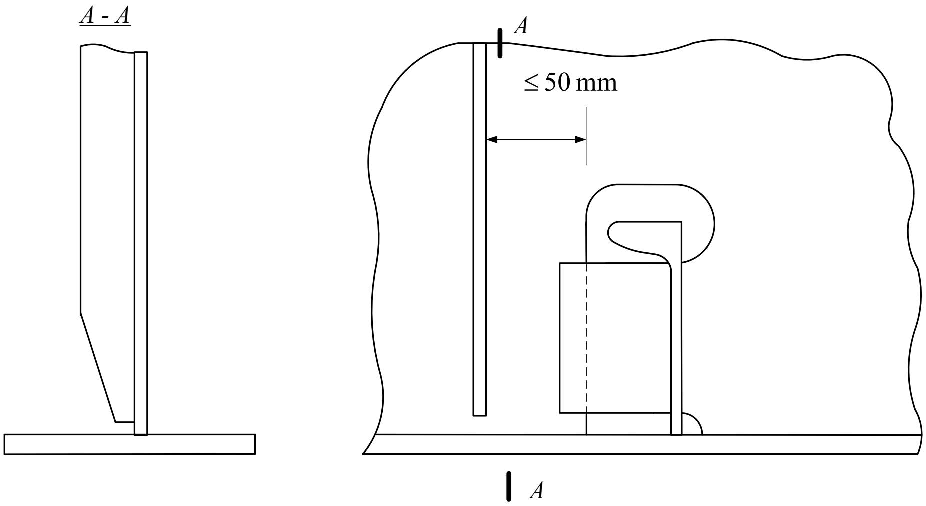



Fig. 7.2.3.4

**7.2.3.5** Primary member web stiffeners may be situated perpendicularly to the planes of plating stiffener webs in order to eliminate stress concentration (occurring in the cases shown in Fig. 7.2.3.3) in places where such structural elements are connected.

The primary member web stiffener which is the closest to a plating stiffener shall not be situated farther than 150 mm from the upper edge of cut-out for the plating stiffener.

## 7.3 Bilge Keels and other Craft Equipment Elements Welded to Hull Structure

### 7.3.1 Bilge Keels

**7.3.1.1** Bilge keels shall not be installed within 0.3*L* aft of the fore perpendicular in craft intended for service in ice conditions (see Chapter 8).

**7.3.1.2** Recommended design of bilge keel is shown in Fig. 7.3.1.2. Bilge keel in the form of flat bar or bulb bar shall be connected to the plating by means of continuous intermediate flat bar.

Intermediate flat bar thickness shall not be lesser than plating thickness in way of the bilge keel, however, not less than 6 mm.

Intermediate flat bar and bilge keel bar shall be made of a material of the same strength and grade as the plating thickness in way of the bilge keel.

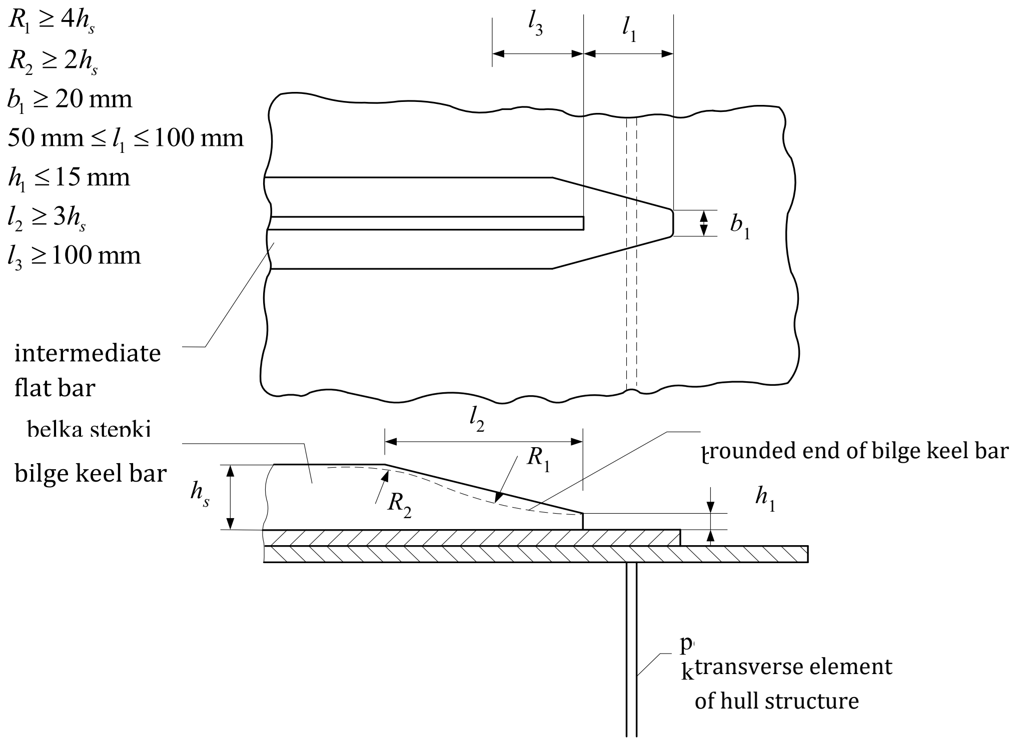



Fig. 7.3.1.2 Recommended design of bilge keel

**7.3.1.3** Intermediate flat bar shall be connected to the plating by means of continuous fillet weld.

In outer segments of length $l_1$ + $l_3$ (see Fig. 7.3.1.2) reinforced weld of thickness determined in accordance with paragraph 4.3.1.1 and using $\alpha$ = 0.45 shall be applied. In other than outer segments $\alpha$ = 0.25 shall be used to determine the weld thickness.

Bilge keel bar shall be connected to the intermediate flat bar by means of surface weld where $\alpha$ = 0.15 is used, except for the outer segments of length $l_3$ (see Fig. 7.3.1.2) where $\alpha$ = 0.35 shall be used.

In the above mentioned outer segments, welds shall be ground to ensure smooth transition of their surface into the plating or intermediate flat bar.

**7.3.1.4** Bilge keel bar ends shall be snipped or rounded (see Fig. 7.3.1.2).

**7.3.1.5** Bilge keel bar shall be coplanar with the longitudinal stiffener of platings, and the bilge keel ends shall be situated in way of the transverse stiffener of plating, transverse primary member, division, etc.

Such a transversal hull structural element shall be situated as close as possible to the centre of the intermediate flat bar outer segment of length $l_1$ (see Fig. 7.3.1.2).

### 7.3.2 Craft Equipment Elements Welded to Hull Structure

**7.3.2.1** Profiles welded to the strength deck in order to form a scupper system shall be so shaped as to minimise stress concentration in the deck plating due to general bending of hull.

**7.3.2.2** Supports or hangers for pipes, wires and other craft equipment elements shall not be welded to the hull structure in the immediate vicinity of ends of brackets of plating stiffeners and primary members, as well as corners of openings in the hull structural elements or other regions where stress concentration is expected.

## 7.4 Single Bottom

### 7.4.1 General

**7.4.1.1** The requirements specified in sub-chapter 7.4 apply to the single bottom structure of transverse or longitudinal framing system. In case of catamarans, they apply for any single hull.

**7.4.1.2** Structural continuity shall be ensured along the hull. Bottom longitudinals shall extend as close to the bow and stern as practicable. If bottom longitudinals terminate at bulkheads or other transverse divisions, then smooth-shaped brackets shall be applied at their ends.

**7.4.1.3** The connections of bottom longitudinals and floors shall fulfil the requirements specified in paragraph 7.2.2.3.

### 7.4.2 Plating

**7.4.2.1** Plating thickness shall fulfil the requirements specified in sub-chapters 6.1 and 6.2.

**7.4.2.2** In way of plating edges on the bilge (point *ZP* in Fig. 1.1.1-a) plating thickness shall be increased by at least 20% compared to that required in paragraph 6.2.1.1. The applied plating thickness value shall not, however, be less than 6.0 mm.

Bottom and side shell plating panels in way of the plating edges shall be welded with full penetration.

**7.4.2.3** If the bottom plating in way of plating edges is connected to the side shell plating by means of tube, then the tube wall thickness shall be greater by at least 20% than the bottom plating thickness required in that region.

Bottom and side shell plating panels shall be welded to the tube walls with full penetration.

### 7.4.3 Bar Keel

**7.4.3.1** Bar keel scantlings shall fulfil the requirements specified in paragraph 10.6.1 of *Part II – Hull*, of the *Rules for the Classification and Construction of Small Sea-going Ships*.

### 7.4.4 Bootom Centre Girder

**7.4.4.1** Bottom centre girder shall, in general, extend throughout the hull length.

Bottom centre girder may be waived only in the forebody and afterbody where the floor breadth measured at their upper edge level is less than 1.5 m.

**7.4.4.2** Bottom centre girder face plate shall be continuous. Bottom centre girder web may be intercostal between floors.

Bottom centre girder height shall, in general, be equal to the height of floors in the centre plane.

Web thickness shall not be lesser than that specified in sub-chapter 6.1.

Web and face plate scantlings shall be so selected as to fulfil the requirements for primary members specified in sub-chapter 6.4.

Face plate thickness shall not be lesser than that of web.

### 7.4.5 Bottom Side Girders

**7.4.5.1** Bottom side girders shall be applied where the breadth of craft at the level of floor face plates exceeds 6.0 m.

The distance between the bottom side girder and craft side or bottom centre girder and the distance between individual bottom side girders shall not exceed 3.0 m.

**7.4.5.2** Bottom side girders shall be applied throughout the longest possible stretch of bottom. They shall be terminated at transverse bulkheads or floors. At bottom side girder termination smooth-ended brackets shall be applied.

**7.4.5.3** Bottom side girder webs shall be intercostal between floors.

**7.4.5.4** Web thickness shall not be lesser than the value specified in sub-chapter 6.1.

Face plate thickness shall not be lesser than that of webs.

Bottom side girder scantlings shall be so selected as to fulfil the strength requirements for primary members as determined in sub-chapter 6.4.

**7.4.5.5** In machinery spaces additional longitudinals may be necessary to provide for engine foundations. Such longitudinals shall fulfil the requirements specified in Chapter 12 of *Part II – Hull*, of the *Rules for the Classification and Construction of Small Sea-going Ships*.

### 7.4.6 Floors

**7.4.6.1** In the case of hull with transverse framing system, T-section floors shall be applied in all the frame planes.

**7.4.6.2** In the case of hull with longitudinal plating stiffeners in the bottom, floors shall be applied in web frame planes and their spacing shall not exceed 2.0 m.

**7.4.6.3** It is recommended that floor webs be continuous throughout the breadth of bottom, however they are permitted to be intercostal at the bottom centre girder.

**7.4.6.4** Floor face plates need not be parallel with the base plane.

**7.4.6.5** Floor web thickness shall not be lesser than the value specified in sub-chapter 6.1. Face plate thickness shall not be lesser than that of webs.

Floor scantlings shall be so selected as to fulfil the strength requirements for primary members as determined in sub-chapter 6.4.

**7.4.6.6** Brackets connecting floors to frames or to stiffeners/primary members of longitudinal bulkheads shall be smooth-ended.

### 7.4.7 Longitudinal Bottom Stiffeners

**7.4.7.1** Longitudinal bottom stiffeners shall fulfil the requirements analogous to those for double bottom stiffeners as specified in sub-chapter 7.5.8.

## 7.5 Double Bottom

In case of catamarans, the following requirements apply for any single hull.

### 7.5.1 General

**7.5.1.1** It is recommended that double bottom be applied in the region between the after peak bulkhead and collision bulkhead.

Inner bottom shall be situated above the bottom plating edge (point *ZP* in Fig. 1.1.1).

### 7.5.2 Bar Keel

**7.5.2.1** Bar keel scantlings shall fulfil the requirements specified in paragraph 7.4.3.1.

### 7.5.3 Bottom Centre Girder

**7.5.3.1** Bottom centre girder height shall not be less than 650 mm.

The girder plates shall fulfil the requirements analogous to those specified in sub-chapter 7.4.4 for bottom centre girder web in craft with single bottom.

### 7.5.4 Duct Keel

**7.5.4.1** Duct keel width shall not be less than 650 mm.

Duct keel shall also fulfil the requirements specified in sub-chapter 6.2.4 of *Part II – Hull*, of the *Rules for the Classification and Construction of Sea-going Ships*.

### 7.5.5 Bottom Side Girders

**7.5.5.1** Bottom side girders shall fulfil the requirements analogous to those specified in sub-chapter 7.4.5 for girder webs in craft with single bottom.

### 7.5.6 Floors

**7.5.6.1** Plate floors shall be continuous in the region from the side to bottom centre girder or duct keel.

**7.5.6.2** In the case of craft with longitudinal framing system, the spacing of plate floors shall not exceed 2.0 m.

In machinery spaces plate floors shall, however, be applied in all the frame planes (with the spacing not exceeding 0.7 m).

In the forebody (forward of amidships), the plate floor spacing shall not exceed 1.0 m.

Plate floors shall also be applied under transverse bulkheads and at those frame planes where pillars are supported by the bottom.

**7.5.6.3** Plate floor panels shall be stiffened vertically, coplanarly with the longitudinal bottom stiffeners or in their immediate vicinity (see paragraph 7.2.3.4). The height of such stiffeners shall not be less than 10 times the minimum floor thickness required in sub-chapter 6.1, and their thickness shall not be less than the required minimum floor thickness.

**7.5.6.4** In the case of craft with transverse framing system in the bottom, the arrangement of plate floors shall fulfil the requirements for the bottom with longitudinal framing system (see paragraph 7.5.6.2).

Between plate floors, open floors shall be applied in all the frame planes (with the spacing not exceeding 0.7 m).

Open floors may be made of plates with holes or of sections.

**7.5.6.5** Plate floors and open floors shall fulfil the strength criteria specified in Chapter 6.

**7.5.6.6** Watertight floors shall fulfil the strength criteria for watertight bulkheads or tank bulkheads specified in Chapter 13 of *Part II – Hull*, of the *Rules for the Classification and Construction of Sea-going Ships*.

### 7.5.7 Supporting Plates

**7.5.7.1** Supporting plates in the double bottom shall fulfil the requirements specified in Chapter 6 of *Part II – Hull*, of the *Rules for the Classification and Construction of Sea-going Ships*.

### 7.5.8 Stiffeners of Bottom Plating and Inner Bottom Plating

**7.5.8.1** In the double bottom with longitudinal framing system, the stiffeners of bottom plating and inner bottom plating shall continuously run through floors or bulkheads (see paragraphs 7.2.3.2 and 7.2.3.3).

If a stiffener needs to be terminated at a floor or bulkhead, it shall be smoothly ended with an appropriate bracket.

**7.5.8.2** Transverse stiffeners of the bottom and inner bottom shall continuously run through the side girders or longitudinal bulkheads (see paragraphs 7.2.3.2 and 7.2.3.3).

### 7.5.9 Bottom Plating and Inner Bottom Plating

**7.5.9.1** Bottom plating shall fulfil requirements analogous to those for single bottom plating (see sub-chapter 7.4.2).

**7.5.9.2** Inner bottom plating thickness shall fulfil the requirements specified in sub-chapters 6.1 and 6.2.

## 7.6 Side Shell

In case of catamarans, the following requirements apply for any single hull.

### 7.6.1 Side Shell Plating

**7.6.1.1** Side shell plating thickness shall fulfil the requirements specified in sub-chapters 6.1 and 6.2.

**7.6.1.2** Sheer strake thickness shall not be less than that required in paragraph 7.6.1.1. Local strengthenings (stiffeners) of sheer strake shall be provided in places where fenders are supported by the sides.

**7.6.1.3** In way of superstructure outer bulkheads, sheer strake plating thickness shall be increased as required in sub-chapter 7.3.2 of *Part II – Hull*, of the *Rules for the Classification and Construction of Sea-going Ships*.

### 7.6.2 Longitudinal Stiffeners of Side Shell Plating

**7.6.2.1** Longitudinal stiffeners of side shell plating shall be supported by web frames, transverse bulkheads, divisions, etc., spaced not more than 2.0 m apart.

They shall continuously run through the structural elements supporting them (see also sub-chapter 7.2).

If a longitudinal stiffener needs to be terminated at a web frame, bulkhead, etc., it shall be extended beyond its support by means of an appropriate bracket.

### 7.6.3 Transverse Stiffeners of Plating (ordinary frames)

**7.6.3.1** Ordinary frames need not continuously run through lower decks.

Frame segments shall be fixed to the bottom and decks by means of brackets ensuring their maximum constrainment on rotation.

**7.6.3.2** Where side stringers are applied in the hull structure, frames shall run through them continuously (see also paragraphs 7.2.2 and 7.2.3).

### 7.6.4 Side Primary Members

**7.6.4.1** Web frames shall, in general, be situated at the same frame planes where floors and transverse deck girders are applied, and shall be integrally (i.e. without added brackets) fixed to those primary members of the bottom and decks.

Application of brackets added to the primary member webs and positioning of web frames not coplanarly with floors or web frames is subject PRS consideration in each particular case.

**7.6.4.2** Side stringers shall run through bulkheads and transverse divisions continuously.

**7.6.4.3** Intersections of side stringers and web frames shall fulfil the requirements specified in paragraph 7.2.2.3 (in the case of their equal heights).

In the case of intersection of the side primary members having different heights, the lower member shall, in general, continuously run through the higher member web.

## 7.7 Bulkheads

### 7.7.1 General

**7.7.1.1** Bulkheads shall fulfil the requirements specified in Chapter 9 of Part II – Hull of the Rules for the Classification and Construction of Sea-going Ships or Chapter 8 of Part II – Hull of the Rules for the Classification and Construction of Small Sea-going Ships (where L < 24 m).

Additionally, the requirements specified in sub-chapter 7.7.2 shall be fulfilled.

While determining the necessary scantlings of tank bulkhead structure, the design pressure determined in accordance with paragraph 5.4.1.1 shall be taken into account.

### 7.7.2 Connections of Bulkhead Stiffeners and Primary Supporting Members to Bottom and Sides

**7.7.2.1** Vertical stiffener ends of bulkheads shall be welded to the bottom longitudinal stiffeners or plating (where the bottom is stiffened transversely). Brackets applied at such stiffener ends shall be smooth-ended.

**7.7.2.2** Where a bulkhead is stiffened by means of horizontal stiffeners, their ends shall be welded to the horizontal side stiffeners or to the side plating (where the sides are stiffened transversely). Brackets applied at such stiffener ends shall be smooth-ended.

**7.7.2.3** At the ends of vertical or horizontal primary members of bulkheads smooth-ended brackets shall be applied.

## 7.8 Decks

In case of catamarans, the following requirements apply for decks any single hull.

### 7.8.1 General

**7.8.1.1** It is recommended that longitudinal system of strength deck stiffeners be applied between the sides and hatch opening edges.

**7.8.1.2** Deck transverses shall be situated at the same frame planes where web frames are applied.

**7.8.1.3** Longitudinal stiffeners of the strength deck plating shall, in the middle portion of hull, continuously run through deck transverses and bulkheads.

**7.8.1.4** Deck structure members shall fulfil the strength requirements specified in Chapter 6.

### 7.8.2 Deck Openings

**7.8.2.1** Deck openings shall be reinforced by respectively sturdy primary members welded on the whole perimeter.

It may be reasonable to support such primary members by means of deck pillars.

The ends of stiffeners or primary members of the deck shall be welded to the coaming of such an opening.

**7.8.2.2** Deck opening corners shall fulfil the requirements specified in sub-chapter 8.5 of *Part II – Hull* of the *Rules for the Classification and Construction of Sea-going Ships*.

## 7.9 Superstructures and Deckhouses

### 7.9.1 General

**7.9.1.1** Superstructure and deckhouse structures shall fulfil the general requirements specified in sub-chapter 10.2 of *Part II – Hull* of the *Rules for the Classification and Construction of Sea-going Ships* in addition to those specified in this sub-chapter.

**7.9.1.2** It is recommended that superstructures and deckhouses have rounded edges of side, front and aft walls.

**7.9.1.3** Primary members of superstructure/deckhouse walls and decks shall form frames connected to the primary supporting members of hull.

Pillars supporting superstructure decks shall be supported by primary supporting members or pillars in the hull.

**7.9.1.4** It is recommended that the stiffeners of deck and wall plating continuously run through the primary members supporting them.

**7.9.1.5** Strengthening measures shall be provided for plating, stiffeners and primary members in places where stress concentration is expected (e.g. in way of deck opening corners or wall opening corners ) or in places subjected to increased loads induced by masts, machinery and equipment, etc.

**7.9.1.6** Adequate stiffness of superstructures/deckhouses shall be provided in the direction transverse to the centre plane by means of transverse divisions supported below the upper deck on bulkheads or divisions or robust frames.

### 7.9.2 Forecastle

**7.9.2.1** Side shell plating thickness within the forecastle shall not be lesser than that required at the upper deck level.

**7.9.2.2** Forecastle sides shall be stiffened by means of frames terminated with brackets at the upper deck. Web frames shall be applied in the side web frame planes below the upper deck.

**7.9.2.3** Where the after bulkhead of forecastle is situated at a distance from the fore perpendicular $l_d > 0.2L_0$, the upper deck plating thickness shall be increased at sides.

The region of increased deck plating thickness shall include the deck portion on both sides of the forecastle after bulkhead (i.e. fore and aft) and shall extend in both directions for a distance not lesser than half the forecastle height.

The plating thickness shall be increased by 20% – where $l_d \geq 0.25L_0$ , and 0% – where $l_d = 0.2L_0$.

For intermediate values of $l_d$ , linear interpolation shall be applied.

**7.9.2.4** Scantlings of the stiffeners and primary members of forecastle sides shall be determined like those of the side shell using the design pressure determined for the side shell at the upper deck level.

#### 7.9.3 Superstructures Participating in General Bending of Hull

**7.9.3.1** In the case of superstructures situated in the midship portion of craft hulls more than 40 in length or in the case of considerable openings made in superstructure side walls or considerable number of small openings (e.g. windows), direct FEM calculations are required to determine the stresses in hull and superstructure in the conditions of general bending. For this purpose, the bending moments and shear forces determined in sub-chapter 6.5 shall be used.

The FEM model shall fulfil the general requirements specified in sub-chapter 14.6 of *Part II – Hull* of the *Rules for the Classification and Construction of Sea-going Ships*.

#### 7.9.4 Connection of Superstructures and Deckhouses of Aluminium Alloy to Steel Hull

**7.9.4.1** General requirements specified in sub-chapter 4.4 of Part II – Hull of the Rules for the Classification and Construction of Small Sea-going Ships shall be fulfilled.

**7.9.4.2** PRS may require to make direct calculations of stresses in the connection of superstructure/deckhouse to the hull using FEM in accordance with the requirements specified in paragraph 7.9.3.1.

### 7.10 Construction of Individual Hull Connection for Catamarans

**7.10.1** The construction of Individual Hull Connection for Catamarans should comply with the Chapter 25 of *Part II – Hull of the Rules for the Classification and Construction of Sea-going Ships.*

## 8 STRENGTHENING REQUIREMENTS FOR NAVIGATION IN ICE CONDITIONS

### 8.1 General

**8.1.1** High speed craft operation in ice conditions is permitted only in the displacement cruising state on condition that the hull fulfils the requirements specified in Chapter 26 of *Part II – Hull* of the *Rules for the Classification and Construction of Sea-going Ships* or Chapter 21 of *Part II – Hull* of the *Rules for the Classification and Construction of Small Sea-going Ships*.

**8.1.2** Craft hull with sides stiffened transversely intended for service in ice conditions shall fulfil the requirements for basic ice strengthening (L4) specified in Chapter 26 of *Part II – Hull* of the *Rules for the Classification and Construction of Sea-going Ships* or the requirements for ice strengthening **Lm1** or **Lm2** specified in Chapter 21 of *Part II – Hull* of the *Rules for the Classification and Construction of Small Sea-going Ships*.

**8.1.3** Craft hull with sides stiffened longitudinally intended for service in ice conditions shall have strength, when subjected to the load due to ice conditions, equivalent to that of hull with sides stiffened transversely resulting from the requirements specified in sub-chapter 8.1.2.

Ice strengthening construction is subject to PRS consideration in each particular case then.

**8.1.4** The problem of ice strengthening of high speed craft intended for service in worse ice conditions that those specified in paragraph 8.1.2 is subject to PRS consideration in each particular case.

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## List of amendments effective as of 1 January 2024

| *Item* | *Title/Subject* | *Source* |
|---|---|---|
| in many places | Adjusting the Rules for High Speed Crafts to cover also catamarans. In particularly, the new Design Loads (Chapter 5) are proposed and Strength Criteria (Chapter 6). The minor changes are introduced to Chapters 1, 4 and 7 to adjust the requirements for catamaran crafts. | PRS |

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