

Small craft — Hull construction and scantlings —

Part 5: Design pressures for monohulls, design stresses, scantlings determination

ICS 47.080

National foreword

This British Standard is the UK implementation of EN ISO 12215-5:2008. It is identical to ISO 12215-5:2008 incorporating amendment 1:2014. It supersedes BS EN ISO 12215-5:2008, which is withdrawn.

The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to ISO text carry the number of the ISO amendment. For example, text altered by ISO amendment 1 is indicated by **A1** ^{A1}.

The UK participation in its preparation was entrusted to Technical Committee GME/33, Small craft.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

The publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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English Version

Small craft - Hull construction and scantlings - Part 5: Design pressures for monohulls, design stresses, scantlings determination (ISO 12215-5:2008)

Petits navires - Construction de la coque et échantillonnage
- Partie 5: Pressions de conception pour monocoques,
contraintes de conception, détermination de
l'échantillonnage (ISO 12215-5:2008)

Kleine Wasserfahrzeuge - Rumpfbauweise und
Dimensionierung - Teil 5: Entwurfsdrücke für
Einrumpffahrzeuge, Entwurfsspannungen, Ermittlung der
Dimensionierung (ISO 12215-5:2008)

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Foreword

This document (EN ISO 12215-5:2008) has been prepared by Technical Committee ISO/TC 188 "Small craft" in collaboration with Technical Committee CEN/SS T01 "Shipbuilding and maritime structures" the secretariat of which is held by CMC.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by October 2008, and conflicting national standards shall be withdrawn at the latest by October 2008.

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Endorsement notice

The text of ISO 12215-5:2008 has been approved by CEN as a EN ISO 12215-5:2008 without any modification.

Foreword to amendment A1

This document (EN ISO 12215-5:2008/A1:2014) has been prepared by Technical Committee ISO/TC 188 "Small craft" in collaboration with CCMC.

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Endorsement notice

The text of ISO 12215-5:2018/Amd 1:2014 has been approved by CEN as EN ISO 12215-5:2008/A1:2014 without any modification.

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 12215-5 was prepared by Technical Committee ISO/TC 188, *Small craft*.

ISO 12215 consists of the following parts, under the general title *Small craft — Hull construction and scantlings*:

- *Part 1: Materials: Thermosetting resins, glass fibre reinforcement, reference laminate*
- *Part 2: Materials: Core materials for sandwich construction, embedded materials*
- *Part 3: Materials: Steel, aluminium alloys, wood, other materials*
- *Part 4: Workshop and manufacturing*
- *Part 5: Design pressures for monohulls, design stresses, scantlings determination*
- *Part 6: Structural arrangements and details*
- *Part 7: Scantling determination of multihulls*
- *Part 8: Rudders*
- *Part 9: Sailing boats — Appendages and rig attachment*

Introduction

The reason underlying the preparation of this part of ISO 12215 is that standards and recommended practices for loads on the hull and the dimensioning of small craft differ considerably from one to another, thus limiting the general worldwide acceptability of boat scantlings. This part of ISO 12215 has been set towards the lower boundary of the range of current practice.

The objective of this part of ISO 12215 is to achieve an overall structural strength that ensures the watertight and weathertight integrity of the craft. It is intended to be a tool to assess the scantlings of a craft against lower bound practice and it is not intended to be a structural design procedure.

The scantling requirements are based principally on providing adequate local strength. Serviceability issues such as deflection under normal operating loads, global strength and its connected shell and deck stability are not addressed. The criteria contained within may need to be supplemented by additional considerations deemed necessary by the designer of the structure.

The mechanical property data supplied as default values make no explicit allowance for deterioration in service nor provide any guarantee that these values can be obtained for any particular craft. The responsibility for the decision to use this part of ISO 12215 as part of the design procedure rests solely with the designer and/or manufacturer.

The design pressures given in this part of ISO 12215 are only used with the given equations.

Considering future development in technology and boat types and small craft currently outside the scope of this part of ISO 12215, provided methods supported by appropriate technology exist, consideration may be given to their use provided equivalent support for this part of ISO 12215 is achieved.

The dimensioning according to this part of ISO 12215 is regarded as reflecting current practice, provided the craft is correctly handled in the sense of good seamanship and operated at a speed appropriate to the prevailing sea state.

A1 This part of ISO 12215 was developed with the aim of creating the lightest but strongest scantlings, applicable to all types of small craft across the globe. The universal approach resulted in a comprehensive document, but for users with little mathematical knowledge may be well perceived as too difficult or requiring the purchase of software or hiring consultants. Annex A of this part of ISO 12215 includes a simplified method to determine scantlings, but its application is very limited [sailing craft of categories C and D of length of hull (L_H) < 9 m].

With the intention of ISO/TC 188 standards being widely usable, interested stakeholders have developed a user-friendly software application of ISO 12215-5 for six modules, covering glass-reinforced plastics (GRP), steel and aluminium, sailing and power boats, using Microsoft Excel. The calculation spreadsheet presented here assists in determining scantlings for craft in design categories A – C up to $L_H = 12$ m and category D up to $L_H = 24$ m. The calculation spreadsheet is not a stand-alone software product; it works as an application guide to the main standard leading through the relevant clauses of this part of ISO 12215. From the beginning of its development, it was proposed to be implemented in the standard. It is distributed as an application of the standard.

See Annex A for further details and a link to software. **A1**

Important notice:

- 1) ISO/TC 188/WG 18 believes that this part of ISO 12215 is the best that can be achieved at the time of publication. It has therefore decided to publish this document as an ISO Standard. It is anticipated that wider usage may reveal a number of issues that require modification. It is for this reason that WG 18 has asked for a revision of the document at the same time as its publication. This revision agreement will enable the group to amend this part of ISO 12215 quickly should this prove necessary.
- 2) In furtherance of this, this part of ISO 12215 needs to be applied with a critical mind, and users are invited to report to the TC secretariat, or national standardization body, any items that are considered to require correction, together with supporting evidence, be that theoretical or based on satisfactory, long-term service experience with actual boats operating in the appropriate design category sea states.

Small craft — Hull construction and scantlings —

Part 5:

Design pressures for monohulls, design stresses, scantlings determination

1 Scope

This part of ISO 12215 applies to the determination of design pressures and stresses, and to the determination of the scantlings, including internal structural members of monohull small craft constructed from fibre-reinforced plastics, aluminium or steel alloys, glued wood or other suitable boat building material, with a length of hull, L_H , in accordance with ISO 8666, between 2,5 m and 24 m. It only applies to boats in the intact condition.

It only applies to craft with a maximum speed ≤ 50 knots in m_{LDC} conditions.

The assessment shall generally include all parts of the craft that are assumed watertight or weathertight when assessing stability, freeboard and buoyancy in accordance with ISO 12217 and are essential to the safety of the craft and of persons on board.

For the complete scantlings of the craft, this part of ISO 12215 is used in conjunction with Part 6, for details, Part 7 for multihulls, Part 8 for rudders and Part 9 for appendages and rig attachment.

The scantling determination of windows, portlights, deadlights, hatches and doors, is in accordance with ISO 12216. The structure supporting these elements is in accordance with this part of ISO 12215.

NOTE 1 Scantlings derived from this part of ISO 12215 are primarily intended to apply to recreational craft including recreational charter vessels and may not be suitable for performance racing craft.

NOTE 2 This part of ISO 12215 is based on the assumption that scantlings are governed solely by local loads.

NOTE 3 The scantling requirements of this part of ISO 12215 are considered to correspond to the minimum strength requirements of motor and sailing craft which are operated in a safe and responsible manner, having due cognisance of the prevailing conditions.

Pressures and stresses are normally expressed in pascals, kilopascals or megapascals. For the purposes of a better understanding for the users of this part of ISO 12215, the pressures are expressed in kilonewtons per square metre ($1\text{ kN/m}^2 = 1\text{ kPa}$) and stresses or elastic moduli are expressed in newtons per square millimetre ($1\text{ N/mm}^2 = 1\text{ MPa}$).

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 178, *Plastics — Determination of flexural properties*

ISO 527-1, *Plastics — Determination of tensile properties — Part 1: General principles*

ISO 527-2, *Plastics — Determination of tensile properties — Part 2: Test conditions for moulding and extrusion plastics*

ISO 844, *Rigid cellular plastics — Determination of compression properties*

ISO 845, *Cellular plastics and rubbers — Determination of apparent density*

ISO 1922, *Rigid cellular plastics — Determination of shear strength*

ISO 8666:2002, *Small craft — Principal data*

ISO 12215-3, *Small craft — Hull construction and scantlings — Part 3: Materials: Steel, aluminium alloys, wood, other materials*

ISO 12215-6, *Small craft — Hull construction and scantlings — Part 6: Structural arrangements and details*

ISO 12215-7, *Small craft — Hull construction and scantlings — Part 7: Scantling determination of multihulls*

ISO 12215-9, *Small craft — Hull construction and scantlings — Part 9: Sailing craft appendages*

ISO 12216, *Small craft — Windows, portlights, hatches, deadlights and doors — Strength and watertightness requirements*

ISO 12217 (all parts), *Small craft — Stability and buoyancy assessment and categorization*

ASTM C393, *Standard Test Method for Flexural Properties of Sandwich Constructions*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1 design categories

sea and wind conditions for which a boat is assessed by this part of ISO 12215 to be suitable, provided the craft is correctly handled in the sense of good seamanship and operated at a speed appropriate to the prevailing sea state

3.1.1 design category A (“ocean”)

category of boats considered suitable to operate in seas with significant wave heights above 4 m and wind speeds in excess of Beaufort Force 8, but excluding abnormal conditions, e.g. hurricanes

NOTE For the application of this part of ISO 12215, the calculation wave height is 7 m.

3.1.2 design category B (“offshore”)

category of boats considered suitable to operate in seas with significant wave heights up to 4 m and winds of Beaufort Force 8 or less

3.1.3 design category C (“inshore”)

category of boats considered suitable to operate in seas with significant wave heights up to 2 m and a typical steady wind force of Beaufort Force 6 or less

3.1.4

design category D ("sheltered waters")

category of boats considered suitable to operate in waters with significant wave heights up to and including 0,3 m with occasional waves of 0,5 m height, for example from passing vessels, and a typical steady wind force of Beaufort Force 4 or less

3.2

loaded displacement mass

m_{LDC}

mass of the craft, including all appendages, when in the fully loaded ready-for-use condition as defined in ISO 8666

3.3

sailing craft

craft for which the primary means of propulsion is wind power, having $A_S > 0,07(m_{LDC})^{2/3}$ where A_S is the total profile area of all sails that may be set at one time when sailing close hauled, as defined in ISO 8666 and expressed in square metres

NOTE In the rest of this part of ISO 12215, non-sailing craft are considered as motor craft.

3.4

second moment of area

I

for a homogeneous material, it is the sum of the component areas multiplied by the square of the distance from centre of area of each component area to the neutral axis, plus the second moment of area of each component area about an axis passing through its own centroid, and is expressed in centimetres to the fourth or millimetres to the fourth

NOTE The second moment of area is also referred to in other documentation as the moment of inertia and for brevity as "second moment" within this part of ISO 12215.

3.5

section modulus

SM

for a homogeneous material, it is the second moment of area divided by the distance to any point from the neutral axis at which the stress is to be calculated and is expressed in cubic centimetres or cubic millimetres

NOTE The minimum section modulus is calculated to the furthest point from the neutral axis.

3.6

displacement craft

craft whose maximum speed in flat water and m_{LDC} conditions, declared by its manufacturer, is such that

$$\frac{V}{\sqrt{L_{WL}}} < 5$$

3.7

displacement mode

mode of running of a craft in the sea such that its mass is mainly supported by buoyancy forces

NOTE This is the case if the actual speed in a seaway and m_{LDC} conditions is such that its speed:length ratio makes the craft behave as a displacement craft.

3.8

planing craft

craft whose maximum speed in flat water and m_{LDC} conditions, declared by its manufacturer, is such that

$$\frac{V}{\sqrt{L_{WL}}} \geq 5$$

NOTE This speed:length ratio limit has been arbitrarily set up in this part of ISO 12215, but it may vary from one boat to another according to hull shape and other parameters.

3.9 planing mode
mode of running of a craft in the sea such that its mass is significantly supported by forces coming from dynamic lift due to speed in the water

- NOTE 1 A planing craft in calm water will run in planing mode.
- NOTE 2 A planing craft may be obliged to significantly reduce its speed when the sea gets worse, running in that case in displacement mode.

4 Symbols

Unless specifically otherwise defined, the symbols shown in Table 1 are used in this part of ISO 12215.

NOTE The symbols are shown in alphabetic order, not in order of appearance.

Table 1 — Symbols, factors, parameters

Symbol	Unit	Designation/meaning of symbol	Reference/subclause concerned
Principal craft data			
A_S	m	Sail area in accordance with ISO 8666	ISO 8666
B_C	m	Chine beam	6.1
B_H	m	Beam of the hull	ISO 8666
B_{WL}	m	Beam of the fully loaded waterline at m_{LDC}	ISO 8666
D_b	m	Depth of bulkhead	11.8.1
L_H	m	Length of the hull	ISO 8666, 6.1
L_{WL}	m	Length of the fully loaded waterline at m_{LDC}	ISO 8666, 6.1
V	knots	Maximum speed at m_{LDC}	6.1
h_b	m	Load head for watertight bulkhead or integral tank	8.3
m_{LDC}	kg	Loaded displacement mass of the craft	3.2
$\beta_{0,4}$	°	Deadrise angle at 0,4 L_{WL} forward of its aft end	6.1, 7.3
Panel or stiffener dimensions			
A_D	m ²	Design area under consideration	7.5.1
b	mm	Shorter dimension of plate panel	9.1, 10
b_e	mm	Effective extent of plating connected to a stiffener	11.6
c	mm	Crown of a curved panel	10.1.3
c_u	mm	Crown of a curved stiffener	11.2.1
h	m	Height of centre of panel or mid stiffener above W_L	7.6
l	mm	Longer dimension of plate panel	9.1.2
l_u	mm	Unsupported span of stiffener or frame	9.2.2
s	mm	Stiffener or frame spacing	9.2.1
x	m	Distance of mid panel or stiffener from of aft end of L_{WL}	7.4
Z	m	Height of top of hull or deck angle above W_L	7.6
Calculation data: factor, pressures, parameters, stresses			
A_W	cm ²	Shear area cross-section	11.4.1
I	cm ⁴ , mm ⁴	Second moment of area	11.4.2

Table 1 (continued)

Symbol	Unit	Designation/meaning of symbol	Reference/subclause concerned
k_{AR}	1	Area pressure reduction factor	7.5
$k_{AR \text{ MIN}}$	1	Minimum value for k_{AR}	7.5
k_{AS}	1	Stiffener shear force correction in Table 21	11.7.2
k_C	1	Curvature correction factor for plating	10.1.3
k_{CS}	1	Curvature correction factor for stiffeners	11.2.1
k_{DC}	1	Design category factor	7.2
k_L	1	Longitudinal pressure distribution factor	7.4
k_R	1	Structural component and boat type factor	7.5
k_{SA}	1	Stiffener shear area factor	11.2.2
k_{SHC}	1	Shear strength aspect ratio factor	10.5.4
k_{SLS}	1	Light and stable sailboat pressure correcting factor for slamming	7.8
k_{SM}	1	Stiffener bending moment correction in Table 21	11.7.2
k_{SUP}	1	Superstructure pressure reduction factor	7.7
k_Z	1	Vertical pressure distribution factor	7.6
k_1	1	Bending stiffness factor for sandwich	10.1.1
k_2	1	Panel aspect ratio factor for bending strength	10.1.2
k_3	1	Panel aspect ratio factor for bending stiffness	10.1.2
k_4	1	Sandwich minimum skin location factor	10.5.6
k_5	1	Sandwich fibre factor	10.5.6
k_6	1	Sandwich core factor	10.5.6
k_7, k_8	1	Minimum thickness factors	10.6.2
n_{CG}	1	Dynamic load factor	7.3
$P_{BM \text{ MIN}}$	kN/m ²	Motorcraft bottom minimum pressure (planing or displacement)	8.1.2, 8.1.3
P_{BMD}	kN/m ²	Motorcraft bottom pressure in displacement mode	8.1.2
$P_{BMD \text{ BASE}}$	kN/m ²	Motorcraft base bottom pressure in displacement mode	8.1.2
P_{BMP}	kN/m ²	Motorcraft bottom pressure in planing mode	8.1.3
$P_{BMP \text{ BASE}}$	kN/m ²	Motorcraft base bottom pressure in planing mode	8.1.3
P_{SMD}	kN/m ²	Motorcraft side pressure in displacement mode	8.1.4
P_{SMP}	kN/m ²	Motorcraft side pressure in planing mode	8.1.5
$P_{SM \text{ MIN}}$	kN/m ²	Minimum motorcraft side pressure (displacement or planing mode)	8.1.4, 8.1.5
P_{DM}	kN/m ²	Motorcraft deck pressure	8.1.6
$P_{DM \text{ BASE}}$	kN/m ²	Motorcraft deck base pressure	8.1.6
$P_{DM \text{ MIN}}$	kN/m ²	Minimum motorcraft deck pressure	8.1.6
$P_{SUP \text{ M}}$	kN/m ²	Motorcraft superstructure pressure	8.1.7
P_{BS}	kN/m ²	Sailing craft bottom pressure	8.2.1
$P_{BS \text{ BASE}}$	kN/m ²	Sailing craft bottom base pressure	8.2.1
$P_{BS \text{ MIN}}$	kN/m ²	Minimum sailing craft bottom pressure	8.2.1

Table 1 (continued)

Symbol	Unit	Designation/meaning of symbol	Reference/subclause concerned
P_{SS}	kN/m ²	Sailing craft side pressure	8.2.2
$P_{SS\ MIN}$	kN/m ²	Minimum sailing craft side pressure	8.2.2
P_{DS}	kN/m ²	Sailing craft deck pressure	8.2.3
$P_{DS\ BASE}$	kN/m ²	Sailing craft deck base pressure	8.2.3
$P_{DS\ MIN}$	kN/m ²	Minimum sailing craft deck pressure	8.2.3
$P_{SUP\ S}$	kN/m ²	Sailing craft superstructure pressure	8.2.4
P_{WB}	kN/m ²	Design pressure, watertight boundaries	8.3.1
P_{TB}	kN/m ²	Design pressure, integral tank boundaries	8.3.2
q	N/mm	Shear flow	H.2.1.7, H.3.2
Q	cm ³ , mm ³	First moment of area	11.4.1
SM	cm ³ , mm ³	Section modulus	11.4.1
σ_d	N/mm ²	Design direct stress	10
σ_u	N/mm ²	Ultimate strength (flexural, compressive, tensile)	10
τ_d	N/mm ²	Design shear stress	10.5.4, 11
τ_u	N/mm ²	Ultimate shear strength	10.5.4, 11
E	N/mm ²	Elasticity modulus (flexural, compressive, tensile)	10.5, 11
w	kg/m ²	Dry fibre reinforcement mass per square metre	10.2.2, 10.5.6
ψ	1	Glass content in mass	Annex A, Annex C
ϕ	1	Glass content in volume	Annex A, Annex C
Other variables contained in annexes are not listed in this table.			

5 General

The scantling determination shall be accomplished as follows:

- for craft with a length L_H of 2,5 m up to 24 m, in accordance with Clauses 6 to 11;
- for sailing craft with a length L_H of 2,5 m up to 9 m of design categories C and D, in accordance with Annex A for plating;
- for craft with a length L_H of 2,5 m up to 6 m and of single-skin construction, the drop test in Annex B may be used as an alternative to the main body of this part of ISO 12215.

NOTE 1 These scantling requirements are based on normal anticipated sea loads during normal usage. Compliance with these requirements does not eliminate the possibility of damage from accidental overloads, careless handling, trailing loads, chocking loads, grounding or berthing. In some instances the requirements may come out lower than fabrication requirements such as welding ability, and should therefore be increased accordingly. For craft < 6 m, in particular, robustness criteria may be the governing aspect for scantling determination, e.g. beaching, grounding, trailer and fender loads. See 10.5.6 and 10.6.

NOTE 2 Annex A is applicable mainly to small, lightweight inshore sailing boats and sailing dinghies that might otherwise find the scantlings from other sections too conservative, but is only available for plating thickness assessment.

NOTE 3 If an annex is used as an alternative to Clauses 6 to 11, the boat builder shall still refer to parts 7 (multihulls), 8 (rudders) and 9 (appendages and rig attachment) of ISO 12215, as appropriate, in addition to using the particular annex.

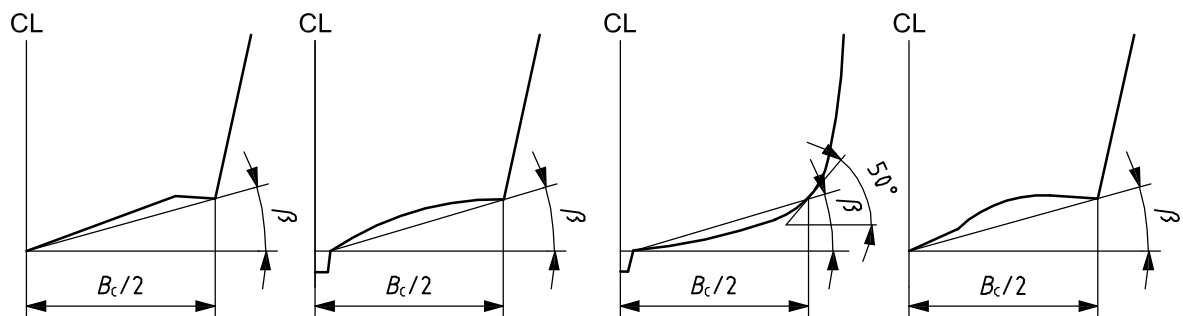
6 Dimensions, data and areas

6.1 Dimensions and data

All dimensions are measured, unless otherwise specified, in accordance with ISO 8666, with the craft in the fully loaded condition, with a mass m_{LDC} (expressed in kilograms) as defined in 3.2.

The main dimensions are

- L_H , the hull length in metres,
- L_{WL} , the length of the waterline, craft at rest in m_{LDC} conditions, in metres,
- B_C , the chine beam, measured in accordance with Figure 1, at $0,4 L_{WL}$ forward of its aft end, in metres,
- $\beta_{0,4}$, the deadrise angle at $0,4 L_{WL}$ forward of its aft end, measured according to Figure 1, not to be taken $< 10^\circ$, nor $> 30^\circ$, in degrees,
- V , for motor craft, the maximum speed in calm water declared by the manufacturer, with the craft in m_{LDC} conditions. This speed shall not be taken as $< 2,36\sqrt{L_{WL}}$. For sailing craft, speed does not need to be declared in knots.



NOTE For round bilge, the outer limit or chine is considered at the point where a tangent at 50° from the horizontal is tangent to the hull.

Figure 1 — Measurement of chine beam, B_C , and deadrise angle, β

6.2 Areas

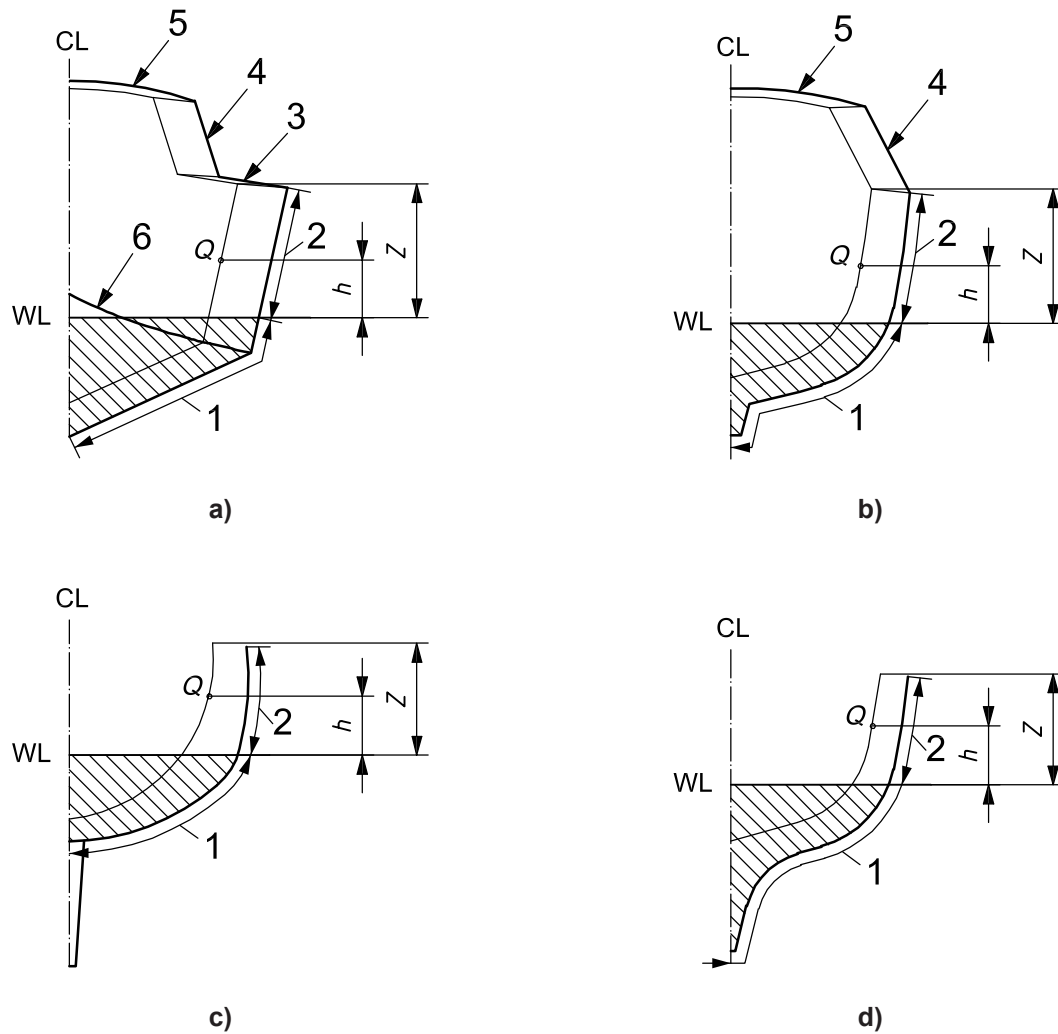
6.2.1 General

The hull, deck and superstructure are divided into various areas: bottom, side, decks and superstructures (see Figure 2).

6.2.2 Bottom areas

For all craft, bottom pressure applies up to waterline (see Figure 2).

The part of the transom following the above definition is considered as bottom.



Key

- 1 bottom (hatched area)
- 2 side
- 3 deck
- 4 superstructures
- 5 superstructure top
- 6 hard chine

Figure 2 — Definitions of areas, and panel height above waterline

6.2.3 Side areas

The extent of the side pressure area, which includes the transom, is the part of the hull not considered as belonging to the bottom area.

6.2.4 Decks and superstructures

Deck areas are parts of the deck exposed to weather and where persons are liable to walk. Cockpit bottom and top of benches and seating areas are included.

Superstructure areas include all areas above deck level. Table 4 lists the different superstructure types.

6.2.5 Panel fully in one area or across two areas

The general situation is as follows:

- 1) where the plate panel or stiffener is fully within a specified design area, e.g. bottom, side, deck, superstructures, etc., its design pressure shall be determined at the middle of the panel or at mid-length of the stiffener;
- 2) where the plate panel or stiffener extends over both bottom area and side area, its design pressure shall be determined as a constant pressure over the entire design area, calculated as a weighted average between the two pressures, as shown in the following example.

EXAMPLE For a sailboat panel that lies 30 % in the bottom area and 70 % in the side area, the average pressure is $0,3 P_b + 0,7 P_s$, where P_s is obtained at the midpoint of that part of the panel which lies above the waterline.

CAUTION — According to 8.1.1, for categories A and B planing motor craft, the side panels and stiffeners shall be analysed both in planing and displacement mode, using the worst case. If the chine is below waterline, the side panel is across side and bottom [see Figure 2 a)]. In that case, method 2) above shall be used.

For large panels, see also 10.1.4.

7 Pressure adjusting factors

7.1 General

Final design pressure is adjusted by a set of factors according to design, boat type, location, etc.

7.2 Design category factor k_{DC}

The design category factor k_{DC} , defined in Table 2, takes into account the variation of pressure loads due to sea with design category.

Table 2 — Values of k_{DC} according to design category

Design category	A	B	C	D
Value of k_{DC}	1	0,8	0,6	0,4

7.3 Dynamic load factor n_{CG}

7.3.1 General

The dynamic load factor n_{CG} is considered to be close to the single amplitude acceleration measured at the craft centre of gravity at the relevant frequency for a certain period of time. This factor is the negative acceleration supported by the craft, either while slamming in an encountered wave at speed or falling from the crest of a wave into its trough. n_{CG} is expressed in g s where $1g$ is the acceleration due to gravity ($9,81 \text{ m/s}^2$).

7.3.2 Dynamic load factor n_{CG} for planing motor craft in planing mode

The dynamic load factor for planing craft running in planing mode shall be determined from Equation (1) or Equation (2).

$$n_{CG} = 0,32 \left(\frac{L_{WL}}{10 \times B_C} + 0,084 \right) \times (50 - \beta_{0,4}) \times \frac{V^2 \times B_C^2}{m_{LDC}} \quad (1)$$

where all data are previously defined.

NOTE 1 Equation (1) is derived from practical tests and is therefore not required to be dimensionally correct.

Where Equation (1) gives an n_{CG} value $\leq 3,0$, the value given by Equation (1) shall be used.

Where Equation (1) gives an n_{CG} value $> 3,0$, that value or the value from Equation (2) shall be used.

$$n_{CG} = \frac{0,5 \times V}{m_{LDC}^{0,17}} \quad (2)$$

In any case, n_{CG} need not be taken > 7 .

NOTE 2 The limitation on n_{CG} in this paragraph is due to the limitation of speed by the crew to keep the slamming accelerations within acceptable comfort and safety limits. The crew of "super sports" or racing boats accept a harder ride than a family cruiser, but need special body support, shock damping seats or equipment to prevent injury from high gs.

7.3.3 Dynamic load factor n_{CG} for sailing craft and displacement motor craft

For sailing craft, n_{CG} is not used for pressure determination. It is only used in the calculation of k_L for which purpose the value of n_{CG} shall be taken as 3. For motor craft where n_{CG} , determined using Equation (1), is $< 3,0$ from Equation (1), a value of 3,0 shall still be used for calculation of k_L .

7.4 Longitudinal pressure distribution factor k_L

The longitudinal pressure distribution factor k_L takes into account the variation of pressure loads due to location on the craft. It shall be taken from Figure 3 or calculated from Equation (3).

k_L is a function of the dynamic load factor defined below for motor craft.

$$k_L = \frac{1 - 0,167 \times n_{CG}}{0,6} \frac{x}{L_{WL}} + 0,167 \times n_{CG} \text{ but not taken } > 1 \text{ for } \frac{x}{L_{WL}} \leq 0,6 \quad (3)$$

$$k_L = 1 \text{ for } \frac{x}{L_{WL}} > 0,6$$

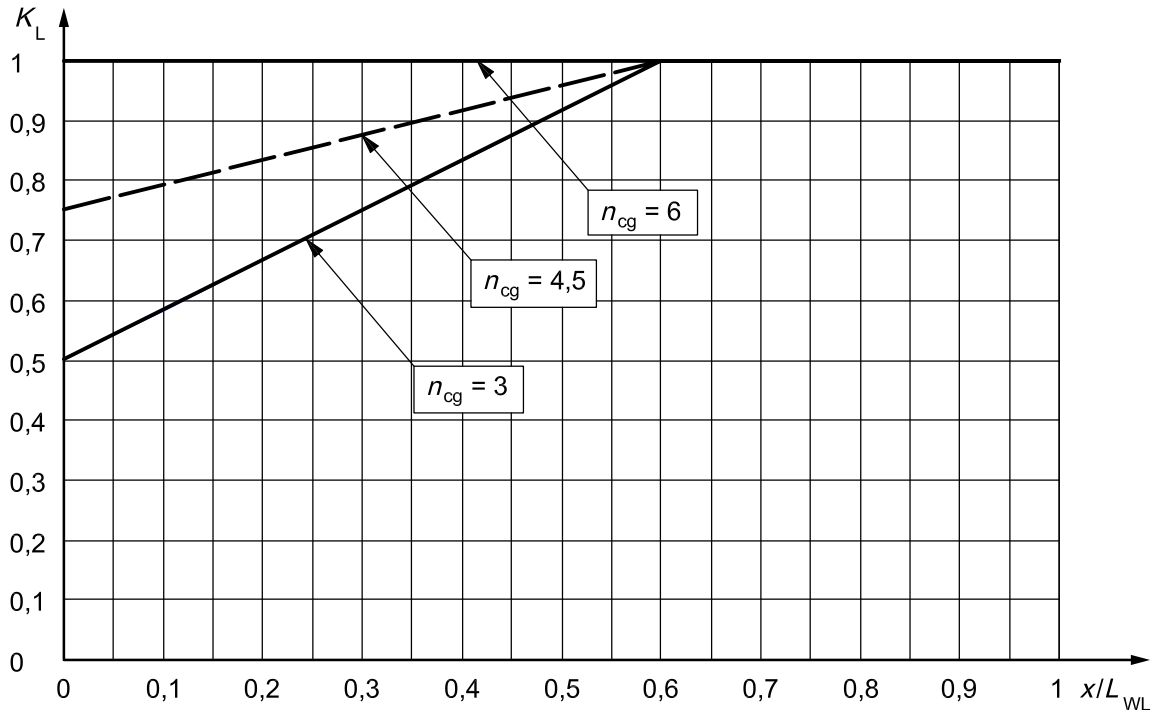
where

n_{CG} is determined in accordance with 7.3, but for the purposes of determination of k_L , n_{CG} shall not be taken < 3 nor > 6 ;

$\frac{x}{L_{WL}}$ is the position of the centre of the panel or middle of stiffener analysed proportional to L_{WL} , where $\frac{x}{L_{WL}} = 0$ and 1 are respectively the aft end and fore end of L_{WL} .

where x is the longitudinal position of the centre of the panel or middle of stiffener forward of aft end of L_{WL} in m_{LDC} conditions, in metres.

The overhangs fore and aft shall have the same value of k_L as their respective end of the waterline.



NOTE In the graph the only represented intermediate value of n_{CG} between 3 and 6 is 4,5; for other intermediate values, k_L shall be determined either by calculation according to Equation (3) or by interpolation in the graph.

Figure 3 — Longitudinal pressure distribution factor k_L

7.5 Area pressure reduction factor k_{AR}

7.5.1 General

The area pressure reduction factor k_{AR} takes into account the variation of pressure loads due to panel or stiffener size.

$$k_{AR} = \frac{k_R \times 0,1 \times m_{LDC}^{0,15}}{A_D^{0,3}} \quad (4)$$

where

k_R is the structural component and boat type factor:

$k_R = 1,0$ for bottom side and deck panels and stiffeners of planing motor craft operating in planing mode;

$k_R = 1,5 - 3 \times 10^{-4} \times b$ for bottom side and deck panels of sailing craft, displacement motor craft and planing motor craft operating in displacement mode;

$k_R = 1 - 2 \times 10^{-4} \times l_u$ for bottom side and deck stiffeners of sailing craft, displacement motor craft and planing motor craft operating in displacement mode;

m_{LDC} is the loaded displacement mass defined in 3.2, in kilograms;

A_D is the design area, in square metres:

$$A_D = (l \times b) \times 10^{-6} \text{ for plating, but shall not be taken } > 2,5 \times b^2 \times 10^{-6};$$

$$A_D = (l_u \times s) \times 10^{-6} \text{ for stiffeners but need not be taken } < 0,33 \times l_u^2 \times 10^{-6};$$

b is the shorter dimension of the panel, as defined in 9.1.1, in millimetres;

l is the longer dimension of the panel, as defined in 9.1.2, in millimetres;

s is the stiffener spacing, as defined in 9.2.1, in millimetres;

l_u is the unsupported span of a stiffener, as defined in 9.2.2, in millimetres.

7.5.2 Maximum value of k_{AR}

k_{AR} shall not be taken > 1 .

7.5.3 Minimum values of k_{AR}

k_{AR} shall not be taken at less than the values given in Table 3.

Table 3 — Minimum values of k_{AR}

Design category	Side and bottom single-skin panels and stiffeners Deck and superstructures sandwich and single-skin panels and stiffeners	Side and bottom sandwich panels ^a		
		$\frac{x}{L_{WL}} \leq 0,4$	$0,4 < \frac{x}{L_{WL}} < 0,6$	$\frac{x}{L_{WL}} \geq 0,6$
A	0,25 any craft hull and deck	0,4 any craft	Interpolation between values at $\frac{x}{L_{WL}} = 0,4$ and $0,6$	0,5 sail bottom and topside 0,5 motor bottom 0,4 motor topside
B	0,25 any craft hull and deck	0,4 any craft		0,4 any craft
C & D	0,25 any craft hull and deck	0,4 any craft		

^a Minimum k_{AR} applies to bending or shear strength and deflection requirement.

7.6 Hull side pressure reduction factor k_Z

The side pressure reduction factor k_Z interpolates the pressure of the hull side between the (bottom) pressure at waterline and deck pressure at the top edge (see Figure 2).

$$k_Z = \frac{Z - h}{Z} \quad (5)$$

where

Z is the height of top of hull or hull/deck limit above the fully loaded waterline, in metres;

h is the height of centre of panel or middle of stiffener above the fully loaded waterline, in metres.

The height of top of hull or hull/deck limit is the one at the longitudinal location under consideration.

7.7 Superstructure and deckhouse pressure reduction factor k_{SUP}

The superstructure and deckhouse pressure reduction factor k_{SUP} is defined according to location and boat type by Table 4.

Table 4 — Values of k_{SUP} for superstructures and deckhouses

Position of panel	k_{SUP} motor and sail	Application
Front	1	Any area
Side	0,67	Walking area
Side	0,5	Non-walking area
Aft end	0,5	Any area
Top, ≤ 800 mm above deck	0,5	Walking area
Top, > 800 mm above deck and upper tiers	0,35	Walking area
Upper tiers ^a	Minimum deck pressure 5 kN/m ³	Non-walking area
^a Elements not exposed to weather shall be considered as upper tiers.		

7.8 Light and stable sailing craft pressure correcting factor for slamming k_{SLS}

The light and stable sailing craft pressure correcting factor k_{SLS} takes into account higher slamming pressures encountered on light and stable sailing craft when sailing upwind (i.e at an angle of up to 90° off true wind). It is defined below.

— In design category C and D: $k_{\text{SLS}} = 1$

— In design category A and B:

— $k_{\text{SLS}} = 1$ if $m_{\text{LDC}} > 5 L_{\text{WL}}^3$

— $k_{\text{SLS}} = \left(\frac{10 GZ_{\text{MAX} < 60} \times L_{\text{WL}}^{0,5}}{m_{\text{LDC}}^{0,33}} \right)^{0,5}$ if $m_{\text{LDC}} \leq 5 L_{\text{WL}}^3$ but shall not be taken < 1 (6)

where $GZ_{\text{MAX} < 60}$ is the maximum righting moment lever taken at a heel angle not $> 60^\circ$, with all stability-increasing devices such as canting keels or water ballast at their most effective position, in fully loaded condition, measured in metres.

If the maximum righting lever occurs at a heel angle $> 60^\circ$, the value at 60° shall be taken. The crew shall be considered in upwind hiking position in the calculation of the above $GZ_{\text{MAX} < 60}$.

NOTE This factor is aimed at craft that are very stable for their displacement (water ballast, canting keels, heavy and deep ballast, etc.). The limitation of the heel angle at 60° is aimed at considering stability characteristics that may be acting on performances, i.e. at angles below 30° , and not "survival" stability at angles $> 60^\circ$.

8 Design pressures

8.1 Motor craft design pressure

8.1.1 General

The bottom pressure of motorcraft shall be the greater of (see NOTE 1)

- the displacement mode bottom pressure P_{BMD} defined in 8.1.2 or
- the planing mode bottom pressure P_{BMP} defined in 8.1.3.

For motorcraft of design categories A and B, the side pressure shall be the greater of (see NOTE 3)

- the displacement mode side pressure P_{SMD} defined in 8.1.4 or
- the planing mode side pressure P_{SMP} defined in 8.1.5.

For motorcraft of design categories C and D, the side pressure shall be the one corresponding to planing or displacement mode: the “mode” to consider is the one where the bottom pressure, planing or displacement is the greater (see NOTE 4).

NOTE 1 The reason behind this double requirement is that, in rough seas, craft that usually plane in flat water must progress at a slower speed in the same manner as a displacement craft.

NOTE 2 Craft well into the planing mode, $\left(\frac{V}{\sqrt{L_{\text{WL}}}} \geq 5 \right)$, will usually experience P_{BMP} values higher than P_{BMD} .

NOTE 3 In planing mode, the side pressure may be smaller than in displacement mode as, in the former case, the side pressure is interpolated between $0,25 P_{\text{BMP}}$ and deck pressure, whereas, in the latter case, the side pressure is interpolated between bottom pressure and deck pressure.

NOTE 4 In design category D there is little risk on having to slow down because of rough sea, and this risk is limited in category C.

8.1.2 Motor craft bottom pressure in displacement mode P_{BMD}

The bottom design pressure for motor craft in displacement mode P_{BMD} is the greater of

$$P_{\text{BMD}} = P_{\text{BMD BASE}} \times k_{\text{AR}} \times k_{\text{DC}} \times k_{\text{L}} \text{ kN/m}^2 \text{ or} \quad (7)$$

$$P_{\text{BMD MIN}} = 0,45 m_{\text{LDC}}^{0,33} + (0,9 \times L_{\text{WL}} \times k_{\text{DC}}) \text{ kN/m}^2 \quad (8)$$

$$\text{where } P_{\text{BMD BASE}} = 2,4 m_{\text{LDC}}^{0,33} + 20 \text{ kN/m}^2 \quad (9)$$

8.1.3 Motor craft bottom pressure in planing mode P_{BMP}

The bottom design pressure for planing motor craft P_{BMP} is the greater of

$$P_{\text{BMP}} = P_{\text{BMP BASE}} \times k_{\text{AR}} \times k_{\text{L}} \text{ kN/m}^2 \text{ or} \quad (10)$$

$$P_{\text{BMD MIN}} = 0,45 m_{\text{LDC}}^{0,33} + (0,9 \times L_{\text{WL}} \times k_{\text{DC}}) \text{ kN/m}^2 \text{ [same as Equation (8)]}$$

where $P_{\text{BMP BASE}} = \frac{0,1 m_{\text{LDC}}}{L_{\text{WL}} \times B_{\text{C}}} \times (1 + k_{\text{DC}}^{0,5} \times n_{\text{CG}})$ is the base bottom pressure for motorcraft, in planing mode, in kilonewtons per square metre (11)

NOTE The index of 0,5 on k_{DC} is there to reflect that, although some design category effect is present, this effect is attenuated in the planing mode. The reason is that peak planing pressure is mainly experienced in category C conditions and hence the difference between design categories is less marked than in the displacement mode.

8.1.4 Motor craft side pressure in displacement mode P_{SMD}

The side design pressure for motor craft in displacement mode P_{SMD} is the greater of

$$P_{\text{SMD}} = \left[P_{\text{DM BASE}} + k_{\text{Z}} \times (P_{\text{BMD BASE}} - P_{\text{DM BASE}}) \right] \times k_{\text{AR}} \times k_{\text{DC}} \times k_{\text{L}} \text{ kN/m}^2 \text{ or} \quad (12)$$

$$P_{\text{SM MIN}} = 0,9 L_{\text{WL}} \times k_{\text{DC}} \text{ kN/m}^2 \quad (13)$$

For decked boats, those parts of the side above hull-deck limit (e.g. bulwark) shall be assessed using $P_{\text{SM MIN}}$.

8.1.5 Motor craft side pressure in planing mode P_{SMP}

For side areas located at or above waterline, the side design pressure P_{SMP} for motor craft in planing mode is the greater of

$$P_{\text{SMP}} = \left[P_{\text{DM BASE}} + k_{\text{Z}} \times (0,25 \times P_{\text{BMP BASE}} - P_{\text{DM BASE}}) \right] \times k_{\text{AR}} \times k_{\text{DC}} \times k_{\text{L}} \text{ kN/m}^2 \text{ or} \quad (14)$$

$$P_{\text{SM MIN}} = 0,9 L_{\text{WL}} \times k_{\text{DC}} \text{ kN/m}^2 \text{ [same as Equation (13)]}$$

For decked boats, those parts of the side above hull-deck limit (e.g. bulwark) shall be assessed using $P_{\text{SM MIN}}$.

8.1.6 Motor craft deck pressure P_{DM}

The design pressure P_{DM} for the motor craft weather deck is the greater of

$$P_{\text{DM}} = P_{\text{DM BASE}} \times k_{\text{AR}} \times k_{\text{DC}} \times k_{\text{L}} \text{ kN/m}^2 \text{ or} \quad (15)$$

$$P_{\text{DM MIN}} = 5 \text{ kN/m}^2 \quad (16)$$

$$\text{where } P_{\text{DM BASE}} = 0,35 L_{\text{WL}} + 14,6 \text{ kN/m}^2 \quad (17)$$

8.1.7 Motor craft pressure for superstructures and deckhouses $P_{\text{SUP M}}$

The design pressure $P_{\text{SUP M}}$ for superstructures and deckhouses exposed to weather of motor craft is proportional to the deck pressure, but not to be taken less than $P_{\text{DM MIN}}$ in walking areas:

$$P_{\text{SUP M}} = P_{\text{DM BASE}} \times k_{\text{DC}} \times k_{\text{AR}} \times k_{\text{SUP}} \text{ kN/m}^2 \quad (18)$$

8.2 Sailing craft design pressure

8.2.1 Sailing craft bottom pressure

The bottom design pressure P_{BS} for sailing craft is the greater of

$$P_{BS} = P_{BS\text{ BASE}} \times k_{AR} \times k_{DC} \times k_L \text{ kN/m}^2 \text{ or} \quad (19)$$

$$P_{BS\text{ MIN}} = 0,35 m_{LDC}^{0,33} + 1,4 L_{WL} \times k_{DC} \text{ kN/m}^2 \quad (20)$$

$$\text{where } P_{BS\text{ BASE}} = (2 m_{LDC}^{0,33} + 18) \times k_{SLS} \text{ kN/m}^2 \quad (21)$$

8.2.2 Sailing craft side pressure P_{SS}

The side pressure for sailing craft P_{SS} is the greater of

$$P_{SS} = \left[(P_{DS\text{ BASE}} + k_Z \times (P_{BS\text{ BASE}} - P_{DS\text{ BASE}})) \right] \times k_{AR} \times k_{DC} \times k_L \text{ kN/m}^2 \text{ or} \quad (22)$$

$$P_{SS\text{ MIN}} = 1,4 L_{WL} \times k_{DC} \text{ but shall not be taken } < 5 \text{ kN/m}^2 \quad (23)$$

where

$P_{BS\text{ BASE}}$ is the base sailboat bottom pressure defined in 8.2.1;

$P_{DS\text{ BASE}}$ is the base sailboat deck pressure defined in 8.2.3.

8.2.3 Sailing craft deck pressure P_{DS}

The design pressure for the weather deck of sailing craft P_{DS} is the greater of

$$P_{DS} = P_{DS\text{ BASE}} \times k_{DC} \times k_{AR} \times k_L \text{ kN/m}^2 \text{ or} \quad (24)$$

$$P_{DS\text{ MIN}} = 5 \text{ kN/m}^2 \quad (25)$$

$$\text{where } P_{DS\text{ BASE}} = 0,5 m_{LDC}^{0,33} + 12 \text{ kN/m}^2 \quad (26)$$

8.2.4 Sailing craft superstructure pressure $P_{SUP\text{ S}}$

The design pressure $P_{SUP\text{ S}}$ for superstructures and deckhouses exposed to weather on sailing craft is proportional to the deck pressure, but not to be taken less than $P_{DS\text{ MIN}}$ in walking areas.

$$P_{SUP\text{ S}} = P_{DS\text{ BASE}} \times k_{AR} \times k_{DC} \times k_{SUP} \text{ kN/m}^2 \quad (27)$$

8.3 Watertight bulkheads and integral tank boundaries design pressure

8.3.1 Watertight bulkheads pressure P_{WB}

The design pressure P_{WB} on watertight bulkheads, where fitted, is

$$P_{WB} = 7 h_B \text{ kN/m}^2 \quad (28)$$

where

h_B is the water head, in metres, measured as follows (see Figure 4):

- for plating, the distance from a point 2/3 of the depth of the panel below the top of bulkhead;
- for vertical stiffeners, the distance from a point 2/3 of the depth of the stiffener below top of bulkhead;
- for horizontal stiffeners, the height measured from the stiffener to the top of bulkhead.

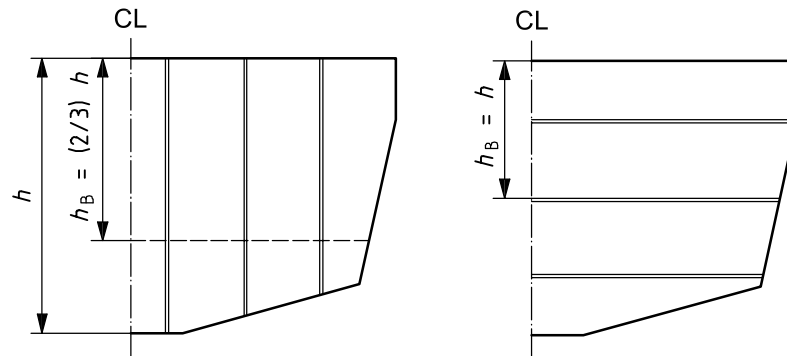


Figure 4 — Watertight bulkheads

8.3.2 Integral tank bulkheads and boundaries P_{TB}

The design pressure P_{TB} on integral tank bulkheads and boundaries is:

$$P_{TB} = 10 h_B \text{ kN/m}^2 \quad (29)$$

where

h_B is the water head, in metres, measured as follows (see Figure 5):

- for plating, the distance from a point 2/3 of the depth of the panel below top of tank or top of overflow, whichever is the greater;
- for vertical stiffeners, the distance from a point 2/3 of the depth of the stiffener below top of tank or top of the overflow, whichever is the greater;
- for horizontal stiffeners, the height measured from the stiffener to top of tank or top of overflow, whichever is the greater.

Where there are plates of different thicknesses or scantlings, h_B for each plate panel shall be measured to the lowest point of the panel.

For determination of the design pressure, the top of the overflow shall not be taken < 2 m above the top of the tank.

Where the tanks form part of the deck, this has to be assessed according to the requirements of this section.

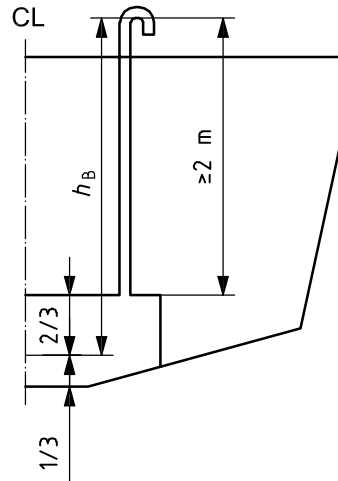


Figure 5 — Measurement of dimensions for integral tank scantling calculation

8.3.3 Wash plates

Tanks shall be subdivided as necessary by internal baffles or wash plates. Baffles or wash plates that support hull framing shall have scantlings equivalent to stiffeners located in the same position.

Wash plates and wash bulkheads shall, in general, have an area of perforation not $< 50\%$ of the total area of the bulkhead. The perforations shall be so arranged that the efficiency of the bulkheads as a support is not impaired.

The general stiffener requirement for both minimum section modulus and second moment of area may be 50% of that required for stiffener members of integral tanks.

8.3.4 Collision bulkheads

The scantlings of collision bulkheads, where fitted, shall not be less than required for integral tank bulkheads.

8.3.5 Non-watertight or partial bulkheads

Where a bulkhead is structural but non-watertight, the scantlings shall be as required in 11.8.

Bulkheads and partial bulkheads that are non-structural are outside the scope of this part of ISO 12215.

8.3.6 Transmission of pillar loads

Bulkheads that are required to act as pillars in the way of under-deck girders subjected to concentrated loads and other structures that carry heavy loads shall be dimensioned according to these loads. See ISO 12215-9 for mast step analysis for sailing craft.

8.4 Design pressures for structural components where k_{AR} would be $\leq 0,25$

The design pressures in 8.1 and 8.2 are intended to represent the dynamic load experienced by craft. The dynamic effect reduces as the structural component size increases. For very large structural components, the design pressure should be based on the hydrostatic pressure, since it is this load that can be reasonably taken as being distributed over the whole area of the component.

“Very large” components are defined as panels or stiffeners for which the product of the shorter and longer panel sides (panels) or the span and spacing (stiffeners) exceeds the following areas:

- for bottom structure, 30 % of the $L_{WL} \times B_{WL}$ product;
- for side structure, 30 % of the $L_{WL} \times D$ product, where D is the hull total depth;
- for deck structure, 30 % of the $L_{WL} \times B_{WL}$ product.

In such cases, irrespective of the pressure loads obtained from 8.1 and 8.2, the design pressures need not be taken greater than:

- for bottom structure, $0,45 m_{LDC}^{0,33}$, but not $< 5 \text{ kN/m}^2$; (30)
- for side structure, $0,3 m_{LDC}^{0,33}$, but not $< 5 \text{ kN/m}^2$; (31)
- for deck structure, 5 kN/m^2 . (32)

9 Dimensions of panels and stiffeners

9.1 Dimensions of plating panels

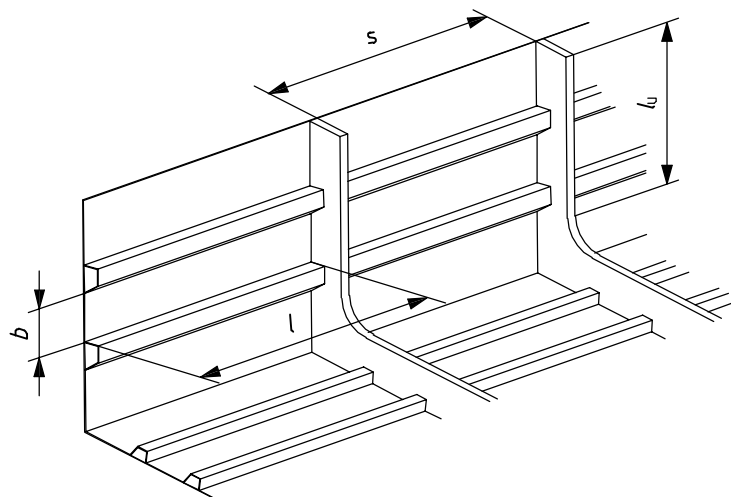


Figure 6 — Sketch explaining the dimensions in 9.1

9.1.1 Short dimension of the panel b

b is the short dimension of the panel between the two closest stiffeners, in millimetres.

In the case of top-hat stiffeners, it is the distance between the web base of a top hat and the web base of the closest top hat or stiffener [see Figure 7 a)].

If there are no definite stiffeners, or in the case of hard chine plating, see respectively 9.1.4 and 9.1.5.

9.1.2 Large dimension of the panel l

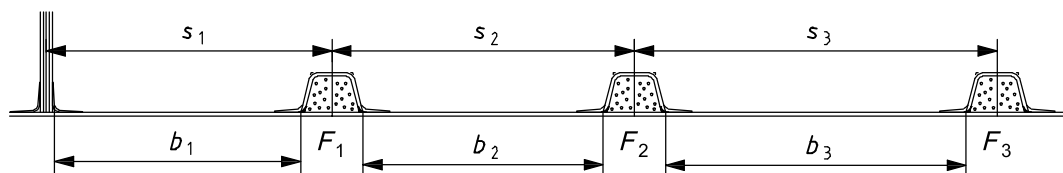
l is the large dimension of the panel between the two closest stiffeners, in millimetres.

In the case of top-hat stiffeners, it is the distance between the web base of a top hat and the web base of the closest top hat or stiffener [see Figure 7 c)].

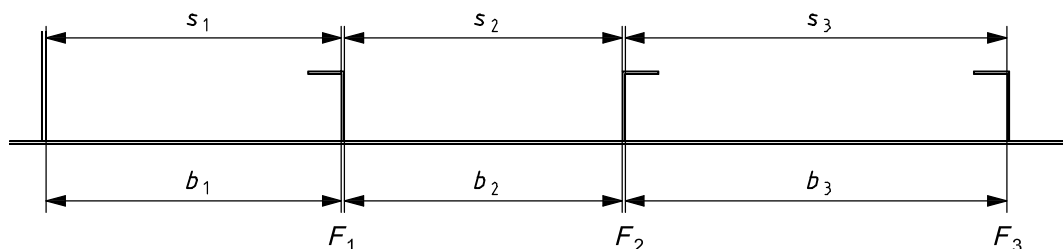
l need not be taken $> 330 \times L_H$, in millimetres.

9.1.3 Non-rectangular panels

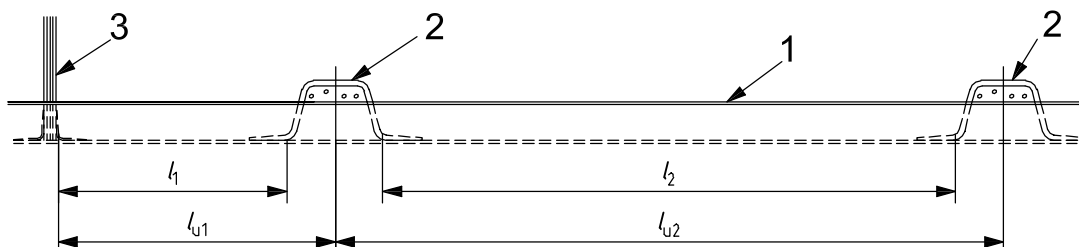
Non-rectangular panels shall be assessed using equivalent rectangular panels with dimensions $b \times l$, or $s \times l_u$. These equivalent rectangular panels shall be assessed on the basis of equal area to the actual panel. Figure 8 gives examples (hatched) of equivalent rectangular panels for a trapeze or a triangle.



a) Bulkhead and transversal top-hat stiffeners



b) L-shaped stiffeners in metallic construction



c) Continuous stringer between top-hat frames and a bulkhead. l_1 and l_2 are the unsupported lengths of the panels between stringers. l_{u1} and l_{u2} are the lengths of the stringer

Key

- 1 stringer
- 2 top-hat frame
- 3 bulkhead

Figure 7 — Examples of b , s , l and l_u measurements

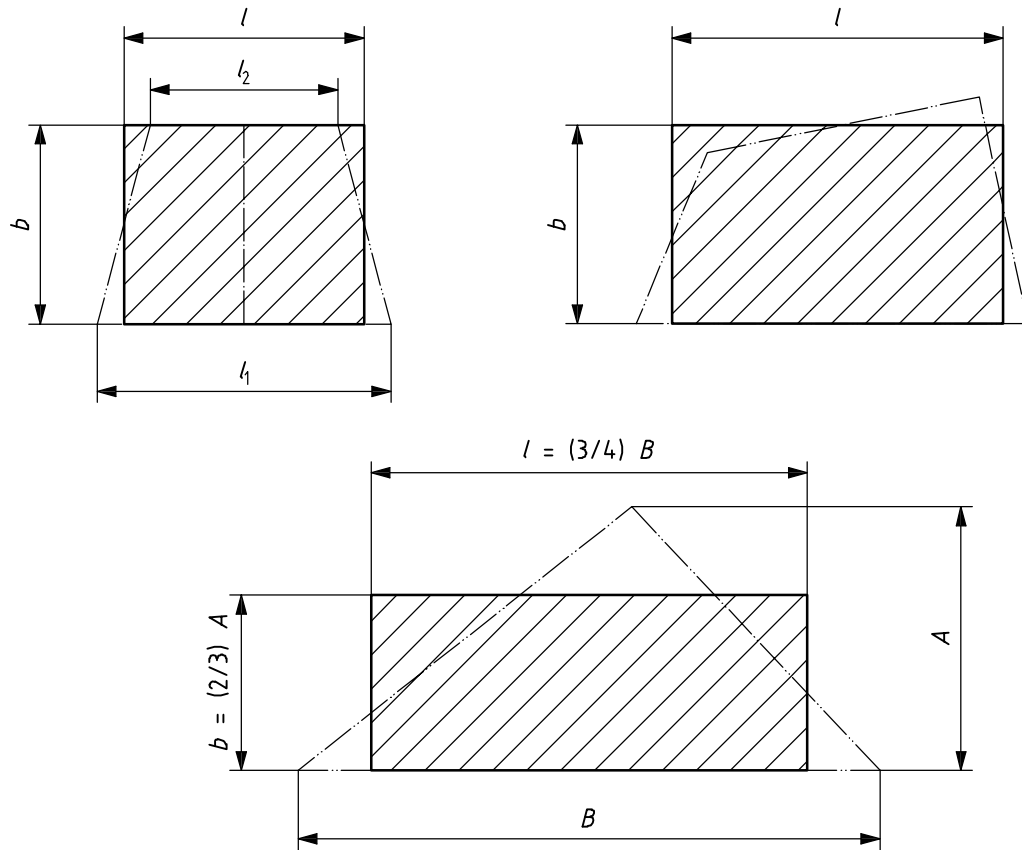


Figure 8 — Examples of equivalent rectangular panels with a trapeze or a triangle

9.1.4 Large panel assessment when there are no or few stiffeners

9.1.4.1 If there are obvious natural or dedicated stiffeners

Natural stiffeners are angled centreline, deck/hull angles, etc. There is a certain degree of interpretation, but natural stiffeners are normally the ones where the angle between two adjacent panels is $< 130^\circ$ with a hard angle or very small radius.

Dedicated stiffeners are stringers, girders, bunk edges, frames, liners, tray mouldings, etc.

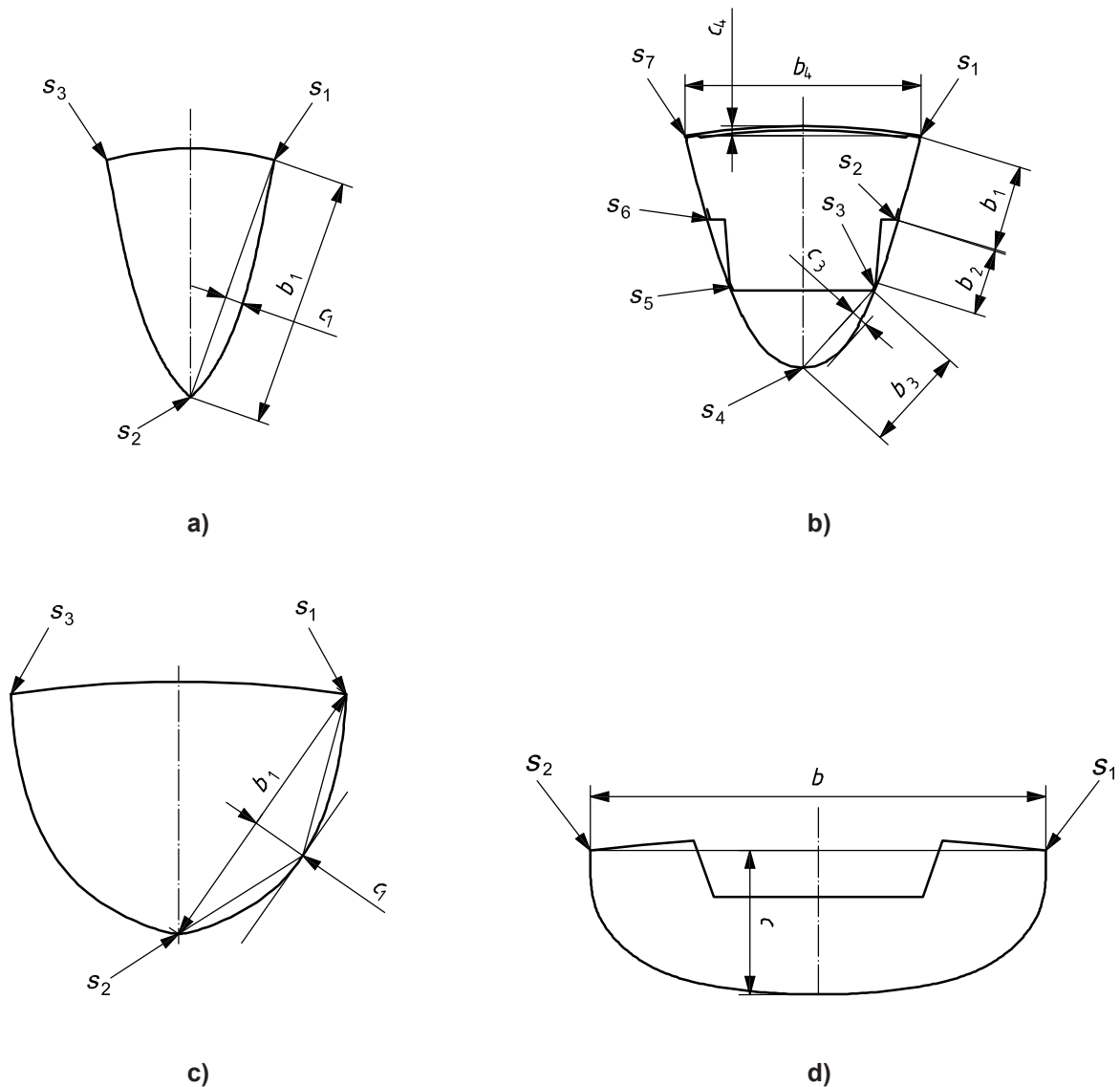
Figure 9 shows a variety of natural and dedicated stiffeners. Figures 9 a) and 9 c) show sections without dedicated natural stiffeners but with three natural stiffeners, s_1 , s_2 , s_3 , made by the hull deck joint and the centreline. In Figure 9 d), the centreline has no chine or V and cannot be considered as a stiffener, and there are only two natural stiffeners, the hull/deck angles. Figure 9 b) shows a section where the liner adds two dedicated stiffeners each side s_2 , s_3 , s_5 and s_6 .

9.1.4.2 Determination of the short dimension and curvature of a panel

Draw a straight line between the closest points of these stiffeners. Measure b and c , then calculate k_C according to Table 5 [see Figure 9 a), and b_1 , b_2 , b_3 and b_4 for the deck in Figure 9 b)].

9.1.4.3 Very wide panels

Find the minimum distance between the two closest “natural” stiffeners. In the case of Figure 9 d), the only natural stiffeners are the two deck/hull angles as the centreline is not stiff enough to be a natural stiffener. Measure the crown of the panel, c , and calculate k_C according to Table 6.



Key

$s_1, s_2, s_3, s_4, s_5, s_6, s_7$ are stiffeners

Figure 9 — Examples of panel size and curvature assessment

9.1.5 Panels between hard chines

The b dimensions are the dimensions between chines (see Figure 10).

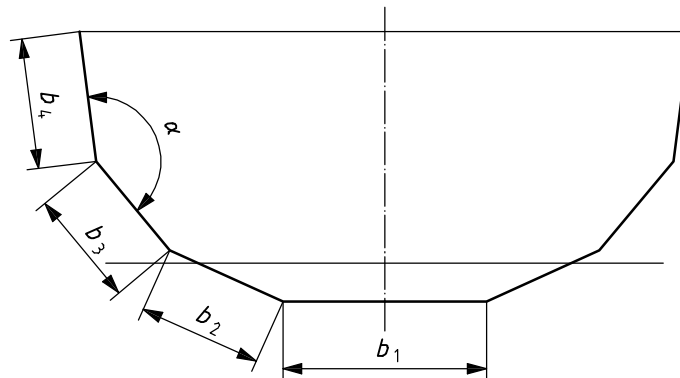


Figure 10 — Hard chine section

9.1.6 Characteristics of natural stiffeners

The above analysis is only valid if the “natural” stiffeners (round bilges, hard chines, etc.) are strong and stiff enough to be considered as proper stiffeners. This means that they shall fulfil the requirements of Clause 11 for stiffeners. The length of these natural stiffeners is their unsupported length between members such as bulkheads, floors and frames. As they are often curved, the factor k_C is usually helpful. The pressure limitation of 8.4 may also apply.

Chines with $130^\circ < \alpha < 150^\circ$ are generally considered to fulfil the above requirements.

Tables G.4 and G.5 give section modulus (see 3.5) values for some round bilges and hard chines.

9.2 Dimensions of stiffeners

9.2.1 Spacing of stiffeners s

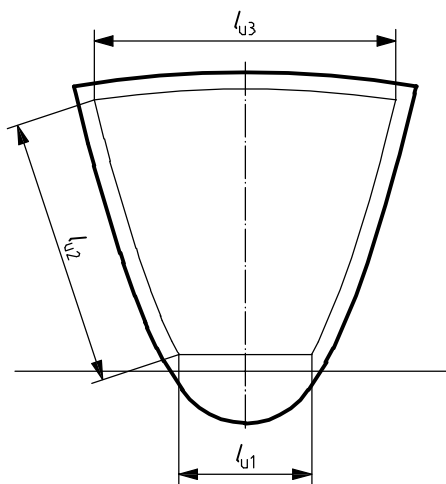
s is the spacing, in millimetres, between centrelines of stiffeners (stringers, frames, web frames, bulkheads, girders, beams, etc.). If the stiffeners are not symmetrical, s is the distance between the middle of the stiffener webs [see Figure 7 b)].

If three consecutive stiffeners do not have the same spacing, s is the mean value of their spacing [see Figures 7 a) and 7 b)].

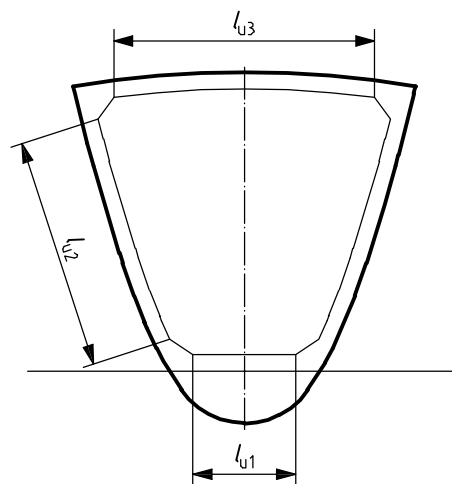
9.2.2 Long dimension of a stiffener l_u (unsupported length)

l_u is the long dimension, in millimetres, of a panel between the two closest stiffeners, it is also the unsupported length of these stiffeners. See Figure 11 for some examples of assessment. In the case of a top-hat stiffener, l_u is the distance between the centrelines of top-hats [see Figure 7 c)].

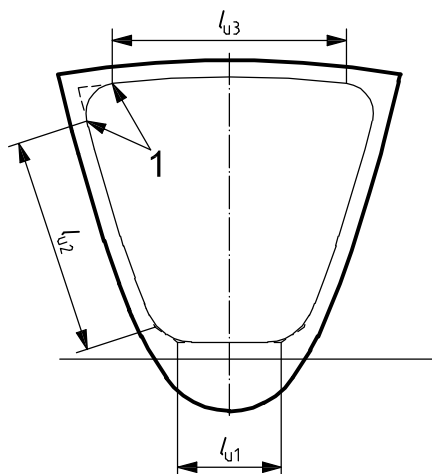
As a consequence of 8.4, l_u need not be taken $> 330 L_H$, in millimetres.



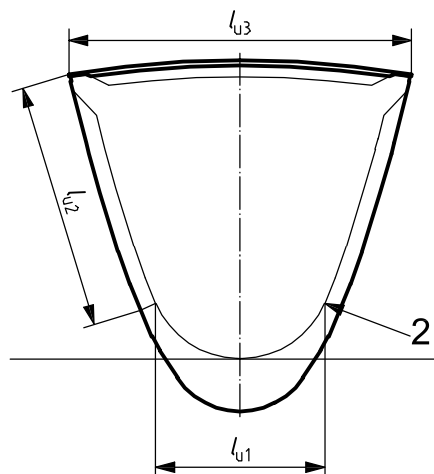
a) Continuous stiffeners l_{u1} for floor, l_{u2} for frame, l_{u3} for beam



b) Stiffeners with brackets at the junctions: l_u is measured inside the gusset junction



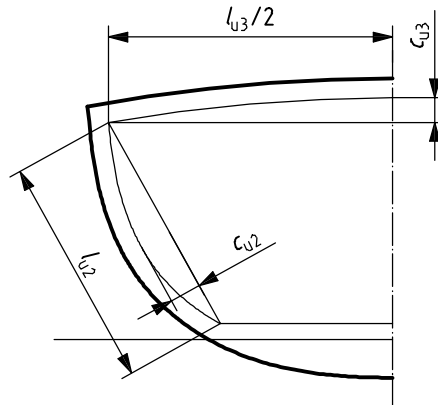
c) Brackets with tangential junctions: the ends of l_u are at the closest tangent points (Key 1)



d) Case where the frames and beams are not continuous to allow the deck to be put at a late stage of building without subsequent lamination.

NOTE The beam is fully fixed at both ends. The frame is simply supported at its top end. The limit floor/frame (Key 2) is at their tangent or junction point, i.e. a change in the stiffener height or stiffness.

Figure 11 — Examples of stiffener dimensions on a FRP craft



e) Case of curved stiffeners c_{u2} and c_{u3} are respectively the crown of the frame and the beam with respective lengths, l_{u2} and l_{u3} ; these are used to assess k_{CS} .

Key

- 1 closest tangent point
- 2 tangent of connection between floor and frame

Figure 11 (continued)

9.2.3 Redundant stiffeners

Panel dimensions, when taken as the distance between frames (or the distance between top-hat webs) require that the stiffeners that make up the panel boundary are able to comply with the strength and stiffness criteria of this part of ISO 12215.

Where it is not possible for the stiffener to achieve this or where the stiffener is not intended to reduce the panel dimensions, the panel may be analysed with the stiffener in question taken as non-effective. This will lead to a large increase in the panel size. If the resulting larger panel is able to comply with this part of ISO 12215, then the stiffener may be designated as “non-structural”.

Builders and designers are cautioned as to the meaning of this term. “Non-structural” means the adjacent panels have been assessed on the basis that the panel is not deriving any support from the stiffener, i.e. as if the stiffener were not physically there. However, the stiffener will attract a load in proportion to its stiffness relative to the adjacent structure. This means that the stiffener could fail in service, even though such a failure would not directly result in adjacent panel failure as would normally be the case for a “structural” stiffener. Should the “non-structural” stiffener fail, it is possible that this could cause cracking of the adjacent structure, which could result in further failure. It is not considered good practice. Builders and designers are advised to clearly explain this in the owner's manual as any such cracking may need to be monitored.

10 Plating — Scantling equations

10.1 Thickness adjustment factors for plating

10.1.1 Bending deflection factor k_1 for sandwich plating

$$k_1 = 0,017$$

NOTE The bending deflection factor k_1 is only used for FRP sandwich (see 10.5.3).

10.1.2 Panel aspect ratio factor for strength k_2 and for stiffness k_3

The panel aspect ratio factors for strength k_2 and for stiffness k_3 are given in Table 5.

NOTE k_3 is only used for the determination of I or EI in sandwich calculation.

Table 5 — Values of k_2 and k_3 in function of aspect ratio l/b for isotropic panels

Panel aspect ratio l/b	Factor k_2 k_2 to be taken = 0,5 for laminated wood plating	Factor k_3
> 2,0	0,500	0,028
2,0	0,497	0,028
1,9	0,493	0,027
1,8	0,487	0,027
1,7	0,479	0,026
1,6	0,468	0,025
1,5	0,454	0,024
1,4	0,436	0,023
1,3	0,412	0,021
1,2	0,383	0,019
1,1	0,349	0,016
1,0	0,308	0,014
	k_2 can be evaluated by the formula below, keeping $0,308 < k_2 < 0,5$	k_3 can be evaluated by the formula below, keeping $0,014 < k_3 < 0,028$
	$k_2 = \frac{0,271(l/b)^2 + 0,910(l/b) - 0,554}{(l/b)^2 - 0,313(l/b) + 1,351}$	$k_3 = \frac{0,027(l/b)^2 - 0,029(l/b) + 0,011}{(l/b)^2 - 1,463(l/b) + 1,108}$

10.1.3 Curvature correction factor k_C for curved plates

The curvature correction factor k_C is given by Table 6, where c is the crown of the panel, as defined in Figure 12. k_C shall not be taken $< 0,5$ nor > 1 .

NOTE k_C applies both for convex and concave curvature.

Table 6 — Curvature correction factor k_C

c/b	k_C
0 to 0,03	1,0
0,03 to 0,18	$1,1 - \frac{3,33c}{b}$
> 0,18	0,5

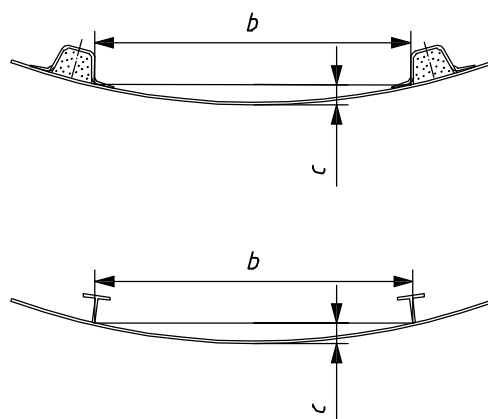


Figure 12 — Measurement of convex curvature

10.1.4 Final design pressure and panel analysis

For bottom, deck and superstructures, the design pressure is constant and shall be applied as defined in Clause 8.

Side pressure varies along the freeboard as specified in 8.1.5 or 8.2.2 for motor or sailing monohulls respectively.

In the case of large panels with variable pressure (because it is a large side panel or because it is across side and bottom), the design pressure shall be taken as an average constant pressure corresponding to the pressure at mid-panel (see also 6.2.4).

In the case of a panel having variable scantlings (single skin or sandwich of variable thickness, single skin transformed into sandwich somewhere in the panel, etc.), all scantlings shall be assessed, the weakest one being used for assessing compliance of the panel with this part of ISO 12215.

NOTE At the time of publication, this part of ISO 12215 has no provision to consider specifically variable pressure or variable scantlings. This is a statically indeterminate case, and the fixity at the ends of the panels may have any value from 0,2 to 1 according to the structural arrangements.

10.1.5 Shear force and bending moment on a panel

The shear force and bending moment on a panel do not generally need to be known as they are included in the thickness requirements of the various paragraphs. However, they sometimes need to be calculated, mostly in the case on non-homogenous or non-isotropic material (see Annex H). Their equations are

$$F_d = \sqrt{k_C} \times k_{SHC} \times P \times b \times 10^{-3} \text{ is the shear force in the middle of the } b \text{ dimension in N/mm} \quad (33)$$

$$M_d = 83,33 \times k_C^2 \times 2k_2 \times P \times b^2 \times 10^{-6} \text{ is the bending moment in the } b \text{ direction in Nmm/mm} \quad (34)$$

where all dimensions are previously defined except k_{SHC} which is defined in Table 12.

Where the panel stiffness is not similar in the two principal panel directions, Equation (34) shall be replaced by Equations (H.4) and (H.5) (see Annex H).

10.2 FRP single-skin plating

10.2.1 Design stress for FRP single-skin plating

Table 7 — Design stresses for FRP single-skin plating

Material	Structural element	Design stress σ_d N/mm ²
FRP single skin	All elements	0,5 σ_{uf}

where σ_{uf} is the minimum ultimate flexural strength, in newtons per square millimetre.

The mechanical properties of the FRP laminate shall be determined in accordance with Annex C.

10.2.2 Required thickness for FRP single-skin plating

The following equation is only valid if the mechanical properties in both directions differ by < 25 %; otherwise the panel shall be analysed in accordance with Annex H, using the shear force and bending moment given by Equations (33) and (34).

The minimum required single-skin plating thickness t is

$$t = b \times k_c \times \sqrt{\frac{P \times k_2}{1000 \times \sigma_d}} \text{ mm} \quad (35)$$

where

b is the short dimension of the panel, according to 9.1.1, in millimetres;

k_c is the curvature correction factor for curved panels given in Table 6;

P is the design pressure (bottom, side, deck, etc.) of the panel in accordance with Clause 8, in kilonewtons per square metre;

k_2 is the panel aspect ratio factor for bending strength given in Table 5;

σ_d is the design stress for FRP plating given in Table 7, in newtons per square millimetre.

For FRP, the thickness required from Equation (35), or wherever such thickness appears in this part of ISO 12215, shall not be measured, but translated into a mass of dry fibre reinforcement w_f (in kilograms per square metre) using the fibre mass content ψ according to the methods of Annex C, and compared to the actual reinforcement mass. An example is given in Annex C. Similarly, the dry fibre mass, w_f , in the laminate of an existing boat or project shall be transformed into thickness in the same manner in order to be compared with the requirements of Equation (35).

The mechanical properties of FRP laminates are those parallel to b , where $l/b \geq 2,0$ and the lesser of the mechanical properties parallel to b or l , where $l/b < 2,0$.

10.2.3 Use of bulking material

10.2.3.1 General

A bulking material is a core material (thick fabric, resin-rich felt, syntactic foam, etc.) intended to increase the thickness of a laminate. The bulking material functions either as an element only carrying shear (like in a sandwich) or as an element of the laminate working both in shear transmission and flexure.