GERMANISCHER LLOYD

Rules for Classification and Construction
I Ship Technology
3 Special Craft

1 High Speed Craft
Edition 2002
I - Part 3 Section 3

Structures

Rules for Classification and Construction

I Ship Technology

3 Special Craft

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SECTION 3 STRUCTURES

C3.0 Documents to be submitted

C3.0.1 General

.1 Table C3.0.1 lists the structural plans that are to be submitted to the Society, in triplicate, for examination and approval.

.2 In addition, information relative to the following is to be submitted:

- longitudinal weight distribution and position of the longitudinal centre of gravity of the craft
- design loading conditions including:
  - still water bending moments (SWBM) distribution
  - shear force (SF) distribution
  - description of corresponding loading cases
- draught and trim of the craft at sea, at rest and at its maximum speed in calm water (for SES, in both off-cushion and on-cushion conditions)
- any direct calculations performed
- results of model tests and full-scale measurements.

C3.0.2 Additional information for fibre-reinforced plastic (FRP) craft

.1 For FRP craft, the drawing and documents to be submitted for examination and listed in C3.0.1 are to contain the following additional information:

- arrangement of laminate for the various structural elements: thickness, definition of successive layers of reinforcement, mass per square metre in layers of reinforcement, proportion in mass of reinforcement for each layer, directions of roving layers and unidirectional reinforcements, decreasing in thickness between layers,
- direction of laminate in relation to craft structure,
- structure of oil tanks or other liquid tanks which are integrated into the hull,
- details of connection among various structural elements and details of attachment to the hull of supplementary reinforcing elements,
- pillars.

.2 Suppliers' technical specifications with indication of types, trademarks and references of resins and gelcoats, reinforcements and core materials are to be supplied.

Table C3.0.1

Plan	Containing information relevant to:
Midship section Main sections	• moulded dimensions, maximum service speed V, design acceleration a_{CG} and, if known, limit wave height (see C3.3.4) • materials • typical structural details
Longitudinal sections	
Decks	• openings • deck loads, if different from Rule loads
Shell expansion	• openings
Machinery space structure	• machinery mass and position of centre of gravity
Watertight bulkheads	• openings • position of air vents • typical structural details
Deckhouses	• details of connections between different materials
Rudder	• rudder stock material
Propeller shaft brackets	• material
Equipment	
Testing plan	• position of air vents

These specifications are to give the following information:

- resins: type (orthophthalic or isophthalic), specific gravity, Young's modulus, Poisson's ratio, breaking strength and elongation at break,
- reinforcements (mats, woven rovings, unidirectional reinforcements): quality (glass or other material, with specific gravity, breaking strength of the elementary fibre, Young's modulus and Poisson's ratio), mass per square metre, thickness and possibly weft-warp distribution,
- core materials: type and quality; specific gravity; tensile, compressive and shear strength and elasticity moduli.

3.1 General

This Section covers those elements of hull and superstructure which provide longitudinal and other primary and local strength of the craft as a whole and also other important components such as foils and skirts which are directly associated with the hull and superstructure.

3.2 Materials

Materials used for the hull and superstructure and the other features referred to in 3.1 should be adequate for the intended use of the craft.

3.3 Structural strength

The structure should be capable of withstanding the static and dynamic loads which can act on the craft under all operating conditions in which the craft is permitted to operate, without such loading resulting in inadmissible deformation and loss of watertightness or interfering with the safe operation of the craft.

3.4 Cyclic loads

Cyclic loads, including those from vibrations (see note), which can occur on the craft should not:

- *impair the integrity of structure during the anticipated service life of the craft or the service life agreed with the Administration;*
- *hinder normal functioning of machinery and equipment; and*
- *impair the ability of the crew to carry out its duties.*

Note: In scope of classification, the structural strength against vibrations is not checked.

The vibration check shall be performed during the sea trials of the craft. Where deemed necessary, the Society may require vibration measurements to be carried out using suitable instruments; where appropriate, remedial measures may be required to adequately eliminate situations deemed unacceptable.

3.5 Design criteria

The Administration should be satisfied that the choice of design conditions, design loads and accepted safety factors corresponds to the intended operating conditions for which certification is sought.

3.6 Trials

If the Administration consider it necessary it should require full-scale trials to be undertaken in which loadings are determined. Cognizance should be taken of the results where these indicate that loading assumptions of structural calculations have been inadequate.

C3.1 General

C3.1.1 Introductory comments

.1 This section C3 contains the requirements for structural scantlings of the craft to which these Rules apply, i.e. to craft for which $V \geq 7{,}16\ \Delta^{1/6}$. Craft for which $V \geq 10\ L^{0{,}5}$ shall be individually considered by the Society (V in knots, Δ in tonnes).

For what concerns multihull craft, this Section provides the requirements for scantlings of twin-hull craft. Other craft will be considered in each separate case by the Society.

.2 The requirements for scantlings of hydrofoils and air-cushion vehicles are contained in Appendices C3A1 and C3A2. Unless otherwise specified, the requirements of this Section apply to such craft only as far as the provisions regarding limit operating conditions, materials and construction criteria are concerned.

.3 The scantlings indicated in the following paragraphs apply to craft constructed of steel, aluminium alloy or fibre reinforced plastic, as specified in C3.2.

C3.1.2 Direct calculations

.1 The Society may require direct calculations to be carried out, if deemed necessary according to the provisions of C3.6.

Such calculations are to be carried out based on structural modelling, loading and checking criteria described in C3.6. Calculations based on other criteria may be accepted if deemed equivalent to those laid down by the Society.

C3.1.3 Units

.1 Unless otherwise specified, the following units are used in the Rules:

- thickness of plating, in mm,
- section modulus of stiffeners, in cm^3,
- shear area of stiffeners, in cm^2,
- span and spacing of stiffeners, in m,
- stresses, in N/mm^2,
- concentrated loads, in kN,
- distributed loads, in kN/m or kN/m^2.

C3.1.4 Definitions and symbols

.1 The definitions of the following terms and symbols are applicable throughout this Section and its Appendices and are not, as a rule, repeated in the different paragraphs. Definitions applicable only to certain paragraphs are specified therein.

- "Moulded base line": The line parallel to the summer load waterline, crossing the upper side of keel plate or the top of skeg at the middle of length L.
- "Hull": The hull is the outer boundary of the enclosed spaces of the craft, except for the deckhouses, as defined below.
- "Chine": For hulls that do not have a clearly identified chine, the chine is the hull point at which the tangent to the hull is inclined 50° to the horizontal.
- "Bottom": The bottom is the part of the hull between the keel and the chines.
- "Main deck": The main deck is the uppermost complete deck of the hull. It may be stepped.
- "Side": The side is the part of the hull between the chine and the main deck.
- "Deckhouse": The deckhouse is a decked structure located above the main deck, with lateral walls inboard of the side of more than 4 per cent of the local breadth. Structure located on the main deck and whose walls are not in the same longitudinal plane as the under side shell may be regarded as a deckhouse.
- "Cross-deck": For twin-hull craft, the cross-deck is the structure connecting the two hulls.
- "Deadrise angle α_d": For hulls that do not have a clearly identified deadrise angle, α_d is the angle between the horizontal and a straight line joining the keel and the chine. For catamarans with non-symmetrical hulls (where inner and outer deadrise angles are different), α_d is the lesser angle.
- "Fore end": Hull region forward of 0,9 L from the aft perpendicular.
- "Aft end": Hull region abaft of 0,1 L from the aft perpendicular.
- "Midship area": Hull region between 0,3 L and 0,7 L from the aft perpendicular.

L : Rule length, in m, equal to L_{WL} where L_{WL} is the waterline measured with the craft at rest in calm water and, for SESs, in the off-cushion condition

FP : forward perpendicular, i.e. the perpendicular at the intersection of the waterline at draught T and the foreside of the stem

AP : aft perpendicular, i.e. the perpendicular located at a distance L abaft of the forward perpendicular

B : the greatest moulded breadth, in m, of the craft

B_w : the greatest moulded breadth, in m, measured on the waterline at draught T; for catamarans, B_w is the breadth of each hull

B_{wm} : the greatest moulded breadth, in m, measured below or on the waterline at draught T; for catamarans, B_{wm} is the breadth of each hull

D : depth, in m, measured vertically in the transverse section at the middle of length L from the moulded base line of the hull(s) to the top of the deck beam at one side of the main deck (if the main deck is stepped, D will be defined in each separate case at the discretion of the Society)

T : draught of the craft, in m, measured vertically on the transverse section at the middle of length L, from the moulded base line of the hull(s) to the full load waterline, with the craft at rest in calm water and, for SESs, in the off-cushion condition

Δ : moulded displacement at draught T, in sea water (mass density = 1,025 t/m^3), in tonnes

C_B : total block coefficient, defined as follows:

$$C_B = \frac{\Delta}{(1,025 \cdot L \cdot B_W \cdot T)}$$

For catamarans, C_B is to be calculated for a single hull, assuming Δ equal to one half of the craft's displacement

V : maximum service speed, in knots

g : acceleration of gravity, equal to 9,81 m/s^2

LCG : longitudinal centre of gravity of the craft.

C3.1.5 Protection against corrosion

.1 Scantlings stipulated in C3.7 assume that the materials used are chosen and protected in such a way that the strength lost by corrosion is negligible.

.2 The Shipyard is to give the Society a document specifying all the arrangements made to protect the material against corrosion at the construction stage: coating types, number and thickness of layers, surface preparation, application conditions, control after completion, anodic protection, etc.

.3 This document must also include maintenance arrangements to be made in service to restore and maintain the efficiency of this protection, whatever the reasons of its weakening, whether incidental or not.

.4 All such maintenance operations are to be listed in a book shown to the Society surveyor at each visit.

C3.1.6 Rounding-off

.1 Values for thickness as deduced from formulae are to be rounded off to the nearest standard value, without such a reduction exceeding 3 per cent.

C3.2 Materials and connections

C3.2.1 General requirements

.1 Materials to be used in hull and equipment construction, in delivery condition, are to comply with these requirements or with specific requirements applicable to individual cases; they are to be tested in compliance with the applicable provisions. Quality and testing requirements for materials covered here are outlined in relevant Society Rules.

.2 These requirements presume that welding and other cold or hot manufacturing processes are carried out in compliance with current sound working practice and relevant Society provisions. The latter, in particular, may include requirements concerning welding operations and techniques and other manufacturing processes (e.g., specific preheating before welding and/or welding or other cold or hot manufacturing processes followed by an appropriate heat treatment).

.3 Welding processes shall be approved for the specified type of material for which they are intended and with limits and conditions as stated in the applicable Society requirements.

C3.2.2 Steel structures

C3.2.2.1 Steels for hull structures, forgings and castings

.1 The provisions of the relevant Society Rules apply.

C3.2.2.2 Under thickness tolerances

.1 The following requirements apply to the under-thickness tolerances of steel plates and wide flats.

.2 The maximum permissible under thickness tolerance for structural hull plates and wide flats for both normal and high strength steels is 0,3 mm.

.3 The thickness is to be measured at random locations located at least 25 mm from an edge. Local surface depressions resulting from imperfections and ground areas resulting from the elimination of defects may be disregarded.

.4 Responsibility for maintaining the required tolerances rests with the Manufacturer, who is to carry out the necessary measurements.

C3.2.2.3 Material factor K for scantlings of structural members made of high strength steel

.1 The value of the material factor K to be introduced into formulae to check structures given in this Section and in the various Appendices is a function of the minimum yield stress R_{eH} value specified for the steel to be used.

.2 Table C3.2.1 shows the values of the material factor K to be taken depending on the R_{eH} value of the various high strength steels for hull structures for which $R_{eH} \leq 390$ N/mm².

Table C3.2.1

R_{eH} (N/mm²)	K
235	1,00
315	0,78
355	0,72
390	0,70

.3 The use of steels for which $R_{eH} > 355$ N/mm² will be considered in each separate case by the Society, which may stipulate special acceptance conditions.

.4 If, for special structures, the use of steels for which $R_{eH} < 235$ N/mm², has been accepted by the Society, the material factor is to be determined by:

$$K = 235 / R_{eH}$$

.5 In the case where the use of steels with R_{eH} values which are intermediate between those indicated in Table C3.2.1 is allowed, the values of the material factor K may be determined by means of linear interpolation.

C3.2.3 Aluminium alloy structures

C3.2.3.1 Aluminium alloys for hull structures, forgings and castings

.1 The designation of aluminium alloys used here complies with the numerical designation used in RRIAD (Registration Record of International Alloy Designation).

Table C3.2.2 - Aluminium alloys for welded construction

Guaranteed mechanical characteristics (1)							
Aluminium alloy				Unwelded condition		Welded condition	
Alloy (2)	Temper (2)	Products	Thickness (mm)	$R_{p\,0,2}$ (N/mm²) (4)	R_m (N/mm²) (5)	$R_{p\,0,2}'$ (N/mm²) (4)	R_m' (N/mm²) (5)
5083	0 / H111	rolled	t ≤ 50	125	275	125	275
	H 321	rolled	t ≤ 40	215	305	125	275
	0	extruded	all	110	270	110	270
5086	0 / H111	rolled	all	100	240	100	240
	H 321	rolled	all	185	275	100	240
	0	extruded	all	95	240	95	240
5383	0 / H111	rolled	t ≤ 40	145	290	145	290
	H 321	rolled	t ≤ 40	220	305	145	290
5059	0 / H111	rolled	t ≤ 40	155	300	155	300
	H 321	rolled	t ≤ 20	270	370	155	300
		rolled	20 < t ≤ 40	260	360	155	300
5454	0 / H111	rolled	all	85	215	85	215
	F	rolled	all	100	210	100	210
5754	0 / H111	rolled	t ≤ 6	80	190	80	190
			t > 6	70	190	70	190
6005	T5 / T6	closed extrusions	t ≤ 6	215	255	105	165
			6 < t ≤ 25	200	250	100	165
		open extrusions	t ≤ 10	215	260	95	165
			10 < t ≤ 25	200	250	80	165
6060 (3)	T5	extruded	t ≤ 6	150	190	65	115
			6 < t ≤ 25	130	180	65	110
6061	T6	extruded	t ≤ 25	240	260	115	155
6082	T6	extruded	t ≤ 15	255	310	115	170
6106	T5	extruded	t ≤ 6	195	240	65	130
6351	T5	extruded	t ≤ 25	240	260	140	165

(1) The guaranteed mechanical characteristics in this Table correspond to general standard values. For more information, refer to the minimum values guaranteed by the product supplier. Higher values may be accepted on the basis of welding tests including recurrent workmanship test at the shipyard only.
(2) Other grades or tempers may be considered, subject to the Society's agreement.
(3) 6060 alloy is not to be used for structural members sustaining impact loads (e.g. bottom longitudinals). The use of alloy 6106 is recommended in that case.
(4) $R_{p\,0,2}$ and $R_{p\,0,2}'$ are the minimum guaranteed yield stresses at 0,2% in unwelded and welded condition respectively.
(5) R_m and R_m' are the minimum guaranteed tensile strengths in unwelded and welded condition respectively.

.2 The characteristics of aluminium alloys to be used in the construction of aluminium craft are to comply with the relevant requirements of the Society Rules.

.3 As a rule, series 5000 aluminium-magnesium alloys or series 6000 aluminium-magnesium-silicon alloys (see Table C3.2.2) shall be used.

.4 The use of series 6000 alloys or extruded platings, for parts which are exposed to sea water atmosphere, will be considered in each separate case by the Society, also taking into account the protective coating applied.

.5 The list of aluminium alloys given in Table C3.2.2 is not exhaustive. Other aluminium alloys may be considered, provided the specification (manufacture, chemical composition, temper, mechanical properties, welding, etc.) and the scope of application be submitted to the Society for review.

.6 In the case of welded structures, alloys and welding processes are to be compatible and appropriate, to the satisfaction of the Society and in compliance with the relevant Rules.

.7 For forgings or castings, requirements for chemical composition and mechanical properties are to be defined in each separate case by the Society.

.8 In the case of structures subjected to low service temperatures or intended for other particular applications, the alloys to be employed are to be defined in each separate case by the Society which is to state the acceptability requirements and conditions.

.9 Unless otherwise specified, the Young's modulus for aluminium alloys is equal to 70000 N/mm^2 and the Poisson's ratio equal to 0,33.

C3.2.3.2 Extruded platings

.1 Extrusions with built-in plating and stiffeners, referred to as extruded plating, may be used.

.2 In general, the application is limited to decks and deckhouses. Other uses may be permitted at the discretion of the Society.

.3 Extruded plating is preferably to be oriented so that the stiffeners be parallel to the direction of main stresses.

.4 Connections between extruded plating and primary members are to be given special attention.

C3.2.3.3 Tolerances

.1 The under-thickness tolerances of plates and rolled sections are to be in accordance with Table C3.2.3.

Table C3.2.3

As-built thickness (mm)	Under-thickness tolerance (mm)
t ≤ 8	0,3
8 < t ≤ 12	0,5
12 < t ≤ 20	0,7
t > 20	1,0

.2 The under-thickness tolerances of extruded platings are to be in accordance with Table C3.2.4, but not taken greater than 7% of the as-built thickness. Otherwise, the reduced plate thickness has to be considered.

Table C3.2.4

As-built thickness (mm)	Under-thickness tolerance (mm)
t ≤ 6	0,3
6 < t ≤ 10	0,4

.3 The responsibility for maintaining the required tolerances lies with the manufacturer, who shall also inspect the surface condition.

C3.2.3.4 Influence of welding on mechanical characteristics

.1 Welding heat input lowers locally the mechanical strength of aluminium alloys hardened by work hardening (series 5000 other than condition 0 or H111) or by heat treatment (series 6000).

.2 Consequently, where necessary, a drop in mechanical characteristics of welded structures is to be considered in the heat-affected zone, with respect to the mechanical characteristics of the parent material.

.3 The heat-affected zone may be taken to extend 25 mm on each side of the weld axis.

.4 Aluminium alloys of series 5000 in 0 condition (annealed) or in H111 condition (annealed flattened) are not subject to a drop in mechanical strength in the welded areas.

.5 Aluminium alloys of series 5000 other than condition 0 or H111 are subjected to a drop in mechanical strength in the welded areas. The mechanical characteristics to consider in welded condition are, normally, those of condition 0 or H111, except otherwise indicated in Table C3.2.2. Higher mechanical characteristics may be taken into account, provided they are duly justified.

.6 Aluminium alloys of series 6000 are subject to a drop in mechanical strength in the vicinity of the welded areas. The mechanical characteristics to be considered in welded condition are, normally, to be indicated by the supplier, if not indicated in Table C3.2.2.

C3.2.3.5 Material factor K for scantlings of structural members made of aluminium alloy

.1 The value of the material factor K to be introduced into formulae for checking scantlings of structural members, given in this Section and the various Appendices, is determined by the following equation:

$$K = \frac{100}{R'_{lim}}$$

where:

R'_{lim} : minimum guaranteed yield stress of the parent metal in welded condition $R'_{p0,2}$, in N/mm^2, but not to be taken greater than 70% of the minimum guaranteed tensile strength of the parent metal in welded condition R'_m, in N/mm^2 (see Table C3.2.2).

.2 For welded constructions in hardened aluminium alloys (series 5000 other than condition 0 or H111 and series 6000), greater characteristics than those in welded condition may be considered, provided that welded connections are located in areas where stress levels are acceptable for the alloy considered in annealed or welded condition.

.3 In case of welding of two different aluminium alloys, the material factor K to be considered for the scantlings of welds is to be the greater material factor of the aluminium alloys of the assembly.

C3.2.3.6 Strength of welding

.1 The effective length in mm of the lines of welding is given by:

$d_e = d - 20$

where d is the actual length in mm of the line of welding.

C3.2.3.7 Riveted connections for aluminium alloy hulls

.1 Use of rivets for connecting structures is limited, in principle, only to members which do not contribute to the overall strength of the hull. Exceptions are to be supported by experimental evidence or good in-service performance.

.2 The conditions for riveted connection acceptability are to be individually stated in each particular case, depending on the type of member to be connected and the rivet material.

.3 Whenever riveted connections are to be employed, a detailed plan, illustrating the process, as well as the dimensions and location of rivets and holes, together with the mechanical and metallurgical properties of the rivets, is to be submitted for approval.

.4 The Society may, at its discretion, require tension, compression and shear tests to be carried out on specimens of riveted connections constructed under the same conditions as during actual hull construction, to be witnessed by a Society surveyor.

.5 The Society reserves the right to accept the results of tests performed by recognized bodies or other Societies.

C3.2.4 Welding connections

C3.2.4.1 General requirements

.1 For welding, the requirements of relevant Society Rules apply. In particular, these provisions make the adoption of welding procedures dependent on their previous qualification by the Society. In addition, individual builders are to hold an authorization by the Society to use these procedures, employing welders qualified by the Society.

.2 For welds design and throat thicknesses, the requirements of relevant Society Rules apply.

In addition, intermittent welds are not allowed in following zones:

- structure in way of waterjets or propellers
- structure in way of stabilisation devices such as foils, interceptors or tabs
- structure submitted to water impact

C3.2.4.2 Accessibility and edge preparation

.1 For correct execution of welded joints, sufficient accessibility is necessary, depending on the welding process adopted and the welding position.

.2 Edge cutting, to be carried out in general by machining, is to be regular and without burrs or cuts.

.3 The structural parts to be welded as well as those adjacent, even if they have been previously pickled, are to be cleaned carefully before welding, using suitable mechanical means, such as stainless steel wire brushes, so as to eliminate oxides, grease or other foreign bodies which could give rise to welding defects.

.4 Edge preparation, alignment of joints, spot-welding methods and root chipping are to be appropriate to the type of joint and welding position, and comply with Society Rule requirements for the welding procedures adopted.

C3.2.4.3 Inspections

.1 Inspections of welded connections by the Society surveyors are, in general, those specified in (a) to (e) below. The extent of inspection will be defined by the Society on a case by case basis.

(a) Inspection of base materials for compliance with the requirements this Article and of structures with the approved plans.

(b) Inspection of the use and application conditions of welding procedures for compliance with those approved and verification that qualified welders are employed.

(c) Visual examination of edge preparations, root chipping and execution of welds in way of structural connections.

(d) Examination of radiographs of welded joints (radiographing is to be performed, if necessary, depending on the extent of the examinations), and inspection of performance of execution of the ultrasonic or magnetic particle examinations, which may be required.

(e) Inspection of any repairs, to be performed with procedures and inspection methods at the discretion of the Society surveyor.

.2 Irrespective of the extent of such inspections, it is the responsibility of the builder to ensure that the manufacturing procedures, processes and sequences are in compliance with relevant Society requirements, approved plans and sound working practice. For this purpose, the shipyard is to have its own production control organization.

C3.2.4.4 Welding processes for light alloys

.1 In general, the welding of the hull structures is to be performed with the MIG (metal-arc inert gas) and TIG (tungsten-arc inert gas) processes using welding consumables recognized as suitable for the base material to be used. Welding processes and filler materials other than those above are to be individually considered by the Society at the time of the approval of welding procedures.

.2 For the authorization to use welding procedures in production, the following details are to be stated:

(a) grade and temper of parent and filler materials

(b) weld execution procedures: type of joint (e.g. butt-joint, fillet joint); edge preparation (e.g. thicknesses, bevelling, right angle edges); welding position (e.g. flat, vertical, horizontal) and other parameters (e.g. voltage, amperage, gas flow capacity)

(c) welding conditions (e.g. cleaning procedures of edges to be welded, protection from environmental atmosphere)

(d) special operating requirements for butt-joints, for example for plating: welding to be started and completed on end pieces outside the joint, back chipping, arrangements for repairs consequent to possible arc restarts

(e) type and extent of controls during production.

C3.2.5 Corrosion protection - heterogeneous steel/aluminium alloy assembly

.1 Connections between aluminium alloy parts, and between aluminium alloy and steel parts, if any, are to be protected against corrosion by means of coatings applied by suitable procedures agreed by the Society.

.2 In any case, any direct contact between steel and aluminium alloy is to be avoided (e.g. by means of zinc or cadmium plating of the steel parts and application of a suitable coating on the corresponding light alloy parts).

.3 Any heterogeneous jointing system is subject to the Society's agreement.

.4 The use of transition joints made of aluminium/steel-cladded plates or profiles is subject to the Society's agreement.

.5 Transition joints are to be type-approved.

.6 Qualifications tests for welding procedures are to be carried out for each joint configuration.

.7 A welding booklet giving preparations and various welding parameters for each type of assembly is to be submitted for review.

C3.2.6 Fibre-reinforced plastic (FRP) structures

C3.2.6.1 Raw materials

.1 The main raw materials are to be homologated by the Society.

It may be accepted as equivalent that main raw materials should be individually inspected by the Society. In such a case, each batch being used is submitted to tests, the conditions and scope of which are stipulated by the Society's surveyor.

.2 Reinforcement fibres

(a) Fibres for reinforcement may be textile glass or aramid or carbon fibres or other fibres.

(b) Products laid on a surface, such as size, binder and coupling finish, are to ensure cohesion between fibres and resins.

(c) During manufacturing, the shipyard is to ensure that reinforcement materials are to be free from scrap matter and without defects, detrimental to their use.

.3 Resins

(a) Resins are to be capable of withstanding ageing in marine environments and industrial atmospheres.

(b) Resins are to be used within the limits fixed by the manufacturer. In this respect, the surveyor may ask for any relevant proof.

.4 Core materials for sandwich laminates

(a) Expanded foams contributing to sandwich laminate strength are to be of the closed cell type and compatible with the resins used.

(b) Expanded polystyrenes may be used only as filling or buoyancy materials.

.5 Additives

(a) Fillers and pigments are to affect neither the conditions of polymerisation of the impregnation resin nor its mechanical characteristics. The percentage of both of them is not to exceed, as a rule, 10% of the mass of resin, with a maximum of 2% for thixotropic agents and 5% for flame retarders.

The use of microspheres is subject to special examination.

(b) The type and proportions of catalyst and accelerator are to be adjusted in any case to the conditions of work (production rate) and ambient atmosphere (temperature).

In order to ensure complete curing, the builder is to respect the indications of the resin manufacturer, particularly for the ratio of catalyst.

.6 Materials for integrated structures

(a) These are elements entirely covered with laminate, and used for reinforcement, moulding, or as lamination support for stiffeners, for example.

(b) The metals used are withstand seawater and fuel corrosion; they are to be of good quality and must not have any influence on resin curing.
They are to undergo appropriate preparation to improve bonding with the resin.

(c) As a rule, wood reinforcements are to be of a plywood type with good seawater resistance. The use of timber is subject to a special examination.

C3.2.6.2 Tests on laminates

.1 General

(a) The shipyard has to make samples representative of shell materials and possibly of other parts of the structure, taking into account the type and size of ship.

(b) If sister ships are built at the same shipyard, and provided that raw materials are not changed, the frequency of samples for testing is determined by the Society.

(c) These test samples are to be submitted to a laboratory approved by the Society to undergo mechanical and physicochemical tests, as defined below.

(d) In general, tests are to be carried out according to the standards indicated below, or other recognized standards previously agreed upon with the Society.

(e) These tests must show that laminate characteristics are at least equivalent to the theoretical values given by direct calculation following the method given in C3.2.6.3. Otherwise, supplementary tests may be required.

(f) The Society reserves the right to require tests different from those defined below, if particular materials or unusual manufacturing process are used.

(g) Tests are to be carried out on a panel, the composition of which is to be the same as that of a shell plating area, without gel-coat.

(h) Identification of the panel is given by the following elements:

- exact name of the resin, with its specific gravity, elasticity modulus, and breaking stress in curing state,
- description of elementary layers,
- characteristics of the laminate (e.g. layer type, direction),
- direction of the panel in respect of longitudinal axis of the ship and indication of direction for warp and weft for the rovings in respect of the same axis.

(i) Conditioning of laminate panels, preparation of testpieces, dimensional measurement of testpieces and the tests defined below are to be carried out according to recognized standards.

(j) Tests are to be carried out on testpieces taken out of the panel in two perpendicular directions. The number of testpieces for each direction is given by the standard used for the particular test.

(k) For each group of testpieces and for each result, the value to consider is the average obtained from the number of tested pieces, provided that the minimum value is not less than 0,9 times the mean value. Otherwise, the value to consider is determined by the Society, taking testing conditions and dispersion of results into account.

(l) Mechanical characteristics are to be obtained from dry testpieces, i.e. not conditioned in water.

(m) In general, the following tests are to be carried out:

- single skin laminates: tensile tests, bending tests (three-point method), measurement of specific gravity and percentage of reinforcement in mass,
- sandwich laminates: bending tests (four-point method), and, for each skin, tensile tests, measurement of specific gravity and percentage of reinforcement in mass.

(n) Bending tests are to be carried out with the load applied either on the gel-coat side or on the opposite side. The choice of the side is to be decided in accordance with the Society, so that the failure mode of the testpiece is representative of the case of scantlings of the plating.

(o) Test results are to be shown in a test report, mentioning the tests in C3.2.6.22 to C3.2.6.24.

.2 Tensile tests

(a) In general, these tests are to be carried out for single skin laminates and the skins of sandwich laminates.

(b) The applicable standard is:
ISO 3268.

(c) For each testpiece, the test report is to provide the following information:

- reference of the standard used for the test,
- widths and thicknesses of the test-piece, in mm,
- length between fixed ends, in mm,
- load (in N) - elongation curve (in mm),
- breaking load, in N,
- tensile breaking stress, in N/mm^2,
- tangential initial elasticity modulus, in N/mm^2,
- other items of information required by the standard, if necessary.

(d) If breaking occurs in several steps, the value taken into account is the first break obtained from the load-elongation curve.

(e) The test report is also to indicate the mean value of the breaking load, breaking tensile strength and tangential initial elasticity modulus.

.3 Bending tests

(a) In general, bending tests using the three-point method are to be carried out only for the single skin laminates.

The applicable standard is:

ISO 178.

(b) In general, bending tests using the four-point method are to be carried out only for sandwich laminates.

The applicable standard is:

ASTM C 393.

(c) For each testpiece, the test report is to provide the following information:

- reference of the standard used for the test,
- widths and thicknesses of the testpiece, in mm,
- length of the span between supports, in mm,
- for the four-point method: location of the points where the load is applied,
- load (in N) - deflection (in mm) curve,
- breaking load, in N, and failure mode,
- bending breaking strength, in N/mm^2, for single skin laminate tests,
- bending breaking strength of skin and shear breaking strength of core for sandwich laminate tests, both in N/mm^2,
- other items of information required by the standard, if necessary.

(d) If breaking occurs in several steps, the value taken into account is the first break obtained from the load-deflection curve.

(e) The test report is also to indicate the mean value of the breaking load and breaking strength.

.4 Specific gravity and percentage of reinforcement

(a) In general, these tests are to be carried out for single skin laminates and the skins of sandwich laminates.

(b) The applicable standards are:

ASTM D 792,

ASTM D 3171.

(c) For each testpiece, the test report is to provide the following information:

- reference of the standard used for the test,
- dimensions, in mm, of the test-piece,
- mass of the test-piece, in g,
- mass by unit of area of the test-piece, in g/m^2,
- specific density, in g/m^3,
- mass of reinforcement of the test-piece, in g,
- mass of reinforcement by unit of area, in g/m^2,
- percentage of reinforcement in mass,
- other items of information required by the standard, if necessary.

(d) The test report is also to indicate the mean value of the mass by unit of area, in g/m^2, specific gravity, in g/m^3, mass of reinforcement by unit of area, in g/m^2, and percentage of reinforcement in mass.

C3.2.6.3 Estimation of mechanical characteristics of FRP materials

.1 The meanings of the symbols used below are as follows:

Ψ : content in mass of reinforcement in a layer,

φ : content in volume of reinforcement in a layer, defined in C3.2.6.32 below,

μ_0 : vacuum content, equal to 0, if there is no available information,

E_1 : Young's modulus of a layer with unidirectional fibres, parallel to fibres, in N/mm^2, defined in C3.2.6.32 below,

E_2 : Young's modulus of a layer with unidirectional fibres, perpendicular to fibres, in N/mm^2, defined in C3.2.6.32 below,

ν_{12}, ν_{21} : Poisson's ratios of a layer with unidirectional fibres, defined in C3.2.6.32 below,

G_{12} : Coulomb's modulus of a layer with unidirectional fibres, in N/mm^2, defined in C3.2.6.32 below,

ρ_v : specific gravity of reinforcement, in g/cm^3,

ρ_r : specific gravity of resin, in g/cm^3,

E_{1v} : Young's modulus of reinforcement in the direction parallel to fibres, in N/mm^2,

E_{2v} : Young's modulus of reinforcement in the direction perpendicular to fibres, in N/mm^2,

E_r : Young's modulus of resin, in N/mm^2,

ν_v : Poisson's ratio of reinforcement,

ν_r : Poisson's ratio of resin,

G_r : Coulomb's modulus of resin, in N/mm^2, defined in C3.2.6.32 below,

G_v : Coulomb's modulus of the reinforcement, in N/mm^2, as given in Table C3.2.7.

When there is no available information, the values given in Table C3.2.7 may be considered.

Table C3.2.7

		Fibres				Resins	
		E Glass	Aramid	HS Carbon	HM Carbon	Polyester	Epoxy
Specific gravity (g/cm³)		2,54	1,45	1,80	1,90	1,20	1,20
Young's modulus (N/mm²)	parallel to fibres	73000	130000	230000	370000	3000	2600
	perpendicular to fibres	73000	5400	15000	6000	–	–
Coulomb's modulus (N/mm²)		30000	12000	50000	20000	–	–
Poisson's ratio		0,25	0,35	0,35	0,35	0,316	0,40

.2 Elementary layer

(a) The content in volume φ of reinforcement in the layer is given by the formula:

$$\varphi = \frac{\psi \cdot (1-\mu_0)}{\psi + (1-\psi) \cdot \frac{\rho_v}{\rho_r}}$$

(b) Whatever the type of reinforcement used in a particular layer, the elastic characteristics of a layer with unidirectional fibres having the same content of reinforcement as that layer are to be calculated first:

- Young's moduli:
  - parallel to fibres

$$E_1 = \varphi \cdot E_{1v} + (1-\varphi) \cdot E_r$$

  - perpendicular to fibres

$$E_2 = \frac{E_r}{1-\nu_r^2} \cdot \frac{1 + 0,85 \cdot \varphi^2}{(1-\varphi)^{1,25} + \varphi \frac{E_r}{E_{2v}(1-\nu_r^2)}}$$

- Poisson's ratios:

$$\nu_{12} = \varphi \cdot \nu_v + (1-\varphi) \cdot \nu_r$$

$$\nu_{21} = \nu_{12} \cdot \frac{E_2}{E_1}$$

- Coulomb's modulus:

$$G_{12} = G_r \cdot \frac{1 + 0,6 \cdot \varphi^{0,5}}{(1-\varphi)^{1,25} + \frac{G_r}{G_v} \cdot \varphi}$$

where:

$$G_r = \frac{E_r}{2 \cdot (1+\nu_r)}$$

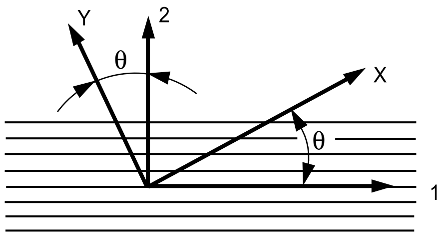
(c) Following any direction that forms an angle θ with the direction of fibres, the Young's moduli of the elementary layer become:

$$\frac{1}{E_x} = \frac{1}{E_1} \cdot \cos^4\theta + \left(\frac{1}{G_{12}} - \frac{2\nu_{12}}{E_1}\right) \cdot \sin^2\theta \cdot \cos^2\theta + \frac{1}{E_2} \cdot \sin^4\theta$$

$$\frac{1}{E_y} = \frac{1}{E_1} \cdot \sin^4\theta + \left(\frac{1}{G_{12}} - \frac{2\nu_{12}}{E_1}\right) \cdot \sin^2\theta \cdot \cos^2\theta + \frac{1}{E_2} \cdot \cos^4\theta$$

The values of E_1, E_2, ν_{12} and G_{12} are calculated above, directions x and y are defined in Figure C3.2.1.

Figure C3.2.1



(d) In general, the content in mass of reinforcement in a layer of mat is between 0,25 and 0,35.

The Young's modulus of a layer of mat may be estimated from:

$$E_M = \frac{3}{8} \cdot E_1 + \frac{5}{8} \cdot E_2$$

In this formula, the values E_1 and E_2 are those defined above.

(e) Woven rovings may be taffeta, cotton serge, satin, etc., warp and weft balanced or not.

In general, the content in mass of reinforcement in a woven roving reinforced layer is between 0,4 and 0,6, and the content in mass of reinforcement in an unidirectional reinforced layer is between 0,6 and 0,7.

The direction of the warp (direction 1) is to be distinguished from that of the weft (direction 2); the elastic characteristics are:

$$E_{1R} = k \cdot E_1 + (1-k) \cdot E_2$$

$$E_{2R} = (1-k) \cdot E_1 + k \cdot E_2$$

where k is the woven balance coefficient equal to the ratio of warp tensile strength to the sum of tensile strengths in warp and weft, E_1 and E_2 being defined above.

Generally, a layer reinforced with woven rovings may be considered as made of two perpendicular unidirectional layers, and it is possible to apply directly to them the formulae laid down above, taking into account the actual content of reinforcement in the layer.

.3 Single skin laminates

(a) A laminate is made of n layers. The characteristics of layer i of the laminate are:

t_i : thickness, in mm, regardless of direction, given by:

$$t_i = \frac{P_{vi}}{(1-\mu_0)} \cdot \left(\frac{1}{\rho_v} + \frac{1-\psi_i}{\psi_i \cdot \rho_r}\right) \cdot 10^{-3}$$

where P_{vi} is the mass of reinforcement by unit of area in layer i in g/m², and Ψ_i is the content in mass of reinforcement in layer i.

z_i : distance, in mm, from the neutral fibre of layer i to an edge (regardless of direction):

$$z_i = z_{i-1} + \frac{t_{i-1} + t_i}{2}$$

E_i : Young's modulus of layer i, in N/mm², assumed to be known and experimentally verified. E_i is the lowest of the values in tension and compression.

(b) The equivalent tensile elasticity modulus E_L, in N/mm², of the multi-layer laminate may be calculated by:

$$E_L = \frac{\sum E_i \cdot t_i}{\sum t_i}$$

(c) The distance of the neutral fibre of the multi-layer laminate is, in mm:

- with regard to the edge of reference:

$$V = \frac{\sum E_i \cdot t_i \cdot z_i}{\sum E_i \cdot t_i}$$

- with regard to the other edge:

$$V' = \sum t_i - V$$

Distances from the neutral fibre of each layer to the neutral fibre of the laminate are, in mm:

$d_i = z_i - V$

(d) The flexural rigidity of the multi-layer laminate EI, by millimetre of width, in N.mm²/mm, is:

$$[EI] = \sum E_i \cdot \left(\frac{t_i^3}{12} + t_i \cdot d_i^2\right)$$

(e) The inertia of the multi-layer laminate, by millimetre of width, in mm⁴/mm, is:

$$[I] = \sum\left(\frac{t_i^3}{12} + t_i \cdot d_i^2\right)$$

(f) The theoretical bending breaking strength of the multi-layer laminate, is, in N/mm²:

$$\sigma_{br} = k \cdot \frac{[EI]}{[I]}((1-\mu_0)^2 \cdot 10^{-3})$$

where:

k :
- 17,0 for laminates using polyester resin,
- 25,0 for laminates using epoxy resin,
- 12,5 for laminates made of carbon reinforcements and epoxy resins.

When the breaking strength of the laminate, given by mechanical tests as stipulated in C3.2.6.2, is greater than the theoretical calculated value σ_{br}, the breaking strength obtained from tests can be taken into account to increase the preceding value of σ_{br}.

.4 Sandwich laminates

(a) The inertia and flexural rigidity of sandwich laminates are to be calculated according to (d) and (e) above, taking into account the core as an elementary layer with its own characteristics (thickness and Young modulus of the core material).

(b) The theoretical bending breaking strength by bending of skins of the sandwich laminate is, in N/mm²:

$$\sigma_{br} = k \cdot \frac{[EI]}{[I]}((1-\mu_0)^2 \cdot 10^{-3})$$

where:

[EI] : flexural rigidity of the sandwich laminate, in N.mm²/mm,

[I] : inertia of the sandwich laminate, in mm⁴/mm,

μ_0 : vacuum content of skins,

k :
- 17,0 for skins using polyester resin,
- 25,0 for skins using epoxy resin,
- 12,5 for skins made of carbon reinforcements and epoxy resins.

When the breaking strength of the laminate by bending of skins, given by mechanical tests as requested in C3.2.6.2, is greater than the theoretical calculated value σ_{br}, the breaking strength obtained from tests can be taken into account to increase the preceding value of σ_{br}.

(c) The shear breaking of a sandwich laminate is to be considered in each particular case, considering the thickness and the shear breaking strength of the core material (see C3.8.4.4).

.5 Stiffener

(a) In general, the characteristics of the member considered as support only for the lamination of the stiffener are not to be taken into account for estimation of the mechanical characteristics of the stiffener.

(b) Symbols are shown in Table C3.2.8, where:

l_b : width of the associated plating, defined in C3.8.4.5.

Table C3.2.8

	Width or height (mm)	Thickness (mm)	Young's modulus (N/mm²)	Section (mm²)
Flange	l_s	t_s	E_s	$S_s = t_s\, l_s$
Core	H	t_a	E_a	$S_a = t_a\, H$
Associated plating	l_b	t_b	E_b	$S_b = t_b\, l_b$

(c) To supplement the symbols defined in Table C3.2.8, the following elements are needed:

z_i : distance from the neutral fibres of the three elements, i.e. core, flange and associated plating (index i refers to each one of them), to the outer face of the associated plating, in mm,

V : distance from the stiffener neutral fibre to the outer face of the associated plating, in mm:

$$V = \frac{\sum E_i \cdot S_i \cdot z_i}{\sum E_i \cdot S_i}$$

V' : distance from the stiffener neutral fibre to the outer face of the flange, in mm:
$V' = H - V + t_s + t_b$

d_i : distances from the neutral fibre of each element to the stiffener neutral fibre, in mm:
$d_i = z_i - V$

I_i : specific inertia of each element, in mm⁴.

(d) The rigidity of a stiffener [EI], in N.mm², is:

$$[EI] = \sum E_i \cdot (I_i + S_i \cdot d_i^2)$$

(e) The inertia of a stiffener [I], in mm⁴, is:

$$[I] = \sum (I_i + S_i \cdot d_i^2)$$

(f) The theoretical bending breaking strength of the stiffener σ_{br}, in N/mm², is:

$$\sigma_{br} = k \cdot \frac{[EI]}{[I]} \cdot 10^{-3}$$

where:

k :
- 17,0 for stiffeners using polyester resin,
- 25,0 for stiffeners using epoxy resin,
- 12,5 for skins made of carbon reinforcements and epoxy resins.

C3.3 Design acceleration

C3.3.1 Vertical acceleration at LCG

.1 The design vertical acceleration at LCG, a_{CG} (expressed in g), is defined by the designer and corresponds to the average of the 1 per cent highest accelerations in the most severe sea conditions expected, in addition to the gravity acceleration.
Generally, it is to be not less than:

$$a_{CG} = foc \cdot Soc \cdot \frac{V}{\sqrt{L}}$$

where foc and Soc values are indicated in Table C3.3.1. and Table C3.3.2.

Table C3.3.1

Type of service	Passenger, Ferry, Cargo	Supply	Pilot, Patrol	Rescue
foc	0,666	1	1,333	1,666

Table C3.3.2

Sea area	Open sea	Restricted open sea	Moderate environment (2)	Smooth sea (3)
Soc	C_F (1)	0,30	0,23	0,14

(1) For passenger, ferry and cargo craft, their seaworthiness in this condition is to be ascertained. In general, Soc should not be lower than the values given in this Table, where:

$$C_F = 0,2 + \frac{0,6}{V/\sqrt{L}} \geq 0,32$$

(2) Not applicable to craft with type of service "Rescue"
(3) Not applicable to craft with type of service "Pilot, Patrol" or "Rescue"

.2 Lower a_{CG} values may be accepted at the Society's discretion, if justified, on the basis of model tests and full-scale measurements.

.3 The sea areas referred to in Table C3.3.2 are defined with reference to significant wave heights H_s which are exceeded for an average of not more than 10 percent of the year:

- Open-sea service:
  $H_s \geq 4,0$ m
- Restricted open-sea service:
  $2,5 \text{ m} \leq H_s < 4,0$ m
- Moderate environment service:
  $0,5 \text{ m} < H_s < 2,5$ m
- Smooth sea service:
  $H_s \leq 0,5$ m.

.4 If the design acceleration cannot be defined by the designer, the a_{CG} value corresponding to the appropriate values of foc and Soc reported in Table C3.3.1 and Table C3.3.2 will be assumed.

.5 An acceleration greater than $a_{CG} = 1,5 \cdot foc$ may not be adopted for the purpose of defining limit operating conditions.

.6 The longitudinal distribution of vertical acceleration along the hull is given by:

$a_v = k_v \cdot a_{CG}$

where:

k_v : longitudinal distribution factor, not to be less than (see Figure C3.3.1):

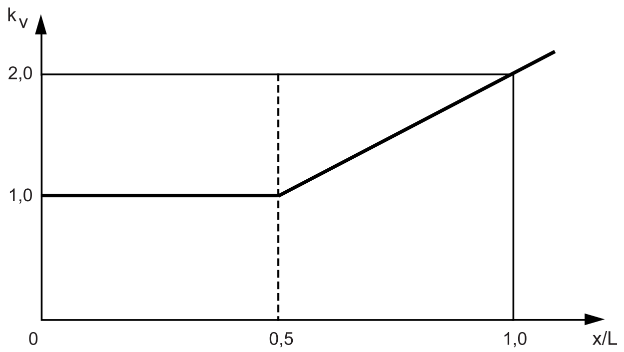
$k_v = 1$ for $x/L \le 0{,}5$

$k_v = 2 \cdot x/L$ for $x/L > 0{,}5$

Higher values may be requested based on pitch consideration.

a_{CG} : design acceleration at LCG.

Figure C3.3.1



.7 Variation of a_v in the transverse direction may generally be disregarded.

C3.3.2 Transverse acceleration

.1 Transverse acceleration is defined on the basis of results of model tests and full-scale measurements, considering their characteristic value as specified in C3.3.4.1.

.2 In the absence of such results, transverse acceleration, in g, at the calculation point of the craft may be obtained from:

$$a_t = 2{,}5 \cdot \frac{H_{sl}}{L} \cdot \left(1 + 5 \cdot \left(1 + \frac{V/(\sqrt{L})}{6}\right)^2 \cdot \frac{r}{L}\right)$$

where:

H_{sl} : permissible significant wave height at maximum service speed V (see C3.3.3),

r : distance of the point from:

- 0,5 D for monohull craft,
- waterline at draught T, for twin-hull craft.

C3.3.3 Assessment of limit operating conditions

C3.3.3.1 General

.1 "Limit operating conditions" in this paragraph are to be taken to mean sea states (characterized only by their significant wave heights) compatible with the structural design parameters of the craft, i.e. the sea states in which the craft may operate depending on its actual speed.

.2 Limit operating conditions are derived from the restrictions presented in C3.3.3.2, C3.3.3.3 and C3.3.3.4 below.

.3 Other specific design parameters influenced by sea state and speed could be also considered at the discretion of the Society.

.4 It is the designer's responsibility to specify the format and the values of the limit operating conditions. Their format may be for example a relation between speed and significant wave height which ascertains actual loads less than the one used for structural design. They must include the maximum allowed significant wave height H_{sm} consistent with the structural strength. H_{sm} is not to be greater than the value calculated according to C3.3.3.1.7 below.

.5 The limit operating conditions are defined, at the discretion of the Society, on the basis of results of model tests and full-scale measurements or by numerical simulations.

.6 The limit operating conditions, taken as a basis for classification, are indicated in the Classification Certificate and are to be considered in defining the worst intended conditions and the critical design conditions in Section 1.

.7 It is assumed that, on the basis of weather forecast, the craft does not encounter, within the time interval required for the voyage, sea states with significant heights, in m, greater than the following:

$$H_{sm} = 5 \cdot \frac{a_{CG}}{V/(\sqrt{L})} \cdot \frac{L}{6 + 0{,}14 \cdot L}$$

where vertical acceleration a_{CG} is defined in C3.3.1.

.8 For craft with a particular shape or other characteristics, the Society reserves the right to require model tests or full-scale measurements to verify results obtained by the above formula.

C3.3.3.2 Limitation imposed by bottom impact pressure and deck loads

.1 Bottom impact pressure, given in C3.5.3, and deck loads, given in C3.5.8, are explicitly or implicitly depending on the vertical acceleration at LCG. Therefore, the design values of these loads, taken as the basis for the classification, directly impose limitation on vertical acceleration level at LCG.

.2 It is the designer's responsibility to provide for a relation between the speed and the significant wave height that provides a maximum vertical acceleration less than the design value.

.3 Model tests if any are to be carried out in irregular sea conditions with a significant wave height corresponding to the operating conditions of the craft and a clearly specified sea spectrum. The scale effect is to be accounted for with an appropriate margin of safety. The characteristic value of acceleration and global loads to be assumed corresponds to the average of the 1 per cent highest values obtained during tests. The duration of the test is, as far as practicable, to be sufficient to guarantee that results are stationary.

.4 Where model test results or full-scale measurements are not available, the formula contained in C3.3.3.2.5 may be used to define maximum speeds compatible with design acceleration of monohulls, depending on sea states having a significant height H_s.

.5 The significant wave height is related to the craft's geometric and motion characteristics and to the vertical acceleration a_{CG} by the following formula:

$$a_{CG} = \frac{(50-\alpha_{dCG})\cdot\left(\frac{\tau}{16}+0,75\right)}{3555\cdot C_B}\cdot\left(\frac{H_S}{T}+0,084\cdot\frac{B_W}{T}\right)\cdot K_{FR}\cdot K_{HS}$$

- for units for which $V / L^{0,5} \geq 3$ and $\Delta / (0,01 \cdot L)^3 \geq 3500$

  $$K_{FR} = \left(\frac{V_X}{\sqrt{L}}\right)^2$$

  and

  $$K_{HS} = 1$$

- for units for which $V/L^{0,5} < 3$ or $\Delta/(0,01 \cdot L)^3 < 3500$

  $$K_{FR} = 0,8 + 1,6\cdot\frac{V_X}{\sqrt{L}}$$

  and

  $$K_{HS} = \frac{H_S}{T}$$

where:

H_s : significant wave height, in m,

α_{dCG} : deadrise angle, in degrees, at LCG, to be taken between 10° and 30°,

τ : trim angle during navigation, in degrees, to be taken not less than 4°,

V : maximum service speed, in knots.

V_x : actual craft speed, in knots.

If V_x is replaced by the maximum service speed V of the craft, the previous formula yields the significant height of the limit sea state, H_{sl}. This formula may also be used to specify the permissible speed in a sea state characterised by a significant wave height equal to or greater than H_{sl}.

.6 On the basis of the formula indicated in C3.3.3.2.5, the limit sea state may be defined (characterised by its significant wave height H_{sl}), i.e. the sea state in which the craft may operate at its maximum service speed. During its voyage, whenever the craft encounters waves having a significant height greater than H_{sl}, it has to reduce its speed.

.7 For catamarans, the relation between speed, wave height and acceleration is to be justified by model test results or full-scale measurements (see also C3.3.3.3).

.8 For craft, such as SESs, for which a speed reduction does not necessarily imply a reduction in acceleration, the speed is to be modified depending on the sea state according to criteria defined, at the discretion of the Society, on the basis of motion characteristics of the craft.

.9 The reduction of vertical acceleration a_{CG} induced by stabilisation system if any is to be disregarded for the purpose of limit operating conditions imposed by bottom impact loads.

C3.3.3.3 Limitation imposed by wet deck impact loads for catamarans

.1 Wet deck impact pressure is given in C3.5.4.

.2 The formula in C3.5.4 may be used to define maximum speeds compatible with actual structure of wet deck, depending on sea states having a significant height H_s.

.3 The reduction of relative impact velocity V_{sl} induced by stabilisation system if any is to be disregarded for the purpose of limit operating conditions imposed by wet deck impact loads.

C3.3.3.4 Limitation imposed by global loads

.1 For monohulls and catamarans, the longitudinal bending moment and shear forces as given in C3.4.1 and C3.4.2 are explicitly or implicitly depending on vertical acceleration along the ship. Therefore, the design values of these loads, taken as the basis for classification, directly impose limitation on vertical acceleration level at LCG. The requirements of C3.3.3.2.2 to C3.3.3.2.9 apply.

.2 For catamarans, the transverse bending moment, the torsional bending moment and the vertical shear force as given in C3.4.2 are depending on vertical acceleration a_{CG}. Therefore, the requirements of C3.3.3.2.2 to C3.3.3.2.9 apply.

.3 For SWATH craft, the global loads as given in C3.4.3 are not depending on ship motions.

.4 For ships with length greater than 100m, the relation between vertical acceleration along the ship and global loads are to be ascertained on basis of results of model tests and/or full-scale measurements or by numerical simulations, as indicated in C3.3.3.2.

.5 The reduction of vertical acceleration along the ship induced by stabilisation system if any is to be disregarded for the purpose of limit operating conditions imposed by global loads.

C3.3.3.5 Hull monitoring

.1 The Society may require a hull monitoring system to be fitted on board, allowing to monitor and display in real time the vertical acceleration and any other sensitive parameter with respect to the strength.

.2 The information is to be available at the wheelhouse and displayed in a clear format allowing to compare with design values.

.3 When a hull monitoring system is requested, its specification is to be submitted for review.

C3.4 Overall loads

C3.4.1 Monohulls

C3.4.1.1 General

.1 As a rule, only longitudinal vertical bending moment and shear force are to be considered for monohulls.

.2 For large craft, values from model tests, or hydrodynamic calculations, may be taken into account, after agreement of the Society on the methodology, the sea conditions and the loading cases. in such cases, values given in C3.4.1.2 must be considered as short term 1/100° values.

C3.4.1.2 Bending moment and shear force

.1 General

.1 The values of the longitudinal bending moment and shear force are given, in first approximation, by the formula in C3.4.1.2.2, C3.4.1.2.3 and C3.4.1.2.4.

.2 The total bending moments M_{blH}, in hogging conditions, and M_{blS}, in sagging conditions, in kN.m, are to be taken as the greatest of those given by the formulae in C3.4.1.2.2 and C3.4.1.2.3.

For ships having L > 100 m, only the formula in C3.4.1.2.3 is generally to be applied; the formula in C3.4.1.2.2 is to be applied when deemed necessary by the Society on the basis of the motion characteristics of the ship. The total shear forces T_{bl}, in kN, is given by the formula in C3.4.1.2.4.

.3 The longitudinal distribution of the total bending moment M_{blH} and M_{blS} is given in C3.4.1.2.5.

.4 If the actual distribution of weights along the craft is known, a more accurate calculation may be carried out according to the procedure in C3.4.1.2.6. the Society reserves the right to require calculation to be carried out according to C3.4.1.2.6 whenever it deems necessary.

.5 Rule requirements are reminded in Table C3.4.1.

Table C3.4.1

Ships		Applicable requirements	
L ≤ 100 m	All cases	Bending moment	C3.4.1.2.2 or C3.4.1.2.3 whichever is the greater
		Shear force	C3.4.1.2.4
L ≤ 100 m	Alternatively, when actual distribution of weights is known	Bending moment and shear force	C3.4.1.2.6
L > 100 m	Normal cases	Bending moment	C3.4.1.2.3
		Shear force	C3.4.1.2.4
L > 100 m	Special cases (when deemed necessary by the Society)	Bending moment	C3.4.1.2.2 or C3.4.1.2.3 whichever is the greater
		Shear force	C3.4.1.2.4
L > 100 m	Alternatively, when actual distribution of weights is known	Bending moment and shear force	C3.4.1.2.6

.2 Bending moment due to still water loads, wave induced loads and impact loads

$$M_{blH} = M_{blS} = 0,55 \cdot \Delta \cdot L \cdot (C_B + 0,7) \cdot (1 + a_{CG})$$

where a_{CG} is the vertical acceleration at the LCG, defined in C3.3.1.

.3 Bending moment due to still water loads and wave induced loads

$$M_{blH} = M_{sH} + 0,60 \cdot Soc \cdot C \cdot L^2 \cdot B \cdot C_B$$

$$M_{blS} = M_{sS} + 0,35 \cdot Soc \cdot C \cdot L^2 \cdot B \cdot (C_B + 0,7)$$

where:

M_{sH} : still water hogging bending moment, in kN.m,

M_{sS} : still water sagging bending moment, in kN.m,

Soc : parameter as indicated in Table C3.3.2, for the considered type of service.

C = 6 + 0,02 L

For the purpose of this calculation, C_B may not be taken less than 0,6.

.4 Total shear force

$$T_{bl} = \frac{3,2 \cdot M_{bl}}{L}$$

where:

M_{bl} : the greatest between M_{blH} and M_{blS}, calculated according to C3.4.1.2.2 and C3.4.1.2.3, as applicable.

.5 Longitudinal distribution of total bending moment

The longitudinal distribution of the total bending moments is given by:

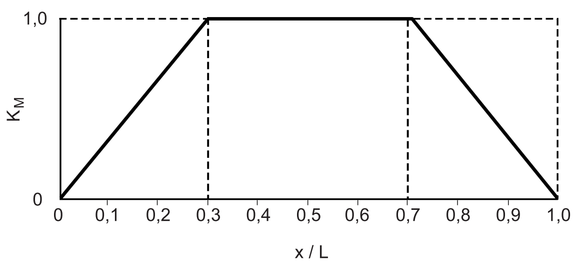
$K_M \cdot M_{blH}$ in hogging

$K_M \cdot M_{blS}$ in sagging

where:

K_M : longitudinal distribution factor as shown on Figure C3.4.1.

Figure C3.4.1



.6 Bending moment and shear force taking into account the actual distribution of weights

.1 The distribution of quasi-static bending moment and shear force, due to still water loads and wave induced loads, is to be determined from the difference in weight and buoyancy distributions in hogging and sagging for each loading or ballast condition envisaged.

.2 For calculation purposes, the following values are to be taken for the design wave:

- wave length, in m:

  $\lambda = L$

- wave height, in m:

  $$h = \frac{L}{15 + \frac{L}{20}}$$

- wave form: sinusoidal.

.3 In addition, the increase in bending moment and shear force, due to impact loads in the fore-body area, for the sagging condition only, is to be determined as specified below. For the purpose of this calculation, the hull is considered longitudinally subdivided into a number of intervals, to be taken, in general, equal to 20. For smaller craft, this number may be reduced to 10 if justified, at the Society's discretion, on the basis of the weight distribution, the hull forms and value of the design acceleration a_{CG}.

For twin-hull craft, the calculation below applies to one of the hulls, i.e. the longitudinal distribution of weight forces g_i and the corresponding breadth B_i are to be defined for one hull.

The total impact force, in kN, is:

$$F_{SL} = \sum q_{SLi} \cdot \Delta x_i$$

where:

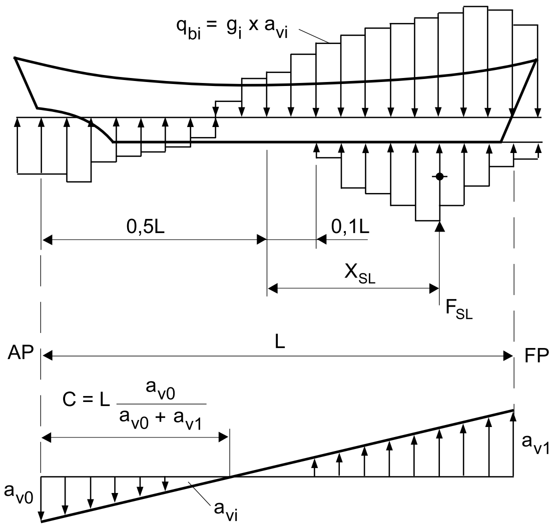
Δx_i : length of interval, in m,

q_{SLi} : additional load per unit length, in kN/m, for x/L ≥ 0,6 (see also Figure C3.4.2), given by:

$$q_{SLi} = p_0 \cdot B_i \cdot \sin\left(2 \cdot \pi \cdot \left(\frac{x_i}{L} - 0,6\right)\right)$$

x_i : distance, in m, from the aft perpendicular,

Figure C3.4.2



B_i : craft breadth, in m, at uppermost deck;

(x_i and B_i to be measured at the centre of interval i),

p_0 : maximum hydrodynamic pressure, in kN/m², equal to:

$$p_0 = \frac{a_{v1} \cdot G \cdot (r_0 - x_W^2)}{f_{SL} \cdot (r_0^2 + 0,5 \cdot L \cdot (x_{SL} - x_W) - x_{SL} \cdot x_W)}$$

a_{v1} : vertical design acceleration at the forward perpendicular, as defined in C3.3,

G : weight force, in kN, equal to:

$$G = \sum g_i \cdot \Delta x_i$$

g_i : weight per unit length, in kN/m, of interval i; for twin-hull craft, g_i is to be defined for one hull,

x_W : distance, in m, of LCG from the midship perpendicular, equal to:

$$x_W = \frac{\sum (g_i \cdot \Delta x_i \cdot x_i)}{\sum (g_i \cdot \Delta x_i)} - 0,5 \cdot L$$

r_0 : radius of gyration, in m, of weight distribution, equal to:

$$r_0 = \left(\frac{\sum g_i \cdot \Delta x_i \cdot (x_i - 0,5L)^2}{\sum g_i \cdot \Delta x_i}\right)^{0,5}$$

normally 0,2 L < r_0 < 0,25 L (guidance value)

x_{SL} : distance, in m, of centre of surface F_{SL} from the midship perpendicular, given by:

$$x_{SL} = \frac{1}{f_{SL}} \sum \Delta x_i \cdot x_i \cdot B_i \cdot \sin\left(2\pi \cdot \left(\frac{x_i}{L} - 0,6\right)\right) - 0,5L$$

f_{SL} : surface, in m², equal to:

$$f_{SL} = \sum \Delta x_i \cdot B_i \cdot \sin\left(2\pi \cdot \left(\frac{x_i}{L} - 0,6\right)\right)$$

.4 The resulting load distribution q_{si}, in kN/m, for the calculation of the impact induced sagging bending moment and shear force is:

(a) For x/L < 0,6:

$q_{si} = q_{bi} = g_i \cdot a_{vi}$

where:

a_{vi} : total dimensionless vertical acceleration at interval i, equal to:

$$a_{vi} = a_h + a_p \cdot (x_i - 0,5L)$$

a_h : acceleration due to heaving motion, equal to:

$$a_h = \frac{F_{SL}}{G} \cdot \left(\frac{r_0^2 - x_{SL} \cdot x_W}{r_0^2 - x_W^2}\right)$$

a_p : acceleration due to pitching motion, in m⁻¹, equal to:

$$a_p = \frac{F_{SL}}{G} \cdot \left(\frac{x_{SL} - x_W}{r_0^2 - x_W^2}\right)$$

a_h and a_p are relative to g

(b) For x/L ≥ 0,6:

$q_{si} = q_{bi} - q_{SLi}$

.5 The impact induced sagging bending moment and shear force are obtained by integration of the load distribution q_{si} along the hull. They are to be added to the respective values calculated according to C3.4.1.3.1 in order to obtain the total bending moment and shear force due to still water loads, wave induced loads and impact loads.

C3.4.2 Catamarans

C3.4.2.1 General

.1 The values of the longitudinal bending moment and shear force are given by the formulae in C3.4.1.2.

.2 For catamarans, the hull connecting structures are to be checked for load conditions specified in C3.4.2.2 and C3.4.2.3. These load conditions are to be considered as acting separately.

.3 Design moments and forces given in the following paragraphs are to be used unless other values are verified by model tests, full-scale measurements or any other information provided by the designer (see C3.3.4.1, Requirements for model tests).

.4 For craft with length L > 65 m or speed V > 45 knots, or for craft with structural arrangements that do not permit a realistic assessment of stress conditions based on simple models, the transverse loads are to be evaluated by means of direct calculations carried out in accordance with criteria specified in C3.6 or other criteria considered equivalent by the Society.

C3.4.2.2 Longitudinal bending moment and shear force

.1 Refer to C3.4.1.2.

.2 In C3.4.1.2.6, the breadth B_i is defined as below:

B_i : maximum breadth of one hull at the considered longitudinal location x_i, in m.

.3 When slamming of wet-deck is expected to occur (cf. C3.5.4), B_i is to be taken as:

B_i : the maximum breadth of one hull at the considered longitudinal location, in m, without being greater than B/2, multiplied by the coefficient f_B, where:

$f_B = 2 \cdot (1 - B_w/B)$

C3.4.2.3 Transverse bending moment and shear force

.1 The transverse bending moment M_{bt}, in kN.m, and shear force T_{bt}, in kN, are given by:

$$M_{bt} = \frac{\Delta \cdot b \cdot a_{CG} \cdot g}{5}$$

$$T_{bt} = \frac{\Delta \cdot a_{CG} \cdot g}{4}$$

where:

b : transverse distance, in m, between the centres of the two hulls,

a_{CG} : vertical acceleration at LCG, defined in C3.3.1.

C3.4.2.4 Transverse torsional connecting moment

.1 The catamaran transverse torsional connecting moment, in kN.m, about a transverse axis is given by:

$$M_{tt} = 0,125 \cdot \Delta \cdot L \cdot a_{CG} \cdot g$$

where a_{CG} is the vertical acceleration at LCG, defined in C3.3.1, which need not to be taken greater than 1,0 g for this calculation.

C3.4.3 Small waterplane area twin-hull (SWATH) craft - Forces and moments acting on twin-hull connections

C3.4.3.1 Side beam force

.1 The design beam side force, in kN, (see Figure C3.4.3) is given by:

$$F_Q = 12,5 \cdot T \cdot \Delta^{2/3} \cdot d \cdot L_S$$

where:

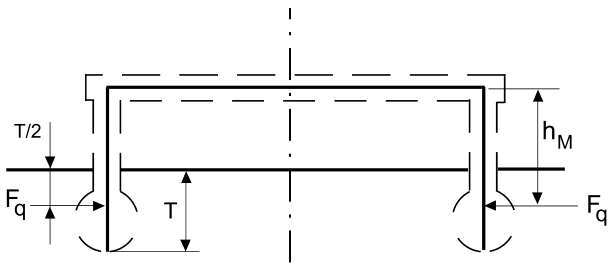
$$d = 1,55 - 0,75 \cdot \tanh\left(\frac{\Delta}{11000}\right)$$

$$L_S = 2,99 \cdot \tanh(\lambda - 0,725)$$

$$\lambda = \frac{0,137 \cdot A_{lat}}{T \cdot \Delta^{1/3}}$$

A_{lat} : lateral area, in m^2, projected on a vertical plane, of one hull with that part of strut or struts below waterline at draught T.

Figure C3.4.3



.2 The lateral pressure, in kN/m^2, acting on one hull is given by:

$$p_Q = \frac{F_Q}{A_{lat}}$$

The distribution of the lateral force F_Q can be taken as constant over the effective length $L_e = A_{lat} / T$, in m. The constant lateral force per unit length, in kN/m, is thus given by:

$$q_Q = \frac{F_Q}{L_e}$$

C3.4.3.2 Bending moment

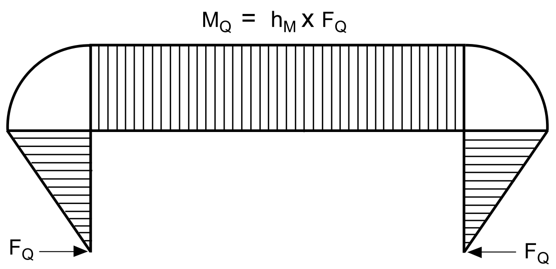
.1 The corresponding design bending moment, in kN.m, is given by:

$$M_Q = h_M \cdot F_Q$$

where:

h_M : half the draught T plus the distance from the waterline at draught T to the midpoint of the cross-deck structure (see Figure C3.4.4), in m.

Figure C3.4.4



C3.5 Local loads

C3.5.1 Introduction

.1 Design loads defined in this Article are to be used for the resistance checks provided for in C3.7 and C3.8 to obtain scantlings of structural elements of hull and deckhouses.

.2 Such loads may be integrated or modified on the basis of the results of model tests or full-scale measurements. Model tests are to be carried out in irregular sea conditions with significant wave heights corresponding to the operating conditions of the craft. The scale effect is to be accounted for by an appropriate margin of safety.

.3 The characteristic value to be assumed is defined as the average of the 1 per cent highest values obtained during testing. The length of the test is, as far as practicable, to be sufficient to guarantee that statistical results are stationary.

C3.5.2 Loads

C3.5.2.1 General

.1 The following loads are to be considered in determining scantlings of hull structures:

- impact pressures due to slamming, if expected to occur,
- sea pressures due to hydrostatic heads and wave loads,
- internal loads.

.2 External pressure generally determines scantlings of side and bottom structures; internal loads generally determine scantlings of deck structures.

.3 Where internal loads are caused by concentrated masses of significant magnitude (e.g. tanks, machinery), the capacity of the side and bottom structures to withstand such loads is to be verified according to criteria stipulated by the Society. In such cases, the inertial effects due to acceleration of the craft are to be taken into account.

Such verification is to disregard the simultaneous presence of any external wave loads acting in the opposite direction to internal loads.

C3.5.2.2 Load points

.1 Pressure on panels and strength members may be considered uniform and equal to the pressure at the following load points:

- for panels:
  - lower edge of the plate, for pressure due to hydrostatic head and wave load
  - geometrical centre of the panel, for impact pressure
- for strength members:
  - centre of the area supported by the element.

.2 Where the pressure diagram shows cusps or discontinuities along the span of a strength member, a uniform value is to be taken on the basis of the weighted mean value of pressure calculated along the length.

C3.5.3 Impact pressure on the bottom of hull

.1 If slamming is expected to occur, the impact pressure, in kN/m², considered as acting on the bottom of hull is not less than:

$$p_{sl} = 70 \cdot \frac{\Delta}{S_r} \cdot K_1 \cdot K_2 \cdot K_3 \cdot a_{CG}$$

where:

Δ : displacement, in tonnes (see C3.1.4). For catamaran, Δ in the above formula is to be taken as half of the craft displacement

S_r : reference area, m², equal to:

$$S_r = 0,7 \cdot \frac{\Delta}{T}$$

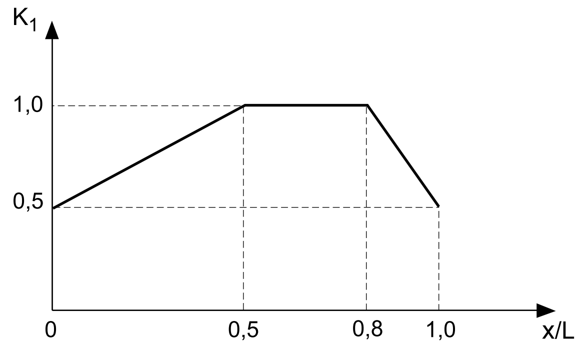
For catamaran, Δ in the above formula is to be taken as half the craft displacement

K_1 : longitudinal bottom impact pressure distribution factor (see Figure C3.5.1):

- for $x/L < 0,5$: $K_1 = 0,5 + x/L$
- for $0,5 \le x/L \le 0,8$: $K_1 = 1,0$
- for $x/L > 0,8$: $K_1 = 3,0 - 2,5 \cdot x/L$

where x is the distance, in m, from the aft perpendicular to the load point

Figure C3.5.1



K_2 : factor accounting for impact area, equal to:

$$K_2 = 0,455 - 0,35 \cdot \frac{u^{0,75} - 1,7}{u^{0,75} + 1,7}$$

with:

- $K_2 \geq 0{,}50$ for plating,
- $K_2 \geq 0{,}45$ for stiffeners,
- $K_2 \geq 0{,}35$ for girders and floors,

$$u = 100 \cdot \frac{s}{S_r}$$

where s is the area, in m², supported by the element (plating, stiffener, floor or girder). For plating, the supported area is the spacing between the stiffeners multiplied by their span, without taking for the latter more than three times the spacing between the stiffeners

K_3 : factor accounting for shape and deadrise of the hull, equal to:

$$K_3 = (70 - \alpha_d)/(70 - \alpha_{dCG})$$

where α_{dCG} is the deadrise angle, in degrees, measured at LCG and α_d is the deadrise angle, in degrees, between horizontal line and straight line joining the edges of respective area measured at the longitudinal position of the load point; values taken for α_d and α_{dCG} are to be between 10° and 30°

a_{CG} : design vertical acceleration at LCG, defined in C3.3.1.

C3.5.4 Impact pressure on bottom of wet-deck of catamarans (including tunnel radius)

.1 Slamming on bottom of the wet deck is assumed to occur if the air gap $H_{A,}$, in m, at the considered longitudinal position is less than $z_{wd,}$
where:

- for $L \leq 65$ m: $z_{wd} = 0{,}05 \cdot L$
- for $L > 65$ m: $z_{wd} = 3{,}25 + 0{,}0214 \cdot (L - 65)$

In such a case, the impact pressure, in kN/m², considered as acting on the wet deck is not less than:

$$p_{sl} = 3 \cdot K_2 \cdot K_{WD} \cdot V_X \cdot V_{SL} \cdot \left(1 - 0,85 \cdot \frac{H_A}{H_S}\right)$$

where:

V_{sl} : relative impact velocity, in m/s, equal to:

$$V_{sl} = \frac{4 \cdot H_S}{\sqrt{L}} + 1$$

H_S : significant wave height,

K_2 : factor accounting for impact area, as defined in C3.5.3.1,

K_{WD} : longitudinal wet deck impact pressure distribution factor (see Figure C3.5.2):

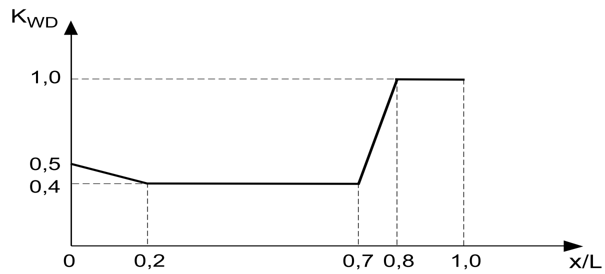
- for $x/L < 0{,}2$:
$$K_{WD} = 0,5 \cdot \left(1,0 - \frac{x}{L}\right)$$
- for $0{,}2 \leq x/L \leq 0{,}7$:
$K_{WD} = 0{,}4$
- for $0{,}7 < x/L < 0{,}8$:
$$K_{WD} = 6,0 \cdot \frac{x}{L} - 3,8$$
- for $x/L \geq 0{,}8$:
$K_{WD} = 1{,}0$

where x is the distance, in m, from the aft perpendicular to the load point,

V_X : ship's speed, in knots,

H_A : air gap, in m, equal to the distance between the waterline at draught T and the wet deck

Figure C3.5.2



.2 If the wet deck at a transverse section considered is not parallel to the design waterline, the impact pressure p_{sl} will be considered at the discretion of the Society.

C3.5.5 Sea pressures

C3.5.5.1 Sea pressure on bottom and side shell

.1 The sea pressure, in kN/m², considered as acting on the bottom and side shell is not less than p_{smin}, defined in Table C3.5.1, nor less than:

- for $z \leq T$:
$$p_s = 10 \cdot \left(T + 0,75 \cdot S - \left(1 - 0,25 \cdot \frac{S}{T}\right) \cdot z\right)$$
- for $z > T$:
$$p_s = 10 \cdot (T + S - z)$$

where:

z : vertical distance, in m, from the moulded base line to load point. z is to be taken positively upwards,

S : as given, in m, in Table C3.5.1 with C_B taken not greater than 0,5.

Table C3.5.1

	S	p_{smin}
$x/L \geq 0,9$	$T \leq 0,36 \cdot a_{CG} \cdot \frac{\sqrt{L}}{C_B} \leq 3,5 \cdot T$	$20 \leq \frac{L+75}{5} \leq 35$
$x/L \leq 0,5$	$T \leq 0,60 \cdot a_{CG} \cdot \sqrt{L} \leq 2,5 \cdot T$	$10 \leq \frac{L+75}{10} \leq 20$

.2 Between midship area and fore end ($0,5 < x/L < 0,9$), p_s varies in a linear way as follows:

$$p_s = p_{sFP} - (2,25 - 2,5 \cdot x/L) \cdot (p_{sFP} - p_{sM}))$$

where p_{sFP} is the sea pressure at fore end and p_{sM} in midship area.

C3.5.5.2 Stern doors and side shell doors

.1 The sea pressures on stern doors and side shell doors is to be taken according to C3.5.5.1 for scantlings of plating and secondary members.

.2 The design forces, in kN, considered for the scantlings of primary members are to be not less than:

- external force: $F_e = A \cdot p_s$
- internal force: $F_i = F_o + 10 \cdot W$

where:

A : area, in m, of the door opening,

W : mass of the door, in t,

F_p : total packing force in kN. Packing line pressure is normally not to be taken less than 5 N/mm,

F_o : the greater of F_c and $5 \cdot A$ (kN),

F_c : accidental force, in kN, due to loose of cargo etc., to be uniformly distributed over the area A and not to be taken less than 300 kN. For small doors, such as bunker doors and pilot doors, the value of F_c may be appropriately reduced. However, the value of F_c may be taken as zero, provided an additional structure such as an inner ramp is fitted, which is capable of protecting the door from accidental forces due to loose cargoes,

p_s : sea pressure as defined in C3.5.5.1

.3 The design forces, in kN, considered for the scantlings of securing or supporting devices of doors opening outwards are to be not less than:

- external force: $F_e = A \cdot p_s$
- internal force: $F_i = F_o + 10 \cdot W + F_p$

where the parameters are defined in C3.5.5.2.2.

.4 The design forces, in kN, considered for the scantlings of securing or supporting devices of doors opening inwards are to be not less than:

- external force: $F_e = A \cdot p_s + F_p$
- internal force: $F_i = F_o + 10 \cdot W$

where the parameters are defined in C3.5.5.2.2.

C3.5.6 Sea pressures on front walls of the hull

.1 The pressure, kN/m², considered as acting on front walls of the hull (in case of stepped main deck), not located at the fore end, is not less than:

$$p_{sf} = 6 \cdot \left(1 + \frac{x_1}{2 \cdot L(C_B + 0,1)}\right)(1 + 0,045 \cdot L - 0,38 \cdot z_1)$$

where:

x_1 : distance, in m, from front walls to the midship perpendicular (for front walls aft of the midship perpendicular, x_1 is equal to 0),

z_1 : distance, in m, from load point to waterline at draught T.

Where front walls are inclined backwards, the pressure calculated above can be reduced to ($p_{sF} \sin \alpha$), where α is the angle in degree between front wall and deck.
p_{sF} is not less than the greater of:
$3 + (6,5 + 0,06 \cdot L) \cdot \sin \alpha$
$3 + 2,4 \cdot a_{CG}$

.2 For front walls located at the fore end, the pressure p_{sF} will be individually considered by the Society.

C3.5.7 Sea pressures on deckhouses

.1 The pressure, kN/m², considered as acting on walls of deckhouses is not less than:

$$p_{su} = K_{su} \cdot \left(1 + \frac{x_1}{2 \cdot L(C_B + 0,1)}\right)(1 + 0,045 \cdot L - 0,38 \cdot z_1)$$

where:

K_{su} : coefficient equal to:

- for front walls of a deckhouse located directly on the main deck not at the fore end:
  $K_{su} = 6,0$
- for unprotected front walls of the second tier, not located at the fore end:
  $K_{su} = 5,0$
- for sides of deckhouses, b being the breadth, in m, of the considered deckhouse:
  $K_{su} = 1,5 + 3,5$ b/B (with 3 <= K <= 5)
- for the other walls:
  $K_{su} = 3,0$

x_1 : distance, in m, from front walls or from wall elements to the midship perpendicular (for front walls or side walls aft of the midship perpendicular, x_1 is equal to 0),

z_1 : distance, in m, from load point to waterline at draught T.

.2 The minimum values of p_{su}, in kN/m², to be considered are:

- for the front wall of the lower tier:
  $p_{su} = 6,5 + 0,06 \cdot L$
- for the sides and aft walls of the lower tier:
  $p_{su} = 4,0$
- for the other walls or sides:
  $p_{su} = 3,0$

.3 For unprotected front walls located at the fore end, the pressure p_{su} will be individually considered by the Society.

C3.5.8 Deck loads

C3.5.8.1 General

.1 The pressure, in kN/m², considered as acting on decks is given by the formula:

$p_d = p\,(1 + 0,4 \cdot a_v)$

where:

p : uniform pressure due to the load carried, kN/m². Minimum values are given in C3.5.8.2 to C3.5.8.6,

a_v : design vertical acceleration, defined in C3.3.

.2 Where decks are intended to carry masses of significant magnitude, including vehicles, the concentrated loads transmitted to structures are given by the corresponding static loads multiplied by $(1 + 0,4\ a_v)$.

C3.5.8.2 Weather decks and exposed areas

.1 For weather decks and exposed areas without deck cargo:

- if $z_d \le 2$:
  $p = 6,0$ kN/m²
- if $2 < z_d < 3$:
  $p = (12 - 3\ z_d)$ kN/m²
- if $z_d \ge 3$:
  $p = 3,0$ kN/m²

where z_d is the vertical distance, in m, from deck to waterline at draught T.

p can be reduced by 20% for primary supporting members and pillars under decks located at least 4 m above the waterline at draught T, excluding embarkation areas.

.2 For weather decks and exposed areas with deck cargo:

- if $z_d \le 2$:
  $p = (p_c + 2)$ kN/m², with $p_c \ge 4,0$ kN/m²
- if $2 < z_d < 3$:
  $p = (p_c + 4 - z_d)$ kN/m², with $p_c \ge (8,0 - 2\ z_d)$ kN/m²
- if $z_d \ge 3$:
  $p = (p_c + 1)$ kN/m², with $p_c \ge 2,0$ kN/m²

where:

z_d : distance defined in C3.5.8.2.1,

p_c : uniform pressure due to deck cargo load, in kN/m², to be defined by the designer with the limitations indicated above.

C3.5.8.3 Sheltered decks

.1 They are decks which are not accessible to the passengers and which are not subjected to the sea pressures. Crew can access such deck with care and taking account of the admissible load, which is to be clearly indicated. Deckhouses protected by such decks may not have direct access to ‘tween-deck below.

For shelter decks:

$p = 1,3$ kN/m²

.2 A lower value may be accepted, at the discretion of the Society, provided that such a value as well as the way of access to the deck are clearly specified by and agreed upon with the Owner.

C3.5.8.4 Enclosed accommodation decks

.1 For enclosed accommodation decks not carrying goods:

$p = 3,0$ kN/m²

p can be reduced by 20 per cent for primary supporting members and pillars under such decks.

.2 For enclosed accommodation decks carrying goods:

$p = p_c$

The value of p_c is to be defined by the designer, but taken as not less than 3,0 kN/m².

C3.5.8.5 Enclosed cargo decks

.1 For enclosed cargo decks other than decks carrying vehicles:

$p = p_c$

where p_c is to be defined by the designer, but taken as not less than 3,0 kN/m².

For enclosed cargo decks carrying vehicles, the loads are defined in C3.5.8.7.

C3.5.8.6 Platforms of machinery spaces

.1 For platforms of machinery spaces:

$p = 15,0 \ kN/m^2$

C3.5.8.7 Decks carrying vehicles

.1 The scantlings of the structure of decks carrying vehicles are to be determined by taking into account only the concentrated loads transmitted by the wheels of vehicles, except in the event of supplementary requirement from the designer.

.2 The scantlings under racking effects (e.g. for combined loading condition 3 defined in C3.6.1.2.9 and C3.6.2.2.9) of the primary structure of decks carrying vehicles is to be the greater of the following cases:

- scantlings determined under concentrated loads transmitted by the wheels of vehicles,
- scantlings determined under a uniform load pc taken not less than 2,5 kN/m². This value of p_c may be increased if the structural weight cannot be considered as negligible, to the satisfaction of the Society.

C3.5.9 Pressures on tank structures

.1 The pressure, in kN/m², considered as acting on tank structures is not less than the greater of:

$$p_{t1} = 9,81 \cdot h_1 \cdot \rho \cdot (1 + 0,4 \cdot a_v) + 100 \cdot p_v$$
$$p_{t2} = 9,81 \cdot h_2$$

where:

h_1 : distance, in m, from load point to tank top,

h_2 : distance, in m, from load point to top of overflow or to a point located 1,5 m above the tank top, whichever is greater,

ρ : liquid density, in t/m³ (1,0 t/m³ for water),

p_v : setting pressure, in bars, of pressure relief valve, when fitted.

C3.5.10 Pressures on subdivision bulkheads

.1 The pressure, in kN/m², considered as acting on subdivision bulkheads is not less than:

$p_{sb} = 9,81 \cdot h_3$

where:

h_3 : distance, in m, from load point to bulkhead top.

C3.6 Direct calculations for monohulls and catamarans

C3.6.1 Direct calculations for monohulls

C3.6.1.1 General

.1 Direct calculations generally require to be carried out, in the opinion of the Society, to check primary structures for craft of length L > 65 m or speed V > 45 knots.

.2 In addition, direct calculations are to be carried out to check scantlings of primary structures of craft whenever, in the opinion of the Society, hull shapes and structural dimensions are such that scantling formulas in C3.7 and C3.8 are no longer deemed to be effective.

.3 This may be the case, for example, in the following situations:

- elements of the primary transverse ring (beam, web and floor) have very different cross section inertiae, so that the boundary conditions for each are not well-defined,
- marked V-shapes, so that floor and web tend to degenerate into a single element,
- complex, non-conventional geometries,
- presence of significant racking effects (in general on ferries),
- structures contributing to longitudinal strength with large windows in side walls.

C3.6.1.2 Loads

.1 In general, the loading conditions specified in C3.6.1.2.6 to C3.6.1.2.9 below are to be considered.
Condition C3.6.1.2.9 is to be checked for craft for which, in the opinion of the Society, significant racking effects are anticipated (e.g. for ferries).

.2 In relation to special structure or loading configurations, should some loading conditions turn out to be less significant than others, the former may be ignored at the discretion of the Society. In the same way, it may be necessary to consider further loading conditions specified by the Society in individual cases.

.3 The vertical and transverse accelerations are to be calculated as stipulated in C3.3.

.4 The impact pressure is to be calculated as stipulated in C3.5. For each floor, the K_2-factor which appears in the formula for the impact pressure is to be calculated as a function of the area supported by the floor itself.

.5 In three-dimensional analyses, special attention is to be paid to the distribution of weights and buoyancy and to the dynamic equilibrium of the craft.
In the case of three-dimensional analyses, the longitudinal distribution of impact pressure is to be considered individu-

ally, in the opinion of the Society. In general, the impact pressure is to be considered as acting separately on each transverse section of the model, the remaining sections being subject to the hydrostatic pressure.

.6 Loading conditions in still water

The following loads are to be considered:

- forces caused by weights which are expected to be carried in the full load condition, distributed according to the weight booklet of the craft,
- outer hydrostatic load in still water.

.7 Combined loading condition 1

The following loads are to be considered:

- forces caused by weights which are expected to be carried in the full load condition, distributed according to the weight booklet of the craft,
- forces of inertia due to the vertical acceleration a_v of the craft, considered in a downward direction.

.8 Combined loading condition 2

The following loads are to be considered:

- forces caused by weights which are expected to be carried in the full load condition, distributed according to the weight booklet of the craft,
- forces of inertia due to the vertical acceleration a_v of the craft, considered in a downward direction,
- impact pressure acting on the bottom of the craft (2 cases):
  - case 1: symmetrically and according to C3.6.1.2.5,
  - case 2: asymmetrically and acting on one side of a complete compartment between transverse bulkheads, the other side being subject to hydrostatic load in still water.

.9 Combined loading condition 3

The following loads are to be considered:

- forces caused by weights which are expected to be carried in the full load condition, distributed according to the weight booklet of the craft,
- forces of inertia due to the transverse acceleration of the craft.

C3.6.1.3 Structural model

.1 Primary structures of craft of this type may usually be modelled with beam elements, according to criteria stipulated by the Society. When, however, grounds for the admissibility of this model are lacking, or when the geometry of the structures gives reason to suspect the presence of high stress concentrations, finite element analyses are necessary.

.2 In general, the extent of the model is to be such as to allow analysis of the behaviour of the main structural elements and their mutual effects.

.3 In craft dealt with by these Rules, the stiffness of longitudinal primary members (girders and stringers) is, at least outside the machinery space area, generally negligible compared with the stiffness of transverse structures (beams, floors and webs), or their presence may be taken account of by suitable boundary conditions. It is therefore acceptable, in general, to examine primary members in this area of the hull by means of plane analyses of transverse rings.

.4 In cases where such approximation is not acceptable, the model adopted is to be three-dimensional and is to include the longitudinal primary members.

.5 When racking behaviour is investigated and loads thus act in the transverse direction (loading condition 3), special attention is to be devoted to modelling of continuous decks and platforms. Such continuous elements, if of sufficient stiffness in the horizontal plane and if sufficiently restrained by the fore- and after-bodies, may withstand transverse deformations of primary rings.

In such cases, taking for granted the provisions above, it is still permissible to examine bidimensional rings, by simulating the presence of decks and platforms with horizontal springs according to criteria specified by the Society.

C3.6.1.4 Boundary conditions

.1 Depending upon the loading conditions considered, the following boundary conditions are to be assigned:

(a) Loading condition in still water and combined loading conditions 1 and 2

- horizontal and transverse restraints, in way of the crossing point of bottom and side shells, if the angle between the two shells is less than approximately 135°,
- horizontal and transverse restraints, in way of keel, if the bottom/side angle is greater than approximately 135°.

(b) Combined loading condition 3

The vertical and horizontal resultants of the loads, in general other than zero, are to be balanced by introducing two vertical forces and two horizontal forces at the fore and aft ends of the model, distributed on the shells according to the bidimensional flow theory for shear stresses, which are equal and opposite to half the vertical and horizontal resultants of the loads.

.2 Where a plane model is adopted, the resultants are to be balanced by vertical and horizontal forces, distributed as specified above and acting on the plane of the model itself.

C3.6.1.5 Checking criteria

.1 For metal structures, the stresses given by the above calculations are to be not greater than the following allowable values, in N/mm²:

- bending stress:

$$\sigma_{am} = \frac{150}{K \cdot f'_m \cdot f_s}$$

- shear stress:

$$\tau_{am} = \frac{90}{K \cdot f'_m \cdot f_s}$$

- Von Mises equivalent bending stress:

$$\sigma_{eq,\,am} = \frac{190}{K \cdot f'_m \cdot f_s}$$

where:

K : material factor defined in C3.2

f'_m : coefficient depending on the material:

- 1,00 for steel structures
- 2,15 for aluminium alloy structures

f_s : safety coefficient, to be assumed:

- 1,00 for combined loading conditions
- 1,25 for loading condition in still water.

.2 The compressive values of normal stresses and shear stresses are not to exceed the values of the critical stresses for plates and stiffeners calculated according to C3.7.5.

.3 In structural elements also subject to high longitudinal hull girder stresses, allowable and critical stresses are to be reduced, according to criteria specified by the Society.

.4 For non-metal structures, allowable stresses are to be defined according to criteria specified by the Society.

C3.6.2 Direct calculations for catamarans

C3.6.2.1 General

.1 Direct calculations generally require to be carried out, at the discretion of the Society, to check primary structures and structures connecting the two hulls for craft of length L > 65 m or speed V > 45 knots.

.2 In addition, as specified in C3.4.2, direct calculations are to be carried out to check structures connecting the two hulls for craft in which structural arrangements do not allow a realistic assessment of their stress level, based upon simple models and on the formulae set out in C3.4.2.

C3.6.2.2 Loads

.1 In general, the loading conditions specified in C3.6.2.2.6 to C3.6.2.2.9 below are to be considered.

Condition C3.6.2.2.6 applies to a still water static condition check.

Conditions C3.6.2.2.7 and C3.6.2.2.8 apply to the check on structures connecting the two hulls. Condition C3.6.2.2.8 requires checking only for craft of L > 65 m or V > 45 knots.

Condition C3.6.2.2.9 is to be checked in craft for which, in the opinion of the Society, significant racking effects are expected (e.g. ferries).

.2 In relation to special structure or loading configurations, should some loading conditions turn out to be less significant than others, the former may be ignored, at the discretion of the Society. In the same way, it may be necessary to consider further loading conditions specified by the Society in individual cases.

.3 Vertical and transverse accelerations are to be calculated as stipulated in C3.3.

.4 The impact pressure is to be calculated as stipulated in C3.5. For each floor, the K_2-factor which appears in the formula for the impact pressure is to be calculated as a function of the area supported by the floor itself.

.5 In three-dimensional analyses, special attention is to be paid to the distribution of weights and buoyancy and the dynamic equilibrium of the craft.

In the case of three-dimensional analyses, the longitudinal distribution of impact pressure is to be considered individually, in the opinion of the Society. In general, the impact pressure is to be considered as acting separately on each transverse section of the model, the remaining sections being loaded by the hydrostatic pressure.

.6 Loading conditions in still water

The following loads are to be considered:

- forces caused by weights which are expected to be carried in the full load condition, distributed according to the weight booklet of the craft,
- outer hydrostatic load in still water.

.7 Combined loading condition 1

The following loads are to be considered:

- forces caused by weights which are expected to be carried in the full load condition, distributed according to the weight booklet of the craft,
- forces of inertia due to the vertical acceleration a_v of the craft, considered in a downward direction.

.8 Combined loading condition 2

The following loads are to be considered:

- forces caused by weights which are expected to be carried in the full load condition, distributed according to the weight booklet of the craft,
- forces of inertia due to the vertical acceleration a_v of the craft, considered in a downward direction,
- impact pressure acting hemisymmetrically on one of the two halves of the hull bottom.

.9 Combined loading condition 3

The following loads are to be considered:

- forces caused by weights which are expected to be carried in the full load condition, distributed according to the weight booklet of the craft,
- forces of inertia due to the transverse acceleration of the craft.

C3.6.2.3 Structural model

.1 In general, primary structures of craft of this type are to be modelled with finite element schematizations adopting a medium size mesh.

In the opinion of the Society, detailed analyses with fine mesh are required for areas where stresses, calculated with medium-mesh schematizations, exceed allowable limits and the type of structure gives reason to suspect the presence of high stress concentrations.

.2 In general, the extent of the model is to be such as to allow the analysis of the behaviour of the main structural elements and their mutual effects.

.3 In craft dealt with by these Rules, the stiffness of longitudinal primary members (girders and stringers) is, at least outside the machinery space area, generally negligible compared with the stiffness of transverse structures (beams, floors and webs), or their presence may be taken account of by suitable boundary conditions. It is therefore permissible, in general, to examine primary members in this area of the hull by means of plane analyses of transverse rings.

.4 In cases where such approximation is not permissible, the model adopted is to be three-dimensional and is to include the longitudinal primary members.

.5 When racking behaviour is investigated and loads thus act in the transverse direction (loading conditions 2 and 3), special attention is to be devoted to modelling of continuous decks and platforms. Such continuous elements, if having sufficient stiffness in the horizontal plane and if sufficiently restrained by the fore- and after-bodies, may withstand transverse deformations of primary rings.

In such cases, taking for granted the provisions above, it is still permissible to examine bidimensional rings, by simulating the presence of decks and platforms with horizontal springs according to criteria specified by the Society.

C3.6.2.4 Boundary conditions

.1 Depending upon the loading conditions considered, the following boundary conditions may be assigned:

(a) Loading condition in still water

The vertical resultant of loads, in general other than zero, is to be balanced by introducing two vertical forces at the fore and aft ends of the model, both distributed on the shells according to the bidimensional flow theory for shear stresses, which are equal and opposite to half the vertical resultant of the loads.

Where a plane model is adopted, the vertical resultant is to be balanced by a single force, distributed as specified above and acting on the plane of the model itself.

(b) Combined loading condition 1

A vertical restraint is to be imposed in way of the keel of each hull.

(c) Combined loading conditions 2 and 3

The vertical and horizontal resultants of the loads, in general other than zero, are to be balanced by introducing two vertical forces and two horizontal forces at the fore and aft ends of the model, distributed on the shells according to the bidimensional flow theory for shear stresses, which are equal and opposite to half the vertical and horizontal resultants of the loads.

.2 Where a plane model is adopted, the resultants are to be balanced by vertical and horizontal forces, distributed as specified above and acting on the plane of the model itself.

C3.6.2.5 Checking criteria

.1 For metal structures, the stresses given by the above calculations are to be not greater than the following allowable values, in N/mm²:

- bending stress:

$$\sigma = \frac{150}{K \cdot f'_m \cdot f_s}$$

- shear stress:

$$\tau = \frac{90}{K \cdot f'_m \cdot f_s}$$

- Von Mises equivalent stress:

$$\sigma_{all} = \frac{190}{K \cdot f'_m \cdot f_s}$$

where:

K : material factor defined in C3.2,

f'_m : coefficient depending on the material:

- 1,00 for steel structures
- 2,15 for aluminium alloy structures,

f_s : safety coefficient, to be assumed:

- 1,00 for combined loading conditions
- 1,25 for loading condition in still water.

.2 The compressive values of normal stresses and the shear stresses are not to exceed the values of the critical stresses for plates and stiffeners calculated according to C3.7.5.

.3 In structural elements also subject to high longitudinal and transversal hull girder stresses, allowable and critical stresses are to be reduced, according to criteria specified by the Society.

.4 For non-metal structures, allowable stresses are to be defined according to criteria specified by the Society.

C3.7 Steel and aluminium alloy craft

C3.7.1 Introduction

.1 This article stipulates requirements for the scantlings of hull structures (plating, stiffeners, primary supporting members). The loads acting on such structures are to be calculated in accordance with the provisions of C3.5.

.2 In general, for craft length L > 65 m or speed V > 45 knots, the scantlings of transverse structures are to be verified also by direct calculations carried out in accordance with C3.6.

.3 For all other craft, the Society may, at its discretion and as an alternative to the requirements of this article, accept scantlings for transverse structures of the hull based on direct calculations in accordance with C3.6.

C3.7.2 Definitions and symbols

.1 The definitions and symbols used are the following ones:

rule bracket: a bracket with arms equal to $\ell/8$, ℓ being the span of the connected stiffener. Where the bracket connects two different types of stiffeners (frame and beam, bulkhead web and longitudinal stiffener, etc.) the value of ℓ is to be that of the member with the greater span, or according to criteria specified by the Society,

t : thickness, in mm, of plating and deck panels,

Z : section modulus, in cm^3, of stiffeners and primary supporting members,

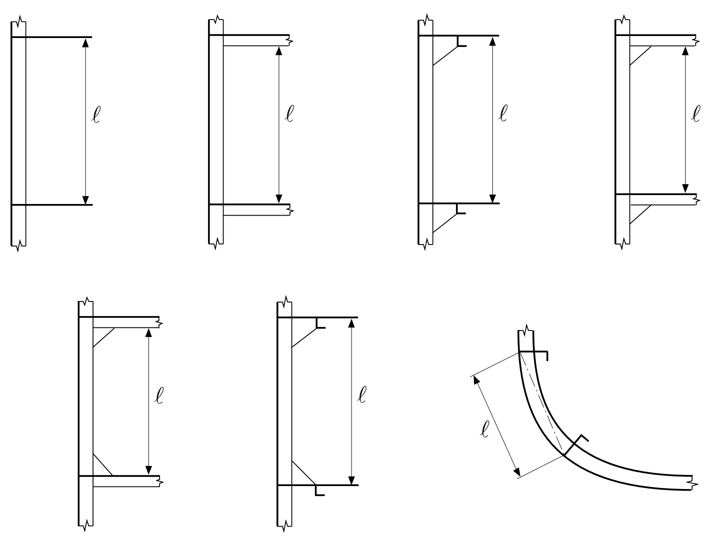
s : spacing of stiffeners, in m, measured along the plating,

ℓ : overall span of stiffeners, in m, i.e. the distance between the supporting elements at the ends of the stiffeners (see Figure C3.7.1),

S : conventional scantling span of primary supporting members, in m, to be taken as given in the examples in Figure C3.7.2. Special consideration is to be given to conditions different from those shown.

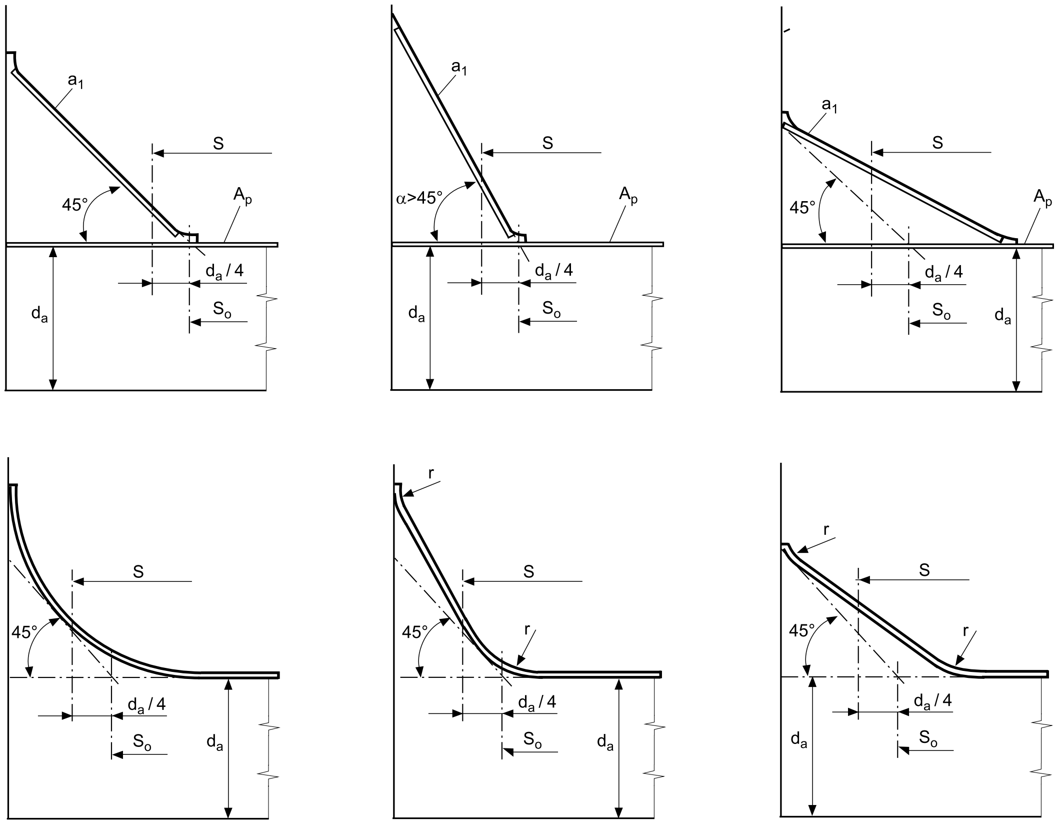
In no case is S to be less than (1,1 S_0), S_0 being the distance between the internal ends of the conventional brackets as indicated in Figure C3.7.2 or, if there are no brackets, between the ends of the members,

Figure C3.7.1 Examples of spans of ordinary stiffeners



Note: the connections with end brackets shown in this Figure are relevant to end brackets with Rule dimensions.

Figure C3.7.2 Examples of conventional scantling spans of primary supporting members



A_p = area of girder face plate; a_1 = area of bracket face plate; $a_1 \geq 0{,}5\ A_p$

b : actual surface width of the load bearing on primary supporting members; for usual arrangements b = 0,5 (l_1 + l_2), where l_1 and l_2 are the spans of stiffeners supported by the primary supporting member,

p : design pressure, in kN/m², calculated as defined in C3.5,

σ_{am} : permissible normal stress, in N/mm²,

τ_{am} : permissible shear stress, in N/mm²,

K : material factor defined in C3.2,

e : ratio between permissible and actual hull girder longitudinal bending stresses (see C3.7.4.1)

$e = \sigma_p / \sigma_{bl}$

σ_p : maximum permissible stress, in N/mm², as defined in C3.7.4.14,

σ_{bl} : longitudinal bending stress, in N/mm², as defined in C3.7.4.14,

μ : defined as follows:

$$\mu = \sqrt{1,1 - 0,5 \cdot \left(\frac{s}{\ell}\right)^2}$$

which needs not be taken greater than 1,0.

C3.7.3 Overall strength

C3.7.3.1 Longitudinal strength

.1 In general, the scantlings resulting from local strength calculations in this article are such as to ensure adequate longitudinal strength of the hull girder for the craft with length less than or equal to 24 m.

.2 Specific longitudinal strength calculations are required for craft whose hull geometry suggests significant bending moments in still water with the craft at rest.

.3 For craft with length less than or equal to 65 m, longitudinal strength calculations are, as a rule, to be carried out at the midship section or any other section of the midship area as deemed necessary by the Society.
For craft with length more than 65 m, longitudinal strength calculations are to be carried out on basis of bending moment distribution as defined in C3.4.1 or C3.4.2.

.4 Longitudinal stress, in N/mm², in each point of the structures contributing to the craft longitudinal strength is obtained from the following equations:

- at bottom:

$$\sigma_{bl} = \frac{M_{bl}}{W_b} \cdot 10^{-3}$$

- at main deck:

$$\sigma_{bl} = \frac{M_{bl}}{W_d} \cdot 10^{-3}$$

- at height z above the bottom:

$$\sigma_{bl} = M_{bl} \cdot \left(\frac{1}{W_b} - \left(\frac{1}{W_b} + \frac{1}{W_d}\right) \cdot \frac{z}{D}\right) \cdot 10^{-3}$$

where:

M_{bl} : total bending moment, in kN.m, defined in C3.4.1 or C3.4.2,

W_b, W_d : section modulus, in m^3, respectively at bottom and main deck at the stress calculation point of the craft section under consideration. In the section modulus calculation, all the elements contributing to longitudinal strength are to be considered, including long deckhouses, as appropriate.

The values of stress σ_{bl} are not to exceed σ_p, with:

- steel structures:

  σ_p = 150/K (N/mm²)

- aluminium alloy structures:

  σ_p = 70/K (N/mm²).

.5 Moreover, the compressive values of σ are not to exceed the values of critical stresses for plates and stiffeners calculated according to C3.7.5 and C3.7.6.

C3.7.3.2 Transverse strength of catamaran

.1 The equivalent Von Mises stresses obtained for load conditions in C3.4.2.3 and C3.4.3.2 are not to exceed the following values:

- steel structures:

  σ_p = 175/K (N/mm²)

- aluminium alloy structures:

  σ_p = 75/K (N/mm²).

.2 The compressive values of normal stresses and the shear stresses are not to exceed the values of critical stresses for plates and stiffeners calculated according to C3.7.5 and C3.7.6.

.3 In general, the bottom of the cross-deck is to be constituted by continuous plating for its entire longitudinal and transverse extension. Alternative solutions may, however, be examined by the Society on the basis of considerations pertaining to the height of the cross-deck above the waterline and to the motion characteristics of the craft.

.4 In the special case of catamaran, when the structure connecting both hulls is formed by a deck with single plating stiffened by n reinforced beams, the normal and shear stresses in the beams for the load condition in C3.4.2.4 can be calculated as indicated in C3.7.3.3.

.5 For craft with L > 65 m or speed V > 45 m knots, or for those craft whose structural arrangements do not permit a realistic assessment of stress conditions based on simple models, the transverse strength is to be checked by means of direct calculations carried out in accordance with the criteria specified in article C3.6.

C3.7.3.3 Transverse strength in the special case of catamaran craft when the structure connecting both hulls is formed by a deck with single plate stiffened by n reinforced beams over the deck

.1 Referring to Figure C3.7.3, G is the centre of the stiffnesses r_i of the n beams. Its position is defined by:

$$a = \frac{\sum r_i \cdot x_i}{\sum r_i}$$

where:

a : abscissa, in m, of the centre G with respect to an arbitrarily chosen origin 0,

r_i : stiffness, in N/m, of the beam i, equal to:

$$r_i = \frac{12 E_i I_i}{S_i^3} 10^6$$

E_i : Young's modulus, in N/mm², of the beam i,

I_i : bending inertia, in m^4, of the beam i,

S_i : span, in m, of the beam i between the inner faces of the hulls,

x_i : abscissa, in m, of the beam i with respect to the origin 0.

If F_i, in N, is the force taken over by the beam i, the deflection y_i, in m, of the hull in way of the beam i, is:

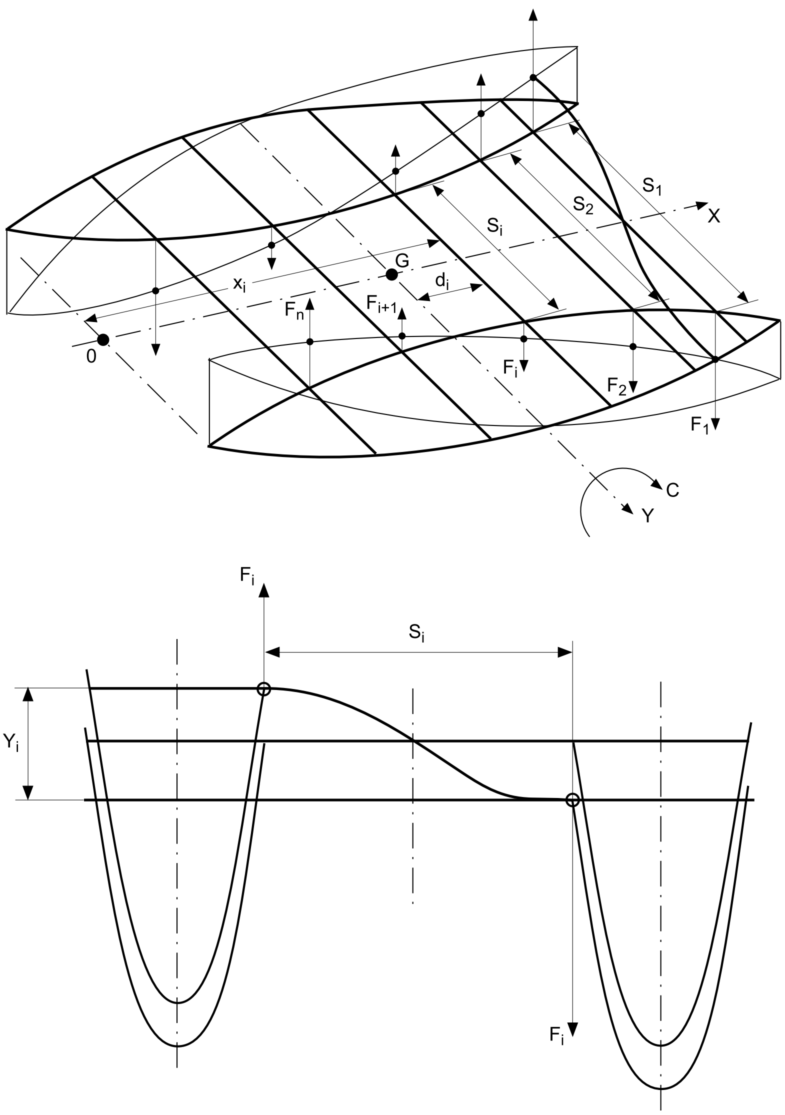
$$y_i = \frac{F_i \cdot S_i^3 \cdot 10^{-6}}{12 \cdot E_i \cdot I_i} = \frac{F_i}{r_i} = d_i \cdot \omega$$

d_i : abscissa, in m, of the beam i in relation to G:

$d_i = x_i - a$,

ω : rotation angle, in rad, of one hull in relation to the other around a transverse axis passing through G.

Figure C3.7.3



.2 From the transverse torsional moment (cf. C3.4.2.4) $M_{tt} = F_i \cdot d_i \ 10^{-3}$, the formula for ω may be obtained:

$$\omega = \frac{M_{tt}}{\sum r_i \cdot d_i^2} \cdot 10^3$$

.3 As M_{tt}, r_i and d_i are known, ω is thus deduced, then the force F_i, in N, the bending moment M_i, in N.m, and the corresponding normal and shear stresses can be evaluated in each beam:

$F_i = \omega \ r_i \ d_i$

$M_i = F_i \ S_i / 2$

Note: Beams calculated by the above method are assumed to be fixed in each hull as beams in way of bulkheads inside hulls. For this hypothesis to be correct, the beams are to extend over the whole breadth of both hulls and their stiffness is to be kept the same over the overall span inside and outside the hulls.

C3.7.4 Fatigue

C3.7.4.1 General

.1 The fatigue strength of structural details is to be checked, when deemed necessary by the Society. In this case, the Society's criteria are to be applied.

C3.7.4.2 Effect of stabilisation system

.1 The beneficial effect of stabilisation system may be considered for the purpose of fatigue analysis.

.2 In such a case, loads reductions are to be justified by designer on basis of tank tests or full scale tests.

C3.7.5 Buckling strength of steel structural members

C3.7.5.1 Application

.1 These requirements apply to steel plates and stiffeners subject to compressive load, to calculate their buckling strength. Other buckling rules can be accepted as agreed with the Society.

C3.7.5.2 Elastic buckling stresses of plates

.1 Compressive stress

The elastic buckling stress, in N/mm², is given by:

$$\sigma_E = 0,9 \cdot m_c \cdot E \cdot \left(\frac{t}{1000 \cdot a}\right)^2$$

where:

m_c :
- for plating with stiffeners parallel to compressive stress:

  $$m_c = \frac{8,4}{\psi + 1,1}$$

- for plating with stiffeners perpendicular to compressive stress:

  $$m_c = c \cdot \left(1 + \left(\frac{a}{b}\right)^2\right)^2 \cdot \frac{2,1}{\psi + 1,1}$$

E : Young's modulus, in N/mm², to be taken equal to $2{,}06 \cdot 10^5$ N/mm² for steel structure,

t : thickness of plating, in mm,

a : shorter side of plate, in m,

b : longer side of plate, in m,

c :
- c = 1,30 when plating is stiffened by floors or deep girders
- c = 1,21 when plating is stiffened by ordinary stiffeners with angle- or T-sections
- c = 1,10 when plating is stiffened by ordinary stiffeners with bulb sections
- c = 1,05 when plating is stiffened by flat bar ordinary stiffeners,

Ψ : ratio between smallest and largest compressive stresses when the stress presents a linear variation across the panel ($0 \le \Psi \le 1$).

.2 Shear stress

The elastic buckling stress is given by:

$$\tau_E = 0,9 \cdot m_t \cdot E \cdot \left(\frac{t}{1000 \cdot a}\right)^2$$

where:

$m_t = 5{,}34 + 4 \cdot (a / b)^2$

E, t, a and b are given in C3.7.5.2.1 above.

C3.7.5.3 Elastic buckling stress of stiffeners

.1 Column buckling without rotation of the cross section

For the column buckling mode (perpendicular to the plane of plating) the elastic buckling stress, in N/mm², is given by:

$$\sigma_E = 0,001 \cdot E \cdot \frac{I_a}{A \cdot \ell^2}$$

where:

E : Young's modulus, in N/mm², to be taken equal to $2{,}06 \cdot 10^5$ N/mm² for steel structures,

I_a : moment of inertia, in cm⁴, of the stiffener, including plate flange,

A : cross-sectional area, in cm², of the stiffener, including plate flange,

ℓ : span, in m, of the stiffener.

.2 Torsional buckling mode

For the torsional mode, the elastic buckling stress, in N/mm², is given by:

$$\sigma_E = \frac{\pi^2 \cdot E \cdot I_w}{10^4 \cdot I_p \cdot \ell^2} \cdot \left(m^2 + \frac{C_K}{m^2}\right) + 0,385 \cdot E \cdot \frac{I_t}{I_p}$$

where:

E, ℓ : given in C3.7.5.3.1 above,

$$C_K = \frac{C \cdot \ell^4}{\pi^4 \cdot E \cdot I_w} \cdot 10^6$$

m : number of half-waves, given in Table C3.7.1,

Table C3.7.1 - Values of m

C_K	m
$0 < C_k < 4$	1
$4 < C_k < 36$	2
$36 < C_k < 144$	3
$(m-1)^2\, m^2 < C_k \le m^2\,(m+1)^2$	m

I_t : St. Venant moment of inertia of profile, in cm⁴, without plate flange, equal to:
- for flat bars:

  $$I_t = \frac{h_w \cdot t_w^3}{3} \cdot 10^{-4}$$

- for flanged profile:

  $$I_t = \frac{1}{3} \cdot \left(h_w \cdot t_w^3 + b_f \cdot t_f^3 \cdot \left(1 - 0,63 \cdot \frac{t_f}{b_f}\right)\right) \cdot 10^{-4}$$

I_p : polar moment of inertia of profile, in cm^4, about connection of stiffener to plate, equal to:

- for flat bars:

$$I_p = \frac{h_w^3 \cdot t_w}{3} \cdot 10^{-4}$$

- for flanged profile:

$$I_p = \left(\frac{h_w^3 \cdot t_w}{3} + h_w^2 \cdot b_f \cdot t_f\right) \cdot 10^{-4}$$

I_w : sectional moment of inertia of profile, in cm^6, about connection of stiffener to plate, equal to:

- for flat bars:

$$I_w = \frac{h_w^3 \cdot t_w^3}{36} \cdot 10^{-6}$$

- for T profiles:

$$I_w = \frac{t_f \cdot b_f^3 \cdot h_w^2}{12} \cdot 10^{-6}$$

- for angles and bulb profiles:

$$I_w = \frac{b_f^3 \cdot h_w^2 \cdot 10^{-6}}{12 \cdot (b_f + h_w)^2} \cdot (t_f \cdot (b_f^2 + 2b_f \cdot h_w + 4 \cdot h_w^2) + 3t_w \cdot b_f \cdot h_w)$$

h_w : web height, in mm,

t_w : web thickness, in mm,

b_f : flange width, in mm,

t_f : flange thickness, in mm; for bulb profiles, the mean thickness of the bulb may be used,

C : spring stiffness factor, exerted by supporting plate panel, equal to:

$$C = \frac{k_p \cdot E \cdot t^3}{3s \cdot \left(1 + \frac{1,33 \cdot k_p \cdot h_w \cdot t^3}{1000 \cdot s \cdot t_w^3}\right)} \cdot 10^{-3}$$

t : plate thickness, in mm,

s : spacing of stiffeners, in m,

$k_p = 1 - \eta_p$, not to be less than zero,

$\eta_p = \sigma_a / \sigma_{Ep}$

σ_a : calculated compressive stress in the stiffener,

σ_{Ep} : elastic buckling stress of plate as calculated in C3.7.5.2.1

.3 Web buckling

The elastic buckling stress, in N/mm^2, is given by:

$$\sigma_E = 3,8 \cdot E \cdot \left(\frac{t_w}{h_w}\right)^2$$

where:

E : given in C3.7.5.3.1 above,

t_w, h_w : given in C3.7.5.3.2 above.

C3.7.5.4 Critical buckling stresses

.1 Compressive stress

The critical buckling stress in compression σ_c, in N/mm^2, for plates and stiffeners, is given by:

$$\sigma_c = \frac{\sigma_E}{SF_1} \qquad \text{if } \sigma_E \le \frac{R_{eH}}{2}$$

$$\sigma_c = \frac{R_{eH}}{SF_1} \cdot \left(1 - \frac{R_{eH}}{4 \cdot \sigma_E}\right) \quad \text{if } \sigma_E > \frac{R_{eH}}{2}$$

where:

R_{eH} : minimum yield stress of steel used, in N/mm^2,

σ_E : elastic buckling stress calculated according to C3.7.5.2.1 and C3.7.5.3.

SF_1 : safety factor defined in C3.7.5.4.3.

.2 Shear stress

The critical buckling shear stress τ_c, in N/mm^2, for panels and stiffeners, is given by:

$$\tau_c = \frac{\tau_E}{SF_1} \qquad \text{if } \tau_E \le \frac{\tau_F}{2}$$

$$\tau_c = \frac{\tau_F}{SF_1} \cdot \left(1 - \frac{\tau_F}{4 \cdot \tau_E}\right) \quad \text{if } \tau_E > \frac{\tau_F}{2}$$

where:

$$\tau_F = \frac{R_{eH}}{\sqrt{3}}$$

R_{eH} : minimum yield stress of steel used, in N/mm^2,

τ_E : elastic buckling stress calculated according to C3.7.5.2.2.

SF_1 : safety factor defined in C3.7.5.4.3

.3 Safety factors

The values of safety factor SF_1 to be used are given below:

- Plating
  - local loads: $SF_1 = 1,00$
  - overall loads: $SF_1 = 1,00$
- Secondary stiffeners
  - local loads: $SF_1 = 1,00$
  - overall loads: $SF_1 = 1,33$
- Primary structure
  - local loads: $SF_1 = 1,00$
  - overall loads: $SF_1 = 1,53$

C3.7.6 Buckling strength of aluminium alloy structural members

C3.7.6.1 Application

.1 These requirements apply to aluminium alloy plates and stiffeners subjected to compressive load, to calculate their buckling strength.Other buckling rules can be accepted as agreed with the Society.

C3.7.6.2 Elastic buckling stresses of plates

.1 Compressive stress

The elastic buckling stress, in N/mm², is given by:

$$\sigma_E = 0,9 \cdot m_c \cdot E \cdot \varepsilon \cdot \left(\frac{t}{1000 \cdot a}\right)^2$$

where:

m_c :
- for uniform compression (Ψ = 1):
  $m_c = (1 + \gamma^2)^2$
- for compression-bending stress ($0 \le \Psi \le 1$):
  - if $\gamma < \gamma_1$:
    $$m_c = 1 + \frac{\gamma}{\gamma_1} \cdot (m_1 - 1)$$
  - if $\gamma \ge \gamma_1$:
    $$m_c = \frac{2,1}{1,1 + \psi} \cdot (1 + \gamma^2)^2$$

γ : c/d, not to be greater than 1,

c : unloaded side of plate, in m,

d : loaded side of plate, in m,

$$\gamma_1 = \sqrt{\frac{\sqrt{4 - \frac{1,1 + \Psi}{0,7}} - 1}{3}}$$

$$m_1 = \frac{2,1}{1,1 + \Psi} \cdot (1 + \gamma_1^2)^2$$

Ψ : ratio between smallest and largest compressive stresses when the stress presents a linear variation across the panel ($0 \le \Psi \le 1$),

E : Young's modulus, in N/mm², to be taken equal to $0,7 \cdot 10^5$ N/mm² for aluminium alloy structures,

ε : coefficient equal to:
- for edge d stiffened by a flat bar or bulb section:
  - if $\gamma \ge 1$: $\varepsilon = 1,0$
  - if $\gamma < 1$: $\varepsilon = 1,1$
- for edge d stiffened by angle- or T-section:
  - if $\gamma \ge 1$: $\varepsilon = 1,1$
  - if $\gamma < 1$: $\varepsilon = 1,25$

t : plate thickness, in mm,

a : shorter side of plate, in m.

.2 Shear stress

The critical buckling stress, in N/mm², is given by:

$$\tau_E = 0,9 \cdot m_t \cdot E \cdot \left(\frac{t}{1000 \cdot a}\right)^2$$

where:

E, t and a are given in C3.7.6.2.1,

$m_t = 5,34 + 4\,(a / b)^2$

b : longer side of plate, in m.

C3.7.6.3 Critical buckling stresses

.1 Compressive stress

The critical buckling stress σ_c, in N/mm², is given by:

$$\sigma_c = \frac{\sigma_E}{SF_1} \qquad \text{if } \sigma_E \le \frac{R_{p0,2}}{2}$$

$$\sigma_c = \frac{R_{p0,2}}{SF_1} \cdot \left(1 - \frac{R_{p0,2}}{4 \cdot \sigma_E}\right) \quad \text{if } \sigma_E > \frac{R_{p0,2}}{2}$$

where:

$R_{p\,0,2}$: minimum guaranteed yield stress of aluminium alloy used, in N/mm², in delivery conditions,

σ_E : elastic buckling stress calculated according to C3.7.6.2.1.

SF_1 : safety factor defined in C3.7.5.4.3

.2 Shear stress

The critical buckling stress τ_c, in N/mm², is given by:

$$\tau_c = \frac{\tau_E}{SF_1} \qquad \text{if } \tau_E \le \frac{R_{p0,2}}{2\sqrt{3}}$$

$$\tau_c = \frac{R_{p0,2}}{SF_1 \cdot \sqrt{3}} \cdot \left(1 - \frac{R_{p0,2}}{4 \cdot \tau_E \cdot \sqrt{3}}\right) \quad \text{if } \tau_E > \frac{R_{p0,2}}{2\sqrt{3}}$$

where:

$R_{p\,0,2}$: as defined in C3.7.6.3.1,

τ_E : elastic buckling stress calculated according to C3.7.6.2.2.

SF_1 : safety factor defined in C3.7.5.4.3

C3.7.6.4 Axially loaded stiffeners

.1 Elastic flexural buckling stress

The elastic flexural buckling stress σ_E, in N/mm², is given by:

$$\sigma_E = 69,1 \cdot \left(\frac{r}{1000 \cdot c}\right)^2 \cdot m \cdot 10^4$$

where:

r : gyration radius, in mm, equal to:

$$r = 10\sqrt{\frac{I}{S + \varphi \cdot t \cdot 10^{-2}}}$$

I : moment of inertia of the stiffener, in cm^4, calculated with a plate flange of width equal to φ,

φ : smaller of:
800 a, and
200 c

S : area of the cross section of the stiffener, in cm^2, excluding attached plating,

m : coefficient depending on boundary conditions:

- m = 1 for a stiffener simply supported at both ends,
- m = 2 for a stiffener simply supported at one end and fixed at the other one,
- m = 4 for a stiffener fixed at both ends.

.2 Local elastic buckling stresses

The local elastic buckling stresses σ_E, in N/mm^2, are given by:

- for flat bars:

$$\sigma_E = 55 \cdot \left(\frac{t_w}{h_w}\right)^2 \cdot 10^3$$

- for built up stiffeners with symmetrical flange:
  - web:

$$\sigma_E = 27 \cdot \left(\frac{t_w}{h_w}\right)^2 \cdot 10^4$$

  - flange:

$$\sigma_E = 11 \cdot \left(\frac{t_f}{b_f}\right)^2 \cdot 10^4$$

where:

h_w : web height, in mm,

t_w : web thickness, in mm,

b_f : flange width, in mm,

t_f : flange thickness, in mm.

.3 Critical buckling stress

The critical buckling stress σ_c, in N/mm^2, is given by:

$$\sigma_c = \frac{\sigma_E}{SF_1} \quad \text{if } \sigma_E \le \frac{R_{p0,2}'}{2}$$

$$\sigma_c = \frac{R_{p0,2}'}{SF_1} \cdot \left(1 - \frac{R_{p0,2}'}{4 \cdot \sigma_E}\right) \quad \text{if } \sigma_E > \frac{R_{p0,2}'}{2}$$

where:

$R_{p\,0,2}'$: minimum as-welded guaranteed yield stress of aluminium alloy used, in N/mm^2,

σ_E : either overall elastic buckling stress or local elastic buckling stress calculated according to C3.7.6.4.1 or C3.7.6.4.2, whichever is the less.

SF_1 : safety factor defined in C3.7.5.4.3

C3.7.7 Plating

C3.7.7.1 Formula

.1 The thickness, in mm, required for the purposes of resistance to design pressure, is given by the formula:

$$t = 22,4 \cdot \mu \cdot s \cdot \sqrt{\frac{p}{\sigma_{am}}}$$

Pressure p, in kN/m^2, and permissible stress σ_{am}, in N/mm^2, are defined in requirements stipulated in C3.7.7.3 to C3.7.7.8 for the various parts of the hull.

.2 In addition, the thicknesses of plating are to be not less than the minimum values given in Table C3.7.2, in general.

.3 Lesser thicknesses than the one given in Table C3.7.2 may be accepted provided that their adequacy in relation to strength against buckling and collapse is demonstrated to the satisfaction of the Society. Adequate provision is also to be made to limit corrosion.

Table C3.7.2

Element	Minimum thickness (mm)
Shell plating: • Bottom shell plating • Side shell plating and wet deck plating	 $1,35 \cdot L^{1/3} \ge 2,5$ $1,15 \cdot L^{1/3} \ge 2,5$
Deck plating	2,5
Bulkhead plating	2,5
Deckhouse side shell plating	2,5

C3.7.7.2 Keel

.1 The thickness of keel plating is to be not less than that required for adjacent bottom plating.

.2 This requirement may be waived in the case of special arrangements for dry-docking of craft of unusual hull design in the opinion of the Society.

C3.7.7.3 Bottom shell and bilge plating

.1 The minimum required thickness is to satisfy the requirements of the formula in C3.7.7.1 under the following two conditions:

(a) p : impact pressure p_{sl} if occurring on the bottom as defined in C3.5.3;

σ_{am} :
- steel structures:
  $\sigma_{am} = 235/K$ (N/mm^2)
- aluminium alloy structures:
  $\sigma_{am} = 95/K$ (N/mm^2),

(b) p : sea pressure p_s as defined in C3.5.5;

σ_{am} :
- steel structures:
  σ_{am} = 185/K (N/mm^2)
- aluminium alloy structures:
  σ_{am} = 85/K (N/mm^2).

.2 The thickness of bilge plating is not, in any case, to be less than that of the bottom and side adjacent, whichever is greater.

.3 The thickness of plates connected to the stern frame, or in way of propeller shaft brackets, is to be at least 1,5 times the thickness of the adjacent plating.

.4 In craft fitted with a bow thruster, the thickness of the connection with the housing of such propeller is to be considered individually by the Society.

C3.7.7.4 Sea intakes and other openings

.1 Sea intakes and other openings are to be well rounded at the corners and located, as far as practicable, well clear of sharp edges.

.2 Sea chests are to have scantlings as for watertight tank bulkheads (see C3.7.11), taking a design pressure p_t, in kN/m^2, equal to:

$p_t = p_s + 0{,}5 \cdot p_{sl}$

where p_s and p_{sl} are as defined in C3.5.5 and C3.5.3 respectively.

C3.7.7.5 Plating of side shell and front walls

.1 The minimum required thickness is given by the formula in C3.7.7.1, assuming:

p :
- sea pressure p_s as defined in C3.5.5, for side shell plating,
- sea pressure p_{sf} as defined in C3.5.6, for front wall plating,

σ_{am} :
- steel structures:
  σ_{am} = 185/K (N/mm^2)
- aluminium alloy structures:
  σ_{am} = 85/K (N/mm^2).

If front walls are located at the fore end of the hull, the pressure p_{sf} (see C3.5.6) and the allowable stresses are to be considered individually by the Society.

.2 The thickness of the sheerstrake is to be not less than that of the side or stringer plate.

.3 At the ends of deckhouses, the thickness of the sheerstrake is to be suitably increased.

.4 Where side scuttles or windows or other openings are located on the sheerstrake, the thickness is to be increased to compensate for the openings.

C3.7.7.6 Plating of wet deck (cross-deck bottom) and internal sides of catamaran

.1 The minimum required thickness for the wet deck plating is given by the formula in C3.7.7.1, assuming:

(a) p : impact pressure p_{sl} as defined in C3.5.4;

σ_{am} :
- steel structures:
  σ_{am} = 235/K (N/mm^2)
- aluminium alloy structures:
  σ_{am} = 95/K (N/mm^2),

(b) p : sea pressure ps as defined in C3.5.5;

σ_{am} :
- steel structures:
  σ_{am} = 185/K (N/mm^2)
- aluminium alloy structures:
  σ_{am} = 85/K (N/mm^2).

.2 Moreover, the thickness of internal sides may be intermediate between that of the bottom of hulls and the bottom of the cross-deck. In any case, it is to be no less than that required in C3.7.7.5 for external sides.

C3.7.7.7 Deck plating

.1 The minimum required thickness is given by the formula in C3.7.7.1, assuming:

p : deck pressure p_d as defined in C3.5.8;

σ_{am} :
- steel structures:
  σ_{am} = 185/K (N/mm^2)
- aluminium alloy structures:
  σ_{am} = 85/K (N/mm^2).

.2 The thickness, in mm, of decks intended for the carriage of vehicles is to be not less than the value calculated by the formula:

$t = f \cdot (c \cdot P \cdot K)^{0,5}$

where:

f : coefficient equal to:
- 3,9 for steel structures
- 5,6 for aluminium alloy structures,

c : coefficient given in Table C3.7.3 as a function of the dimensions u and v of the tyre print (see Figure C3.7.4),

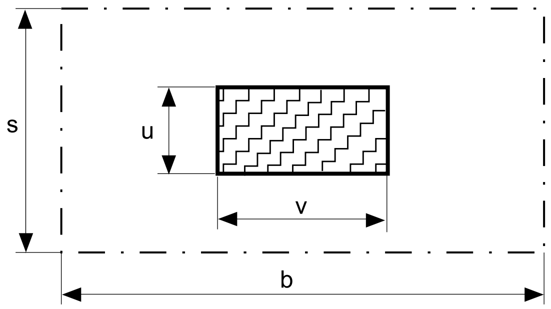
P : static load on the tyre print, in kN, increased by $(1 + 0{,}4 \cdot a_v)$, a_v being the design vertical acceleration defined in C3.3.

Where there are double wheels, the tyre print consists of both.

Table C3.7.3 - Coefficient c

b/s	v/u	u/s									
		0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1,0
1	0,5	0,242	0,174	0,138	0,113	0,094	0,080	0,077	0,060	0,052	0,045
	1,0	0,222	0,160	0,122	0,099	0,079	0,066	0,055	0,045	0,037	0,030
	2,0	0,198	0,134	0,098	0,073	0,053	–	–	–	–	–
	3,0	0,175	–	–	–	–	–	–	–	–	–
1,4	0,5	0,228	0,189	0,158	0,128	0,111	0,096	0,083	0,073	0,064	0,056
	1,0	0,217	0,177	0,143	0,116	0,098	0,082	0,070	0,060	0,051	0,043
	2,0	0,196	0,153	0,119	0,092	0,072	0,058	0,046	–	–	–
	3,0	0,178	0,134	0,100	0,072	–	–	–	–	–	–
≥ 2,5	0,5	0,232	0,196	0,163	0,135	0,117	0,100	0,087	0,077	0,067	0,059
	1,0	0,219	0,184	0,150	0,123	0,105	0,088	0,076	0,066	0,056	0,048
	2,0	0,199	0,161	0,129	0,101	0,082	0,067	0,055	0,046	0,037	0,031
	3,0	0,185	0,142	0,108	0,083	0,064	0,051	0,038	0,028	0,019	0,012

Figure C3.7.4



.3 The designer is to supply details of tyre pressure, wheel dimensions, loads on wheels and tyre print dimensions. Where this information is not available, an approximate value of the thickness, in mm, may be obtained from the following formula:

$t = f_1 \cdot C_1 \cdot (P_1 \cdot K)^{0,5}$

where:

f_1 : coefficient equal to:
- 0,28 for steel structures
- 0,38 for aluminium alloy structures,

C1 : coefficient equal to:
- 3,60 for vehicles with 4 wheels per axle
- 4,45 for vehicles with 2 wheels per axle,

P_1 : static axle load, in kN, increased by $(1 + 0,4 \cdot a_v)$, a_v being the design vertical acceleration defined in C3.3.

.4 The thickness of areas of watertight decks or flats forming steps in watertight bulkheads or the top or the bottom of a tank is also to comply with the provisions of C3.7.11.

C3.7.7.8 Plating of deckhouse walls

.1 The minimum required thickness is given by the formula in C3.7.7.1, assuming:

p : sea pressure p_{su} as defined in C3.5.7;

σ_{am} :
- steel structures:

  $\sigma_{am} = 185/K$ (N/mm²)
- aluminium alloy structures:

  $\sigma_{am} = 85/K$ (N/mm²).

.2 Openings (doors, windows) are to be well rounded at the corners.

.3 Where there is no access from inside deckhouses to ’tween-decks below or where one of the boundary walls concerned is in a particularly sheltered position, reduced scantlings compared with those above may be accepted, at the discretion of the Society.

.4 For unprotected front walls located at the fore end, the pressure p_{su} and allowable stresses are to be considered individually by the Society.

C3.7.8 Ordinary stiffeners

C3.7.8.1 General

.1 This sub-article states the requirements to be complied with for ordinary stiffeners of the bottom, sides, decks and, for catamaran, the cross-deck and internal sides.

.2 The section modulus Z, in cm^3, and the shear area A_t, in cm^2, required for the purpose of supporting the design pressure transmitted by the plating, are given by the following formulae:

$$Z = 1000 \cdot \frac{\ell^2 \cdot s \cdot p}{m \cdot \sigma_{am}}$$

$$A_t = 5 \cdot \frac{\ell \cdot s \cdot p}{\tau_{am}}$$

where m is a coefficient depending on the type of stiffener and on whether there are Rule brackets at the end of each individual span. The values of m are indicated in Table C3.7.4.

The pressure p, in kN/mm^2, and allowable stresses σ_{am} and τ_{am}, in N/mm^2, are defined in C3.7.8.2 to C3.7.8.6 for the various regions of the hull.

Table C3.7.4 - Coefficient m

Type of stiffener	m
Continuous longitudinal stiffeners without Rule brackets at the ends of span	12
Longitudinal and transverse stiffeners with Rule brackets at the ends of span	19
Longitudinal and transverse stiffeners with Rule brackets at one end of span	15
Non-continuous longitudinal stiffeners and transverse stiffeners without Rule brackets at the ends of span	8

.3 These formulae are valid for stiffeners whose web is perpendicular to the plating, or forms an angle to the plating of less than 15°.

In the case of stiffeners whose web forms an angle $\alpha > 15°$ to the perpendicular to the plating, the required modulus and shear area may be obtained from the same formulae, dividing the values of Z and A_t by cos (α).

.4 The section modulus of ordinary stiffeners is to be calculated in association with an effective width of plating equal to the spacing of the stiffeners, without exceeding 20 per cent of the span.

.5 For steel stiffeners, the web thickness is to be not less than:

- 1/18 of the depth, for flat bars,
- 1/50 of the depth, for other sections,

and the thickness of the face plate is to be not less than 1/15 of its width.

.6 For aluminium alloy stiffeners, the web thickness is to be not less than:

- 1/15 of the depth, for flat bars,
- 1/35 of the depth, for other sections,

and the thickness of the face plate is to be not less than 1/20 of its width.

.7 The ends of ordinary stiffeners are, in general, to be connected by means of rule brackets to effective supporting structures.

Ends without brackets are accepted at the penetrations of primary supporting members or bulkheads by continuous stiffeners, provided that there is sufficient effective welding section between the two elements. Where this condition does not occur, bars may be accepted instead of the brackets, at the discretion of the Society.

.8 In general, the resistant weld section A_w, in cm^2, connecting the ordinary stiffeners to the web of primary members, is not to be less than:

$$A_w = \varphi \cdot p \cdot s \cdot \ell \cdot K \cdot 10^{-3}$$

where:

φ : coefficient as indicated in Table C3.7.5,

p : design pressure, in kN/m^2, acting on the secondary stiffeners, defined below for various hull regions,

s : spacing of ordinary stiffeners, in m,

ℓ : span of ordinary stiffeners, in m,

K : greatest material factor of ordinary stiffener and primary member, defined in C3.2.

Table C3.7.5 - Coefficient φ

Case	Weld	Aluminium alloy	Steel
1	Parallel to the reaction exerted on primary member	200	100
2	Perpendicular to the reaction exerted on primary member	160	75

.9 For aluminium alloys, when calculating the resistant connecting weld section, the fillet weld length d_e, in mm, is determined as follows (see cases 1 and 2 in Table C3.7.5):

case 1 : $d_e = d - 20$,
where d is the length of the weld, in mm,

case 2 : for extruded T stiffeners, the lesser of:
$d_e = d - 20$ and $d_e = 4\ t$,
where b, in mm, is the flange width of the ordinary stiffener and t, in mm, is the web thickness of the primary member.

C3.7.8.2 Bottom and bilge stiffeners

.1 Both single and double bottoms are generally to be longitudinally framed.

.2 The section modulus, shear area and welding section required for bottom and bilge stiffeners are given by the formulae in C3.7.8.1, assuming:

(a) p : impact pressure p_{sl} if occurring on the bottom as defined in C3.5.3;

σ_{am} , τ_{am} :
- steel structures:
  σ_{am} = 150/K (N/mm²)
  τ_{am} = 90/K (N/mm²)
- aluminium alloy structures:
  σ_{am} = 70/K (N/mm²)
  τ_{am} = 45/K (N/mm²),

(b) p : sea pressure p_s as defined in C3.5.5;

σ_{am}, τ_{am} :
- stiffeners contributing to the longitudinal strength:
  - steel structures:
    σ_{am} = 150 C_S/K (N/mm²)
    τ_{am} = 90/K (N/mm²)
  - aluminium alloy structures:
    σ_{am} = 70 C_A/K (N/mm²)
    τ_{am} = 45/K (N/mm²),
- stiffeners not contributing to the longitudinal strength:
  - steel structures:
    σ_{am} = 150/K (N/mm²)
    τ_{am} = 90/K (N/mm²)
  - aluminium alloy structures:
    σ_{am} = 70/K (N/mm²)
    τ_{am} = 45/K (N/mm²),

where C_S and C_A are given by Table C3.7.6.

.3 Bottom longitudinals are preferably continuous through the transverse elements. Where they are interrupted at a transverse watertight bulkhead, continuous brackets are to be positioned through the bulkhead so as to connect the ends of longitudinals.

C3.7.8.3 Side and front wall stiffeners

.1 The section modulus, shear area and welding section are given by the formulae in C3.7.8.1, assuming:

p :
- sea pressure p_s as defined in C3.5.5, for side stiffeners,
- sea pressure p_{sf} as defined in C3.5.6, for front wall stiffeners,

σ_{am} , τ_{am} :
- side stiffeners contributing to the longitudinal strength:
  - steel structures:
    σ_{am} = 150 C_S/K (N/mm²)
    τ_{am} = 90/K (N/mm²)
  - aluminium alloy structures:
    σ_{am} = 70 C_A/K (N/mm²)
    τ_{am} = 45/K (N/mm²),
- side stiffeners not contributing to the longitudinal strength and front wall stiffeners:
  - steel structures:
    σ_{am} = 150/K (N/mm²)
    τ_{am} = 90/K (N/mm²)
  - aluminium alloy structures:
    σ_{am} = 70/K (N/mm²)
    τ_{am} = 45/K (N/mm²),

where C_S and C_A are given by Table C3.7.6.

.2 For unprotected front walls located at the fore end, the pressure p_{sf} (see C3.5.6) and allowable stresses are to be considered individually by the Society.

Table C3.7.6 - Coefficients C_S and C_A

L	x/L	Steel structures C_S	Aluminium alloy structures C_A
L ≤ 24 m	$0 \le x/L \le 1$	1	1
L > 24 m (Note 2)	$0 \le x/L \le 1$	1,4 - 1/e	1,3 - 1/e
Alternative method for 24 m < L ≤ 65 m (Note 3)	$x/L < 0{,}1$	1	1
	$0{,}1 \le x/L \le 0{,}3$	$1 + 0{,}5 \cdot \left(0{,}4 - \frac{1}{e}\right) \cdot \left(10 \cdot \frac{x}{L} - 1\right)$	$1 + 0{,}5 \cdot \left(0{,}3 - \frac{1}{e}\right) \cdot \left(10 \cdot \frac{x}{L} - 1\right)$
	$0{,}3 < x/L < 0{,}7$	$1{,}4 - \frac{1}{e}$	$1{,}3 - \frac{1}{e}$
	$0{,}7 \le x/L \le 0{,}9$	$1 - 0{,}5 \cdot \left(0{,}4 - \frac{1}{e}\right) \cdot \left(10 \cdot \frac{x}{L} - 9\right)$	$1 - 0{,}5 \cdot \left(0{,}3 - \frac{1}{e}\right) \cdot \left(10 \cdot \frac{x}{L} - 9\right)$
	$0{,}9 < x/L \le 1$	1	1

Note 1 : In these formulae, the values of C_S and C_A are to be taken less than or equal to 1.

Note 2 : The ratio e is to be calculated at the location x, on basis of bending moment distribution defined in C3.4.1and C3.4.2.

Note 3 : The ratio e is to be calculated at the section comprised between 0,3 · L and 0,7 · L at which e takes the highest value.

C3.7.8.4 Stiffeners of wet deck (cross-deck bottom) and internal sides of catamaran

.1 The section modulus, shear area and welding section required for bottom stiffeners of the cross-deck are given by the formulae in C3.7.8.1, assuming:

(a) p : impact pressure p_{sl} as defined in C3.5.4;

σ_{am} , τ_{am} :
- steel structures:
  σ_{am} = 180/K (N/mm^2)
  τ_{am} = 90/K (N/mm^2)
- aluminium alloy structures:
  σ_{am} = 85/K (N/mm^2)
  τ_{am} = 45/K (N/mm^2),

(b) p : sea pressure p_s as defined in C3.5.5;

σ_{am} , τ_{am} :
- stiffeners contributing to the longitudinal strength:
  - steel structures:
    σ_{am} = 150 C_S/K (N/mm^2)
    τ_{am} = 90/K (N/mm^2)
  - aluminium alloy structures:
    σ_{am} = 70 C_A/K (N/mm^2)
    τ_{am} = 45/K (N/mm^2),
- stiffeners not contributing to the longitudinal strength:
  - steel structures:
    σ_{am} = 150/K (N/mm^2)
    τ_{am} = 90/K (N/mm^2)
  - aluminium alloy structures:
    σ_{am} = 70/K (N/mm^2)
    τ_{am} = 45/K (N/mm^2),

where C_S and C_A are given by Table C3.7.6.

.2 Internal side stiffeners may have characteristics intermediate between those of the bottom of the hull and those of the bottom of the cross-deck. In any case, such characteristics are not to be less than those required in C3.7.8.3 for external sides.

C3.7.8.5 Deck stiffeners

.1 The section modulus, shear area and welding section are given by the formulae in C3.7.8.1, assuming:

p : deck pressure p_d as defined in C3.5.8,

σ_{am} , τ_{am} :
- stiffeners contributing to the longitudinal strength:
  - steel structures:
    σ_{am} = 150 C_S/K (N/mm^2)
    τ_{am} = 90/K (N/mm^2)
  - aluminium alloy structures:
    σ_{am} = 70 C_A/K (N/mm^2)
    τ_{am} = 45/K (N/mm^2),
- stiffeners not contributing to the longitudinal strength:
  - steel structures:
    σ_{am} = 150/K (N/mm^2)
    τ_{am} = 90/K (N/mm^2)
  - aluminium alloy structures:
    σ_{am} = 70/K (N/mm^2)
    τ_{am} = 45/K (N/mm^2),

where C_S and C_A are given by Table C3.7.6.

.2 Where there are concentrated loads of significant magnitude, deck stiffeners are to be adequately strengthened. In particular, stiffeners of decks intended for the carriage of vehicles are to be able to support the concentrated loads transmitted by the wheels, including inertia effects.
In this case, the structural check is, in general, to be carried out adopting the static model of the continuous girder on several supports (formed by primary supporting members) and considering the most severe vehicle loading arrangement for deck stiffeners. The normal and shear stresses thus calculated are not to exceed the allowable limits defined above.

.3 The ordinary stiffeners of decks or flats constituting the top or bottom of tanks are also to comply with the requirements of C3.7.11.

.4 Where longitudinals are interrupted in way of watertight bulkheads or reinforced transverse structures, the continuity of the structure is to be maintained by means of brackets penetrating the transverse element. The Society may allow double brackets welded to the transverse element, provided that special provision is made for the alignment of longitudinals, and full penetration welding is used.

C3.7.8.6 Stiffeners of boundary walls of deckhouses

.1 The section modulus, shear area and welding section are given by the formulae in C3.7.8.1, assuming:

p : sea pressure p_{su} as defined in C3.5.7,

σ_{am} , τ_{am} :
- steel structures:
  σ_{am} = 150/K (N/mm^2)
  τ_{am} = 90/K (N/mm^2),
- aluminium alloy structures:
  σ_{am} = 70/K (N/mm^2)
  τ_{am} = 45/K (N/mm^2).

.2 If unprotected front walls are located at the fore end, the pressure p_{su} and the allowable stresses are to be considered individually by the Society.

.3 Any front or side wall vertical stiffeners of first tier deckhouses are to be connected, by means of brackets at the ends, to strengthening structures for decks or adjacent sides.

.4 Longitudinal stiffeners are to be fitted on the upper and lower edges of large openings in the plating. The openings for doors are, in general, to be stiffened all the way round.

.5 Where there is no access from inside deckhouses to 'tween-decks below, or where a deckhouse boundary wall is in a particularly sheltered location, reduced scantlings with respect to those stipulated above may be accepted, in the opinion of the Society.

C3.7.9 Primary supporting members

C3.7.9.1 General

.1 This article gives the requirements to be complied with for primary supporting members of the bottom, sides, decks and, for catamaran, the cross-deck.

.2 The primary supporting members (floors, frames, beams) are to form continuous transverse frames. In general, the stiffened frame spacing, in mm, is not to exceed:

1200 + 10 L

without being greater than 2 m.

Primary supporting members with spacing other than that defined above may be required for specific parts of the hull (e.g. machinery space, under pillars), as stipulated in the provisions below.

.3 The section modulus Z, in cm^3, and shear area A_t, in cm^2, required to support the design pressure transmitted by the ordinary stiffeners are given by the following formulae:

$$Z = 1000 \cdot \frac{S^2 \cdot b \cdot p}{m \cdot \sigma_{am}}$$

$$A_t = 5 \cdot \frac{S \cdot b \cdot p}{\tau_{am}}$$

where:

m : coefficient which depends on support conditions at the ends of the girder span, generally assumed to be equal to:

- 10 for floors, bottom girders, side frames, deck beams and girders, vertical webs of superstructures
- 12 for side stringers.

In special circumstances, a different value may be taken for m, at the discretion of the Society.

The pressure p, in kN/m^2, and allowable stresses σ_{am} and τ_{am}, in N/mm^2, are defined in C3.7.9.2 to C3.7.9.6 for various parts of the hull.

.4 The above formulae are applicable where reinforced structures are not of the grillage type. Otherwise, the scantlings of reinforced structures are to be stipulated by means of direct calculations performed on the basis of criteria agreed upon with the Society.

.5 The section modulus of primary supporting members is to be calculated in association with an attached plating, according to criteria specified by the Society.

.6 For steel stiffeners, the following geometric ratios are to be satisfied:

- the web thickness is to be not less than 1/80 of web depth,
- the face plate thickness is to be not less than 1/30 of face plate breadth (1/15 for face plates which are not symmetrical with respect to the web).

.7 For aluminium stiffeners, the following geometric ratios are to be satisfied, where the compressive stress is not known:

- the web thickness is to be not less than 1/35 of web depth,
- the face plate thickness is to be not less than 1/20 of face plate breadth (1/10 for face plates which are not symmetrical with respect to the web).

.8 Particular attention is to be paid to compressive buckling strength of associated plating of transverse primary members

.9 In case of primary structure made of floating frames and extruded panels, the flexural contribution of the extruded plating may generally be disregarded.

C3.7.9.2 Floors and girders of single bottom

.1 The section modulus and shear area are given by the formulae in C3.7.9.1 for the following two conditions:

(a) p : impact pressure p_{sl} if occurring on the bottom as defined in C3.5.3;

σ_{am} , τ_{am} :
- steel structures:
  σ_{am} = 150/K (N/mm^2)
  τ_{am} = 90/K (N/mm^2)
- aluminium alloy structures:
  σ_{am} = 70/K (N/mm^2)
  τ_{am} = 45/K (N/mm^2),

(b) p : sea pressure p_s as defined in C3.5.5;

σ_{am} , τ_{am} :
- steel floors:
  σ_{am} = 150/K (N/mm^2)
  τ_{am} = 90/K (N/mm^2)
- aluminium alloy floors:
  σ_{am} = 70/K (N/mm^2)
  τ_{am} = 45/K (N/mm^2)
- steel girders:
  σ_{am} = 150 C_S/K (N/mm^2)
  τ_{am} = 90/K (N/mm^2)
- aluminium alloy girders:
  σ_{am} = 70 C_A/K (N/mm^2)
  τ_{am} = 45/K (N/mm^2),

where C_S and C_A are given by Table C3.7.6.

.2 Floors are to be positioned in way of side and deck transverses. Intermediate floors may also be fitted provided that they are adequately connected at the ends.

.3 Manholes and other openings are not to be located at the ends of floor or girder spans, unless shear stress checks are carried out in such areas.

.4 Floors are to be fitted in machinery spaces, generally at every frame, and additional stiffeners are to be provided at bottom in way of machinery and pillars.

.5 In way of main machinery seatings, girders are to be positioned extending from the bottom to the foundation plate of main engines.

.6 A girder is, generally, to be fitted centreline for dry-docking. The height of such a girder is to be not less than that of floors amidships and the thickness less than the value t, in mm, obtained from the formula:

- for steel:

  $t = (0,05 \cdot L + 2) \cdot K^{0,5}$

- for aluminium alloys:

  $t = (0,07 \cdot L + 2,5) \cdot K^{0,5}$

The girder is to be fitted with a continuous face plate above the floors, its area not less than the value A_p, in cm^2, given by the formula:

- for steel:

  $A_p = 0,25 \cdot L \cdot K$

- for aluminium alloys:

  $A_p = 0,50 \cdot L \cdot K$

In hulls with a longitudinally framed bottom and width B > 8 m, side girders are also to be positioned in such a way as to divide the floor span into approximately equal parts. In catamaran, B is to be taken as the width of a single-hull. The thickness of the web may be assumed to be equal to that of the centre girder less 1 mm, and the area of the face plate may be reduced to 60% of that of the centre girder. Where side girders are intended to support floors, a structural check of their scantlings is to be carried out as deemed necessary by the Society.

C3.7.9.3 Primary supporting members of sides and front walls

.1 The section modulus and shear area are given by the formulae in C3.7.9.1, assuming:

p :
- sea pressure p_s as defined in C3.5.5 for primary members of sides,
- sea pressure p_{sf} as defined in C3.5.6 for primary members of front walls,

σ_{am} , τ_{am} :
- steel structures:

  $\sigma_{am} = 150/K - \sigma_a$ (N/mm^2)

  $\tau_{am} = 90/K$ (N/mm^2),

- aluminium alloy structures:

  $\sigma_{am} = 70/K - \sigma_a$ (N/mm^2)

  $\tau_{am} = 45/K$ (N/mm^2),

σ_a being the stress induced by the normal force in side transverses due to deck loads transmitted by deck beams.

.2 For unprotected front walls located at the fore end, the pressure p_{sf} (see C3.5.6) and allowable stresses are to be considered individually by the Society.

C3.7.9.4 Primary supporting members of the wet deck (cross-deck) and internal sides of catamaran

.1 In the most common case of cross-deck structures constituted by transverse stiffener plates enclosed between lower plating and a deck, and connected at the ends to reinforced hull structures, the scantlings are determined by transverse strength checks aimed at ensuring an adequate connection between the hulls (see C3.7.4).

.2 Where the cross-deck is formed by multiple structures, each of the latter is also to be checked for the effect of local loads, in accordance with the following provisions.

.3 The section modulus and shear area required for transverse structures of the cross-deck are given by the formulae in C3.7.9.1, for the following two conditions:

(a) lower structures of the cross-deck:

p : impact pressure p_{sl} as defined in C3.5.4

σ_{am} , τ_{am} :
- steel structures:

  $\sigma_{am} = 180/K$ (N/mm^2)

  $\tau_{am} = 90/K$ (N/mm^2)

- aluminium alloy structures:

  $\sigma_{am} = 85/K$ (N/mm^2)

  $\tau_{am} = 45/K$ (N/mm^2),

(b) cross-deck structures supporting decks:

p : sea pressure p_d as defined in C3.5.8

σ_{am} , τ_{am} :
- steel structures:

  $\sigma_{am} = 150/K$ (N/mm^2)

  $\tau_{am} = 90/K$ (N/mm^2)

- aluminium alloy structures:

  $\sigma_{am} = 70/K$ (N/mm^2)

  $\tau_{am} = 45/K$ (N/mm^2).

.4 Where the lower structure of the cross-deck also supports a deck, such a structure is to be checked separately for conditions (a) and (b) above.

.5 The section modulus and shear area required for side transverses of internal sides are given by the formulae in C3.7.9.1 for condition (a) above.

C3.7.9.5 Primary supporting members of decks

.1 In the absence of concentrated loads transmitted to the primary supporting member by pillars or other primary supporting members, the section modulus and shear area required for deck transverses and deck girders supporting longitudinals and beams, respectively, are given by the formulae in C3.7.9.1, assuming:

p : deck pressure p_d as defined in C3.5.8,

σ_{am} , τ_{am} :
- steel deck transverses:
  σ_{am} = 150/K (N/mm²)
  τ_{am} = 90/K (N/mm²),
- aluminium alloy deck transverses:
  σ_{am} = 70/K (N/mm²)
  τ_{am} = 45/K (N/mm²),
- steel deck girders:
  σ_{am} = 150 C_S/K (N/mm²)
  τ_{am} = 90/K (N/mm²),
- aluminium alloy deck girders:
  σ_{am} = 70 C_A/K (N/mm²)
  τ_{am} = 45/K (N/mm²),

where C_S and C_A are given by Table C3.7.6.

.2 The primary members of decks or flats constituting the top or bottom of tanks are also to comply with the requirements of C3.7.11.

.3 When there are concentrated loads of significant magnitude (e.g. transmitted by pillars or other primary members or due to the carriage of vehicles), deck girders are to be adequately strengthened.

In this case the structural check is, generally, to be carried out by using the static model of a beam with partial clamping at its ends (clamping coefficient = 0,30).

The allowable stresses stipulated above are to be considered.

The beam section is to be kept constant over its length.

.4 At the discretion of the Society, calculations based on different static models may be accepted, depending on the structural typology adopted.

C3.7.9.6 Primary supporting members of deckhouse boundary walls

.1 The section modulus and shear area are given by the formulae in C3.7.9.1, assuming:

p : sea pressure p_{su} as defined in C3.5.7,

σ_{am} , τ_{am} :
- steel structures:
  σ_{am} = 150/K (N/mm²)
  τ_{am} = 90/K (N/mm²),
- aluminium alloy structures:
  σ_{am} = 70/K (N/mm²)
  τ_{am} = 45/K (N/mm²).

.2 Where there is no access from inside deckhouses to 'tween-decks below or where a deckhouse boundary wall is in a particularly sheltered location, reduced scantlings with respect to those stipulated above may be accepted at the discretion of the Society.

.3 For unprotected front walls located at the fore end, the pressure p_{su} and allowable stresses are to be considered individually by the Society.

C3.7.10 Pillars

C3.7.10.1 Steel pillars

.1 The minimum area A, in cm², of the section of a pillar, is to be not less than:

- for $0 \le \lambda \le 1,5$

$$A = \frac{Q \cdot (1 + 0,75 \cdot \lambda^2)}{12}$$

- for $\lambda > 1,5$

$$A = \frac{Q \cdot \lambda^2}{10}$$

where:

λ : slenderness of the pillar, i.e. the ratio between the pillar length, in m, and the minimum radius of gyration of the pillar cross-section, in cm,

Q : load acting on the pillar, in kN, equal to:
$Q = A_{PG} \cdot p + Q_C$

A_{PG} : area of the deck acting on the pillar, in m²,

p : deck load as defined in C3.5.8,

Q_C : load from pillars above, if any, or any other concentrated load acting on the pillar, in kN.

.2 The formula for the calculation of A applies in the case of solid, tubular or prismatic pillars of normal steel. Where higher tensile steel is used, the minimum area may be determined as follows:
$A' = A \cdot (235/R_{eH})$ provided $\lambda \le 1$
where:

R_{eH} : yield stress, in N/mm², of the steel considered.

.3 Where possible, each pillar is to be aligned with another pillar above or below. Stiffeners ensuring efficient load distribution are to be fitted at the ends of pillars. Where, in exceptional circumstances, pillars support eccentric loads, the scantlings are to be adequately increased to withstand the bending moment due to the eccentricity of the load.

.4 Where pillars on the inner bottom are not in way of intersections of floors and girders, partial floors or other structures are to be provided to support the load transmitted.

.5 In general, solid or open-section pillars are to be fitted in tanks; this is compulsory for pillars located in spaces intended for products which may produce explosive gases.

.6 Heads and heels of pillars are to be continuously welded. The welded connections of stiffeners directly involved in the arrangement of pillars are to be adequately stiffened where necessary.

.7 The thickness of tubular or closed-section pillars is generally to be not less than 1/35 of the nominal diameter or greater dimension of the section. In no case is this thickness to be less than 3mm.

.8 The thickness of face plates of built-up pillars is to be not less than 1/18 of the unsupported span of the face plate.

C3.7.10.2 Pillars made of aluminium alloys

.1 Loads on pillars

Where pillars are aligned, the compressive load Q, in kN, is equal to the sum of loads supported by the pillar considered and those supported by the pillars located above, multiplied by a weighting factor.

The weighting factor depends on the relative position of each pillar with respect to that considered.

This coefficient is equal to:

- 1,0 for the pillar considered,
- 0,9 for the pillar immediately above (first pillar of the line),
- $0{,}81 = 0{,}9^2$ for the following pillar (second pillar of the line),
- $0{,}729 = 0{,}9^3$ for the third pillar of the line,
- in general, $0{,}9^n$ for the n^{th} pillar of the line, but not less than $0{,}9^7 = 0{,}478$.

.2 Critical stress for overall buckling of pillars

For global buckling behaviour of pillars made of aluminium alloy, the critical stress, σ_c, in N/mm², is given by the formula:

$$\sigma_c = \frac{R_{p0,2}'}{0,85 + 0,25 \cdot \left(\frac{f \cdot \ell}{r}\right)} \cdot C$$

where:

$R_{p\,0,2}'$: minimum as-welded guaranteed yield stress of aluminium alloy used, in N/mm²,

C : coefficient as given in Figure C3.7.5, and equal to:

- for alloys without heat treatment:

$$\frac{1}{1 + \lambda + \sqrt{(1+\lambda)^2 - (0,68 \cdot \lambda)}}$$

- for alloys with heat treatment:

$$\frac{1}{1 + \lambda + \sqrt{(1+\lambda)^2 - (3,2 \cdot \lambda)}}$$

$$\lambda = \frac{R_{p0,2}'}{\sigma_E}$$

$$\sigma_E = \frac{69,1}{\left(\frac{f \cdot \ell}{r}\right)^2}$$

ℓ : length of pillar, in m,

r : minimum radius of gyration, in cm, of the pillar cross section, equal to:

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

I : minimum moment of inertia, in cm⁴, of the pillar cross section,

A : area, in cm², of the pillar cross section,

f : coefficient given in Table C3.7.7 depending on the conditions of fixing of the pillar.

Table C3.7.7 - Coefficient f

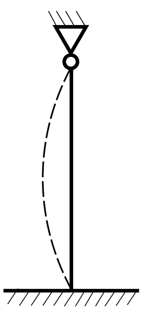
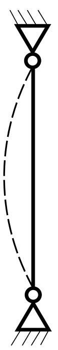
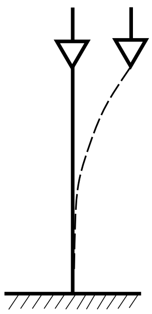
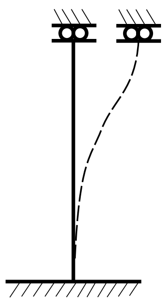
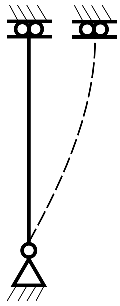
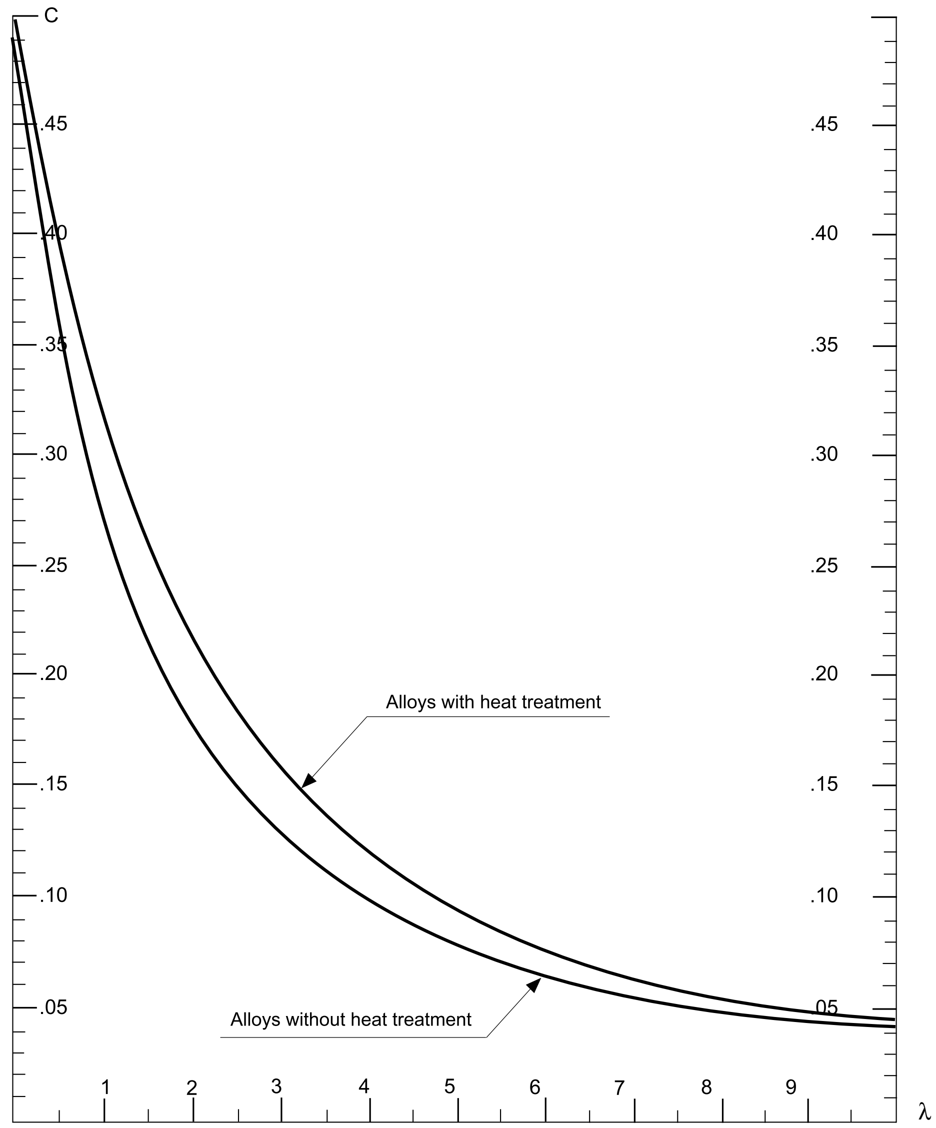
Conditions of fixity					
f	0,7	1,0	2,0	1,0	2,0

Figure C3.7.5 Coefficient C



.3 Critical stress for local buckling of pillars

(a) For local buckling behaviour of a pillars made of aluminium alloy, the admissible stress σ_{cl}, in N/mm², is given by the formula:

$$\sigma_{cl} = 2 \cdot R_{p0,2}' \cdot C$$

where:

C : coefficient as defined in C3.7.10.2.2,

$$\lambda = \frac{R_{p0,2}'}{\sigma_{El}}$$

$R_{p\,0,2}$' : minimum as-welded guaranteed yield stress of aluminium alloy used, in N/mm²,

σ_{El} : stress defined below.

(b) For tubular pillars with a rectangular cross-section, the stress σ_{El}, in N/mm², is given by:

$$\sigma_{El} = 252000 \cdot \left(\frac{t}{b}\right)^2$$

where:

b : greatest dimension of the cross-section, in mm,

t : plating thickness, in mm.

(c) For tubular pillars with a circular cross-section, the stress σ_{El}, in N/mm², is given by:

$$\sigma_{El} = 43000 \cdot \frac{t^2}{D^2}$$

D : outer diameter, in mm,

t : plating thickness, in mm.

(d) For pillars with I cross-sections, the stress σ_{EI}, in N/mm², is the lesser of the following values:

$$\sigma_{EI} = 252000 \cdot \left(\frac{t_w}{h_w}\right)^2$$

$$\sigma_{EI} = 105000 \cdot \left(\frac{t_f}{b_f}\right)^2$$

where:

t_w : web thickness, in mm,

h_w : web height, in mm,

t_f : thickness of face plate, in mm,

h_f : width of face plate, in mm.

.4 Scantlings of pillars

(a) The scantlings of pillars are to comply with the following requirements:

$\sigma \le \sigma_c$

$\sigma \le \sigma_{cl}$

where:

σ : compressive stress, in N/mm², in the pillar due to load Q,

$\sigma = 10\ Q/A$,

A being the cross-sectional area, in cm², of the pillars,

σ_c : overall buckling critical stress, as defined in C3.7.10.2.2 above,

σ_{cl} : local buckling critical stress, as defined in C3.7.10.2.3 above.

(b) The maximum allowable axial load, in kN, is the smaller of the following two values:

$P_c = \sigma_c \cdot A \cdot 10^{-1}$

$P_{cl} = \sigma_{cl} \cdot A \cdot 10^{-1}$

C3.7.11 Tank bulkheads

C3.7.11.1 General

.1 Hollow profiles are not permitted as tank walls or in tanks for flammable liquids.

C3.7.11.2 Plating

.1 The required thickness, in mm, is given by the following formula:

$$t = 22,4 \cdot f_m \cdot \mu \cdot s \cdot \sqrt{\frac{p_t}{\sigma_{am}}}$$

where:

f_m : coefficient depending on the material:

- f_m = 0,80 for steel structures
- f_m = 0,75 for aluminium alloy structures,

p_t : design pressure, in kN/m², as defined in C3.5.9,

σ_{am} :
- steel structures:
  σ_{am} = 185/K (N/mm²)
- aluminium alloy structures:
  σ_{am} = 85/K (N/mm²).

C3.7.11.3 Ordinary stiffeners

.1 The section modulus, shear area and welding section required for ordinary stiffeners are given by the formulae in C3.7.8.1, assuming:

p : design pressure p_t as defined in C3.5.9,

m : coefficient depending on the type of stiffener and support conditions at the ends of the stiffener span, to be taken according to Table C3.7.4,

σ_{am}, τ_{am} :
- steel structures:
  σ_{am} = 150/K (N/mm²)
  τ_{am} = 90/K (N/mm²),
- aluminium alloy structures:
  σ_{am} = 70/K (N/mm²)
  τ_{am} = 45/K (N/mm²).

C3.7.11.4 Primary supporting members

.1 The section modulus, shear area and welding section required for horizontal and vertical girders are given by the formulae in C3.7.9.1, assuming:

p : design pressure p_t as defined in C3.5.9,

m : coefficient depending on support conditions at the ends of the girder span, generally to be taken equal to 10. A value of 12 could be accepted if supported by direct calculation,

σ_{am}, τ_{am} :
- steel structures:
  σ_{am} = 150/K (N/mm²)
  τ_{am} = 90/K (N/mm²),
- aluminium alloy structures:
  σ_{am} = 70/K (N/mm²)
  τ_{am} = 45/K (N/mm²).

C3.7.11.5 Corrugated bulkheads

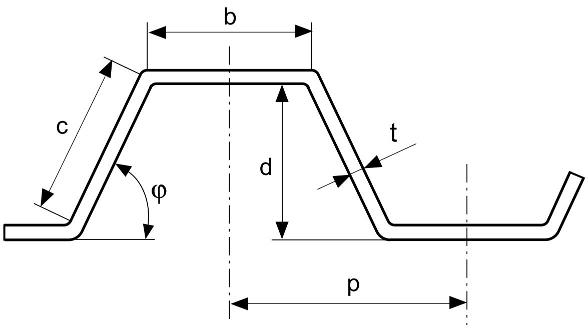
.1 The thickness and section modulus of corrugated bulkheads, calculated as stated in C3.7.11.2 to C3.7.11.4 are to be increased by 10% and 20%, respectively.

.2 The section modulus W_c, in cm^3, of a corrugation may be derived from the following formula:

$W_c = d\ t\ (3\ b + c) / 6000$

where the symbols are as shown in Figure C3.7.6 and are expressed in mm. In no case is the angle φ to be less than 40°.

Figure C3.7.6



C3.7.12 Subdivision bulkheads

C3.7.12.1 Plating

.1 The required thickness, in mm, is given by the following formula:

$$t = 22,4 \cdot f_m \cdot \mu \cdot s \cdot \sqrt{\frac{p_{sb}}{\sigma_{am}}}$$

where:

f_m : coefficient depending on the material:

- f_m = 0,75 for steel structures
- f_m = 0,70 for aluminium alloy structures,

p_{sb} : design pressure, in kN/m^2, as defined in C3.5.10,

σ_{am} :
- steel structures:
  σ_{am} = 235/K (N/mm^2)
- aluminium alloy structures:
  σ_{am} = 95/K (N/mm^2).

.2 The thickness of the collision bulkhead is to be calculated from the formula given in C3.7.12.1.1, multiplied by 1,15.

C3.7.12.2 Ordinary stiffeners

.1 The section modulus, shear area and welding section required for ordinary stiffeners are given by the formulae in C3.7.8.1, assuming:

p : design pressure p_{sb} as defined in C3.5.10,

m : coefficient depending on the type of stiffener and support conditions at the ends of the stiffener span, to be taken according to Table C3.7.4,

σ_{am} , τ_{am} :
- steel structures:
  σ_{am} = 210/K (N/mm^2)
  τ_{am} = 120/K (N/mm^2),
- aluminium alloy structures:
  σ_{am} = 95/K (N/mm^2)
  τ_{am} = 55/K (N/mm^2).

.2 The section modulus, shear area and welding section required for the ordinary stiffeners of the collision bulkhead are to be calculated from C3.7.12.2.1, considering σ_{am} and τ_{am} divided respectively by 1,15 and 1,05.

C3.7.12.3 Primary supporting members

.1 The section modulus, shear area and welding section required for horizontal and vertical girders are given by the formulae in C3.7.9.1, assuming:

p : design pressure p_{sb} as defined in C3.5.10,

m : coefficient depending on support conditions at the ends of the girder span, generally to be taken equal to 10,

σ_{am} , τ_{am} :
- steel structures:
  σ_{am} = 210/K (N/mm^2)
  τ_{am} = 120/K (N/mm^2),
- aluminium alloy structures:
  σ_{am} = 95/K (N/mm^2)
  τ_{am} = 55/K (N/mm^2).

.2 The section modulus, shear area and welding section required for the primary supporting members of the collision bulkhead are to be calculated from C3.7.12.3.1, considering σ_{am} and τ_{am} divided respectively by 1,3 and 1,2.

C3.7.12.4 Corrugated bulkheads

.1 The thickness and section modulus of corrugated bulkheads, calculated as stated in C3.7.12.1 to C3.7.12.3, are to be increased by 10% and 20%, respectively.

.2 The section modulus of a corrugation is to be calculated as indicated in C3.7.11.5.

C3.7.13 Non-tight bulkheads

.1 The thickness of plating of non-tight bulkheads which do not act as pillars is to be not less than 2 mm for steel bulkheads, and 3 mm for aluminium alloy bulkheads, and vertical stiffeners are to be not more than 900 mm apart.

.2 Vertical stiffeners of bulkheads which do not act as pillars are to have a section modulus (calculated in association with a width of plating equal to the stiffener spacing but not exceeding 750 mm) not less than the value, in cm³, given by the formula:

$Z = 2\,s\,S^2$

.3 The thickness of plating of non-tight bulkheads which act as pillars is to be not less than 2 mm for steel bulkheads, and 3 mm for aluminium alloy bulkheads, and vertical stiffeners are to be not more than 750 mm apart.

.4 Vertical stiffeners of bulkheads which act as pillars are to have a section modulus (calculated in association with a width of plating equal to the stiffener spacing but not exceeding 750 mm) not less than the value, in cm³, given by the formula:

$Z = 2{,}65\,s\,S^2$

.5 In addition, each vertical stiffener, in association with a width of plating equal to 50 times the plating thickness, is to comply with the requirements for pillars given in C3.7.10, the load supported being determined in accordance with the same provisions.

.6 In the case of tanks extending from side to side, a wash bulkhead is generally to be fitted amidships; the plating thickness is to be not less than 2 mm for steel bulkheads, and 3 mm for aluminium alloy bulkheads, and it is to be strengthened by vertical stiffeners.

C3.7.14 Independent prismatic tanks

.1 The required thickness for the plating of independent prismatic tanks, in mm, is given by the formula:

$$t = 1{,}25 \cdot f_m \cdot s \cdot \mu \cdot (p_t \cdot K)^{0{,}5}$$

where:

f_m : coefficient depending on the material:

- f_m = 1,0 for steel bulkheads
- f_m = 1,45 for aluminium alloy bulkheads,

p_t : design pressure, in kN/m², as defined in C3.5.9.

.2 In no case is the thickness to be less than 2,5 mm for steel bulkheads, and 3,5 mm for aluminium alloy bulkheads.

.3 The section modulus required for stiffeners, in cm³, is given by the formula:

$$Z = 0{,}4 \cdot f'_m \cdot s \cdot \ell^2 \cdot p_t \cdot K$$

where:

f'_m : coefficient depending on the material:

- f'_m = 1,0 for steel bulkheads
- f'_m = 2,15 for aluminium alloy bulkheads.

.4 The connections to reinforced hull structures of independent tanks are to be able to withstand the dynamic loads induced by the tank weight and the acceleration a_v of the craft (see C3.3).

.5 It is recommended that stiffener plates should be arranged so as to prevent undue movement of the liquid.

C3.7.15 Side and stern doors

C3.7.15.1 Plating

.1 The required thickness, in mm, is given by the following formula:

$$t = 22{,}4 \cdot \mu \cdot s \cdot \sqrt{\frac{p_s}{\sigma_{am}}}$$

where:

p_s : design pressure, in kN/m², as defined in C3.5.5.2.1,

σ_{am} :
- steel structures:
  σ_{am} = 185/K (N/mm²)
- aluminium alloy structures:
  σ_{am} = 85/K (N/mm²).

C3.7.15.2 Ordinary stiffeners

.1 The section modulus, shear area and welding section required for ordinary stiffeners are given by the formulae in C3.7.8.1, assuming:

p : design pressure p_s as defined in C3.5.5.2.1,

m : coefficient depending on the type of stiffener and support conditions at the ends of the stiffener span, to be taken according to Table C3.7.4,

σ_{am} , τ_{am} :
- steel structures:
  σ_{am} = 150/K (N/mm²)
  τ_{am} = 90/K (N/mm²),
- aluminium alloy structures:
  σ_{am} = 70/K (N/mm²)
  τ_{am} = 45/K (N/mm²).

C3.7.15.3 Primary members, securing and supporting devices

.1 The scantlings of the primary members, securing and supporting devices of side shell doors and stern doors are to be determined to withstand the design loads defined respectively in C3.5.5.2.2 and C3.5.5.2.3, using the following permissible stresses, where k is the material factor defined in C3.2.2.3 for steel (not to be taken less than 0,72) or in C3.2.3.5 for aluminium alloys:

σ_{am} : bending stress

- steel structures: σ_{am} = 120/K (N/mm^2)
- aluminium alloy structures: σ_{am} = 55/K (N/mm^2),

τ_{am} : shear stress

- steel structures: τ_{am} = 80/K (N/mm^2)
- aluminium alloy structures: τ_{am} = 35/K (N/mm^2),

σ_{cam} : $\sigma_{cam} = \sqrt{\sigma^2 + 3 \cdot \tau^2}$

- steel structures: σ_{am} = 150/K (N/mm^2)
- aluminium alloy structures: σ_{am} = 70/K (N/mm^2).

C3.8 Fibre-reinforced plastic craft

C3.8.1 Introduction

.1 This article stipulates requirements for the scantlings of hull structures (plating, stiffeners, primary supporting members). The loads acting on such structures are to be calculated in accordance with the provisions of C3.5.

.2 In general, for craft with length L > 65 m or speed V > 45 knots, the scantlings of transverse structures are to be verified by direct calculations carried out in accordance with C3.6.

For all other craft, the Society may, at its discretion and as an alternative to the requirements of this article, accept scantlings for transverse structures of the hull based on direct calculations, in accordance with C3.6.

C3.8.2 Definitions

.1 In addition to the definitions in C3.1, the following is to be considered:

- “Superstructure”: In this article, it is a decked structure located above the uppermost continuous deck, extending from side to side of the craft, or with the side plating not inboard of the shell plating by more than 4 per cent of the local breadth.

C3.8.3 Longitudinal strength

C3.8.3.1 General

.1 This article gives the criteria to be used for the longitudinal strength calculation of monohull ships more than 24 m in length.

For multihulls, the strengths due to longitudinal bending, transverse bending and torsion are to be examined individually by the Society.

.2 The longitudinal strength of monohull craft more than 65 m in length is to be checked.

.3 The longitudinal strength of monohull craft more than 24 m and less than 65 m in length is to be checked when the following conditions are not simultaneously satisfied:

- $L/D \le r_2$,
- no longitudinal members located at more than 0,04 D above the strength deck at side,
- in any transverse section of strength deck, the sum of the breadths of openings is less than:

$$b = \frac{65 - L}{40} \cdot B$$

Values of r_2 factor are given in Table C3.8.1 depending on the type of service of the craft.

Table C3.8.1 - Factor r_2

Type of service	r_2
Open sea Restricted open sea	16,5
Moderate environment	18,0
Smooth sea	22,0

.4 In general, the strength deck is the uppermost continuous complete deck or the uppermost superstructure deck contributing to the longitudinal strength, if any.

- The deck number n of a superstructure or a roof with lateral sides in line with the shell plating, at least 5 n H in length and located in the midship region, can be taken as the strength deck in way of the considered transverse sections, where:

  H : mean height, in m, of the ’tween deck.

- If such a deck is not considered as the strength deck, arrangements are to be made so that this deck does not participate in the longitudinal strength of the ship.
- Ships with shell openings such that the length of openings is greater than half the length of the shell are to be individually examined by the Society.

.5 The section moduli at bottom, at the strength deck and at the top of longitudinal members located above the strength deck, if any, calculated according to C3.8.3.2, are not to be less than the value defined in C3.8.3.3.

C3.8.3.2 Calculation of strength modulus

.1 The data given in Table C3.8.2 for plating and C3.8.3 for longitudinals are necessary for calculation of the midship section modulus.

Table C3.8.2

	Deck	Side shell	Bottom
Mean thickness, in mm	t_p	t_m	t_f
Young modulus, in N/mm²	E_p	E_m	E_f

Table C3.8.3

		Deck	Side shell (1 side)	Bottom
Flange	Thickness (mm)	t_{ps}	t_{ms}	t_{fs}
	Young modulus (N/mm²)	E_{ps}	E_{ms}	E_{fs}
	Breadth (mm)	l_{ps}	l_{ms}	l_{fs}
Web	Thickness equivalent to I section (mm)	t_{pa}	t_{ma}	t_{fa}
	Young modulus (N/mm²)	E_{pa}	E_{ma}	E_{fa}
	Height (m)	H_{pa}	H_{ma}	H_{fa}
	Number of longitudinals	n_p	n_m	n_f

.2 Where there is a sandwich member, the two skins of the laminate are to be taken into account only with their own characteristics. The cores are taken into account if they offer longitudinal continuity and appreciable strength against axial tension-compression.

.3 For each transverse section within the midship region, the section modulus, in m³, is given by:

$$W = \frac{1}{E_p} \cdot \left(C' \cdot P + \frac{C'}{6} \cdot A \cdot \left(1 + \frac{F - P}{F + 0,5 \cdot A}\right)\right) \cdot 10^{-3}$$

where:

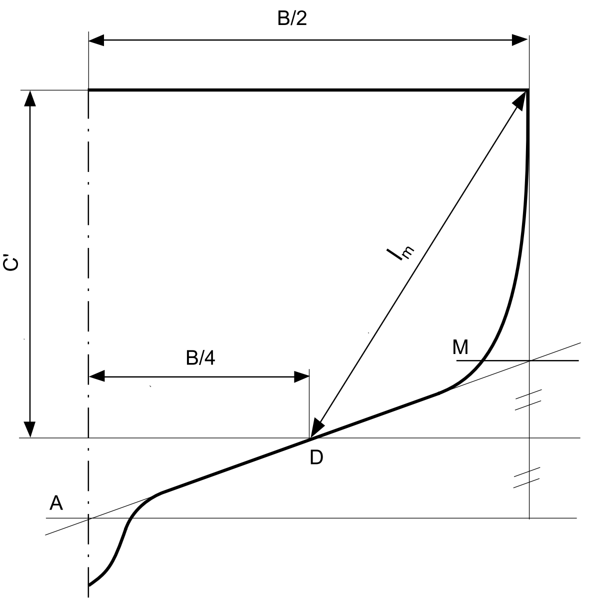
$$P = t_p \cdot B \cdot E_p + n_p \cdot (t_{ps} \cdot l_{ps} \cdot E_{ps} + t_{pa} \cdot H_{pa} \cdot E_{pa})$$

$$A = 2 \cdot (t_m \cdot l_m \cdot E_m + n_m \cdot (t_{ms} \cdot l_{ms} \cdot E_{ms} + t_{ma} \cdot H_{ma} \cdot E_{ma}))$$

$$F = t_f \cdot \frac{B}{2} \cdot E_f + n_f \cdot (t_{fs} \cdot l_{fs} \cdot E_{fs} + t_{fa} \cdot H_{fa} \cdot E_{fa})$$

See also Figure C3.8.1.

Figure C3.8.1



C3.8.3.3 Rule section modulus

.1 The midship section modulus at the strength deck, at the bottom and above the strength deck, if any, is not to be less, in m³, than:

$$W_m = 11 \cdot \alpha \cdot r_1 \cdot F \cdot L^2 \cdot B \cdot (C_B + 0,7) \cdot 10^{-6}$$

where:

r_1 : value given in Table C3.8.4,

$$\alpha = \frac{L}{r_2 D} \quad \text{but not less than 1}$$

$$F = (118 - 0,36 \cdot L)\frac{L}{1000}$$

r_2 : value given in Table C3.8.1.

Table C3.8.4 - Factor r_1

Type of service	r_1
Open sea Restricted open sea	1,0
Moderate environment	0,96
Smooth sea	0,92

C3.8.3.4 Bending longitudinal stress

.1 The bending stress, in N/mm², due to the longitudinal bending moment is given by the formula:

$$\sigma_{bl} = \frac{M_{bl}}{W} \cdot 10^{-3}$$

where M_{bl} is the total bending moment, defined in C3.4.1, and W is the actual value of the midship section modulus, in m³, either at bottom or at the deck.

C3.8.4 Structural scantling - general

C3.8.4.1 Main principles

.1 Scantlings are given for the midship region and end regions. In intermediate regions, scantlings are to vary gradually from the midship region to the end regions.

.2 Plating and stiffener scantlings are determined by the fact that the sum of stress due to local design load and longitudinal bending of the hull (if applicable) is to be less than the corresponding allowable stress of the material, i.e. the breaking strength divided by a safety factor, defined below.

.3 Scantlings may be increased where the structure is likely to be subjected to particular forces, for instance due to:

- very high speed,
- nature or uneven distribution of its loading, such as concentrated loads,
- particular conditions of operation, construction or design.

.4 When design assumptions not covered by the present Rules or unusual structural arrangements are provided, the proposed scantlings are to be backed by direct calculations carried out with an agreed method, and submitted to the Society for examination.
If so, the shipyard is to provide, to the satisfaction of the Society, all information needed to verify the calculation. The owner's agreement may be required where the Society deems it appropriate.

.5 In addition to the cases explicitly foreseen by these Rules, subject to justifications submitted for examination, the Society may consider scantlings and structural arrangement, other than those derived from the application of these Rules, in order to take special account of:

- calculation method or a method for the determination of stresses offering a high level of accuracy; calculation data and all information necessary for their assessment are to be submitted to the Society,
- development of the applied techniques, the builder's practical experience and the means he brings into use to ensure an appropriate level of quality and building consistency,
- satisfactory behaviour in service of the type of hull structure concerned,
- particular loading cases.

.6 Bottom - side shell boundary for catamarans

For the structure of a catamaran, the inner walls of which are nearly vertical, the limit between bottom and side shell inside the two hulls is to be taken at the level of chine for external walls, as defined in C3.1.4.

C3.8.4.2 Safety factors

.1 The safety factor SF is equal to the ratio between the breaking strength (bending or shear) and the allowable stress for a material.

.2 The safety factor to be considered for allowable bending stresses of platings and stiffeners is given in Table C3.8.5.

Table C3.8.5 - Safety factor SF

	SF
General	6,0
Members subject to impact load	4,5
Watertight transverse bulkheads	5,0
Sides and ends of superstructures and deckhouses	4,0
Members subjected to the testing pressure p_e	4,0

.3 The safety factor to be considered for allowable shear stress of core material of sandwiches and of web primary stiffener is given in Table C3.8.6.

Table C3.8.6 - Safety factor SF

		SF
Core of sandwich	General	3,0
	Sandwiches subjected to impact load	2,5
Web of primary members	General	5,0
	Stiffeners subject to impact load	3,5
	Stiffeners on watertight transverse bulkhead	4,0
	Stiffeners of sides and ends of superstructures and deckhouses	3,0
	Stiffeners calculated with the testing pressure p_e	3,0

.4 For ships of unusual construction and/or with special service conditions, another value of the safety factor can be defined in accordance with the yard, which is to justify the new safety factor.

C3.8.4.3 Single skin laminates

.1 The bending stress, in N/mm², of the laminate is to be multiplied by the following reduction factor k_s:

$k_s = \mu_1 \, \alpha \, r_c^2$

where:

$\mu_1 = 1$ if $\ell \geq 2s$

$\mu_1 = 1 - 1,5 \cdot \left(1 - \frac{\ell}{2 \cdot s}\right)^2$ if $s < \ell < 2s$

$\mu_1 = 0,625$ if $\ell \leq s$

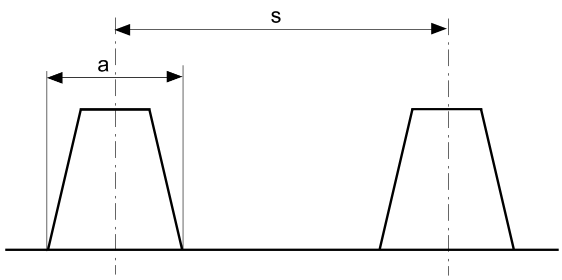
α and r_c are defined respectively in C3.8.4.3.2 and C3.8.4.3.3.

.2 In case of shell plating with stiffeners with a wide base, the coefficient α is given by the formula:

$$\alpha = 1 - 3 \cdot \frac{a}{s} \cdot \left(1 - \frac{a}{s}\right)$$

where α is not to be less than 0,4 and a and s are defined in Figure C3.8.2.

Figure C3.8.2



.3 The curvature factor r_c is given by the formula:

$$r_c = 1 - \left(0,8 \cdot \frac{f}{s}\right)$$

without being less than 0,85, where f and s are defined in Figure C3.8.3.
In the case of unstiffened shell plating with a large curvature, a relevant study of the stress is to be submitted to the Society for examination.

.4 The minimum thicknesses of the single skin laminate platings are not to be, as a rule, less than the following values:

- for bottom and bilge platings:

  $t = 1,5 \cdot \sqrt{L + 10}$

- for shell plating:

  $t = 1,25 \cdot \sqrt{L + 10}$

- for other platings:

  $t = \sqrt{L + 10}$

Lower values can be considered if a justification is submitted to the Society.

.5 The bending stress, in N/mm², due to the design pressure p (defined in C3.5) is given by the formula:

$$\sigma_d = k_s \cdot \frac{V}{[I]} \cdot \frac{p \cdot s^2}{12} \cdot 10^3$$

where:

V : maximum distance of the neutral axis of the laminate, in mm, as defined in C3.2.6.3.3,

[I] : inertia of the laminate, by mm of width, in mm⁴/mm, as defined in C3.2.6.3.3.

.6 The bending stress due to the design pressure p is given by the following formula:

$$\sigma_d < \frac{\sigma_{br}}{SF} - \sigma_{bl}$$

where:

σ_{br} : breaking bending strength of the laminate, as defined in C3.2.6.3.3,

σ_{bl} : bending stress due to the total bending moment, as defined in C3.8.3.4. σ_{bl} is to be equal to zero for all platings of ships of less than 24 m in length and for longitudinal framed platings and all platings at ends of other ships,

SF : safety factor, as defined in C3.8.4.2.

.7 The bending stress σ_{de}, in N/mm², calculated for the test pressure p_e is to be such that:

$$\sigma_{de} < \frac{\sigma_{br}}{SF}$$

.8 The bending deflection, due to design pressure p (see C3.5), of a single-skin laminate between stiffeners is to be less than about 1% of the stiffener spacing. The bending deflection, in mm, of a single-skin laminate, fixed on its edges, is given by:

$$f = \frac{\mu_2}{384} \cdot \frac{p \cdot s^4}{(EI)} \cdot 10^9$$

where:

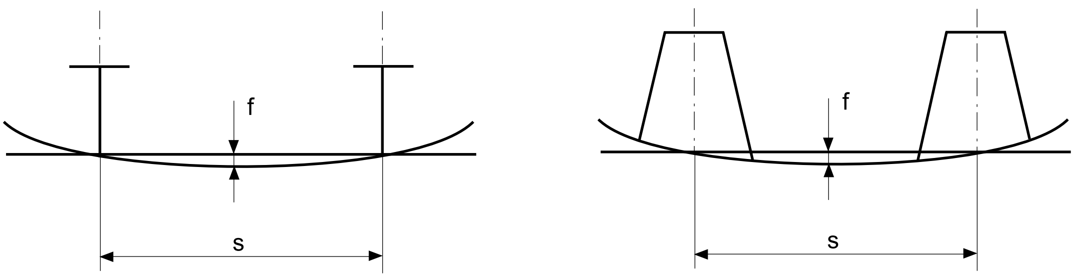
[EI] : rigidity of the laminate, for 1 mm width, in N·mm²/mm, defined in C3.2.6.3.3

$\mu_2 = 1$ if $\ell \geq 2s$

$\mu_2 = 1 - 2,1 \cdot \left(1 - \frac{\ell}{2 \cdot s}\right)^2$ if $s < \ell < 2s$

$\mu_2 = 0,475$ if $\ell \leq s$

Figure C3.8.3



C3.8.4.4 Sandwich laminates

.1 Refer to C3.8.4.3.1 to C3.8.4.3.3.

.2 The minimum thicknesses of each skin of sandwich laminate platings are in general not to be less than the following values:

- for bottom and bilge platings:

$t = 0,6 \cdot \sqrt{L + 10}$

- for shell plating:

$t = 0,5 \cdot \sqrt{L + 10}$

- for other platings:

$t = 0,4 \cdot \sqrt{L + 10}$

Lower values can be considered if a justification is submitted to the Society.

.3 The bending stress, in N/mm², due to the design pressure p (defined in C3.5) is equal to:

$$\sigma_d = k_s \cdot \frac{V}{[I]} \cdot \frac{p \cdot s^2}{12} \cdot 10^3$$

where:

V : maximum distance of the neutral axis of the sandwich, in mm, as defined in C3.2.6.3.3,

[I] : inertia of the sandwich, by mm of width, in mm⁴/mm, as defined in C3.2.6.3.3.

.4 The bending stress due to the design pressure p is to be such that:

$$\sigma_d < \frac{\sigma_{br}}{SF} - \sigma_{bl}$$

where:

σ_{br} : breaking bending strength of the sandwich, as defined in C3.2.6.3.4,

σ_{bl} : bending stress due to the total bending moment, as defined in C3.8.3.4. σ_{bl} is to be equal to zero for all platings of ships of less than 24 m in length and for longitudinal framed platings and all platings at ends of other ships,

SF : safety factor, as defined in C3.8.4.2.

.5 The bending stress σ_{de}, in N/mm², calculated for the test pressure p_e is to be such that:

$$\sigma_{de} < \frac{\sigma_{br}}{SF}$$

.6 The shear stress, in N/mm², due to the design pressure p is to be:

$$\tau_d = \frac{p \cdot s}{2 \cdot t_a}$$

where t_a is the thickness of the core, in mm.

.7 The shear stress due to the design pressure is to be such that:

$$\tau_d < \frac{\tau_{br}}{SF}$$

where:

τ_{br} : shear breaking strength of the core material, in N/mm2,

SF : safety factor, as defined in C3.8.4.2.

.8 The sum of the bending and shear deflections, due to the design pressure p (see C3.5), of a sandwich laminate between stiffeners is to be less than about 1% of the stiffener spacing. The total deflection, in mm, of a sandwich laminate, fixed on its edges, is given by the formula:

$$f = \frac{\mu_2}{384} \cdot \frac{p \cdot s^4}{[EI]} \cdot 10^9 + \frac{\mu_3}{8} \cdot \frac{p \cdot s^2}{t_a \cdot G} \cdot 10^3$$

where:

[EI] : rigidity of the sandwich laminate, for 1 mm width, in $N \cdot mm^2/mm$, as defined in C3.2.6.3.3,

t_a : core thickness, in mm,

G : shear modulus of the core material, in N/mm²,

μ_2 : coefficient defined in C3.8.4.3.8,

$\mu_3 = 1$ if $\ell \geq 2s$

$\mu_3 = 1 - 1,8 \cdot \left(1 - \frac{\ell}{2 \cdot s}\right)^2$ if $s < \ell < 2s$

$\mu_3 = 0,550$ if $\ell \leq s$

C3.8.4.5 Stiffeners

.1 The Rule values of stiffener stresses take account of the width l_b of the attached plating, defined below:

- for primary stiffeners, l_b is the smaller of the two values:
  - I stiffener: s or 0,2 ℓ
  - Ω stiffener: s or (0,2 ℓ + a), where a is defined in C3.8.4.3.2,
- for ordinary stiffeners, l_b is equal to the spacing s between stiffeners.

.2 To take account of the actual conditions of fixation of a stiffener, the following coefficient ε is considered in the scantling formulae:

- if the stiffener is fixed at its ends: ε = 1,0
- in the other cases: ε = 1,5.

.3 Cut-outs for the passage of ordinary stiffeners are to be as small as possible. As a rule, the depth of cut-outs is not to be greater than half the web height of the primary stiffener.

.4 The bending stress, in N/mm², due to the design pressure p (defined in C3.5) is given by the formula:

$$\sigma_d = \varepsilon \cdot \frac{p \cdot s \cdot \ell^2}{12} \cdot \frac{V}{[I]} \cdot 10^6$$

where:

V : distance from the stiffener neutral axis to the flange, in mm, as defined in C3.2.6.3.5,

[I] : inertia of the stiffener, in mm⁴, as defined in C3.2.6.3.5.

.5 The bending stress due to the design pressure is to be such that:

$$\sigma_d < \frac{\sigma_{br}}{SF} - \sigma_{bl}$$

where:

σ_{br} : breaking bending strength of the stiffener, as defined in C3.2.6.3.5,

σ_{bl} : bending stress due to the total bending moment, as defined in C3.8.3.4. σ_{bl} is to be equal to zero for all stiffeners of ships of less than 24 m in length and for stiffeners not contributing to the longitudinal strength and all stiffeners at ends, for other ships,

SF : safety factor, as defined in C3.8.4.2.

.6 The shear stress, in N/mm², due to the design pressure p (defined in C3.5) is given by the formula:

$$\tau_d = \frac{p \cdot s \cdot \ell}{2 \cdot S_a} 10^3$$

where S_a is the total web cross-sectional area, in mm².

.7 For primary stiffeners, the shear stress due to the design pressure is to be:

$$\tau_d < \frac{\tau_{br}}{SF}$$

where:

τ_{br} : shear breaking strength, in N/mm², of the laminate being the web of the primary stiffener. If a precise value of τ_{br} obtained from tests or other agreed method is not available, τ_{br} is to be taken equal to 60 N/mm²,

SF : safety factor, as defined in C3.8.4.2.

.8 The bending stress σ_{de}, in N/mm², calculated for the testing pressure p_e is to be such that:

$$\sigma_{de} < \frac{\sigma_{br}}{SF}$$

.9 For primary stiffeners, the shear stress τ_{de}, in N/mm², calculated for the testing pressure p_e is to be:

$$\tau_{de} < \frac{\tau_{br}}{SF}$$

C3.8.5 Bottom structure

C3.8.5.1 Application

.1 The requirements of C3.8.5 apply to single or double-bottom structures with longitudinal or transverse framing.

.2 The requirements of C3.5.8 are to be used for the scantlings of the main structural members located between the keel and the chine, as defined in C3.1.4. Refer also to C3.8.4.1.6 for catamarans.

.3 The requirements of C3.5.8 apply also to structural members of the cross-deck of catamarans.

C3.8.5.2 General arrangements

.1 In general, a continuous centreline girder is to be provided over the full length of the ship.

.2 In the engine room, additional girders are to be fitted in order to provide a sufficient structural strength. Unless otherwise specified, the shipyard is to submit the supporting structure to the engine builder for agreement on rigidity and arrangements.

.3 Floors are to be continuous between the centreline keelson and the bilge.

.4 A floor or a girder is to be provided under each line of pillars.

.5 Main engines and thrust blocks are to be secured to the hull structure by seatings with adequate strength to withstand forces transmitted by the propulsive installation.

.6 When solid ballast is fitted, it is to be securely positioned. If necessary, intermediate floors may be fitted for the purpose.

.7 For each member of web of floor or keelson, the height thickness ratio is not to exceed 25.

.8 Provision is to be made for the free passage of water from all parts of the bottom to the suctions, taking into account the pumping rate required.

C3.8.5.3 Plating scantlings

.1 Plating scantlings are to be calculated in accordance with C3.8.4.3 and C3.8.4.4.

.2 The width of the keel plate, in m, is not to be less than (0,6 + 0,01 L).

C3.8.5.4 Stiffener scantlings

.1 Stiffener scantlings are to be calculated in accordance with C3.8.4.5.

.2 For the scantlings of a bottom girder, its span ℓ is to be measured:

- between transverse bulkheads, if the keelson can be considered as a support, i.e. if its height is at least 1,5 times the height of the floors in the centreline, and its moment at least twice the moment of the floors in the centreline,
- between floors, if the keelson is intercostal, its height not exceeding the floor height.

.3 For the scantlings of a floor, its span ℓ is to be measured:

- between side shell platings, if the bottom is flat and supporting bottom girders or longitudinal bulkheads do not exist,
- between side shell plating and keel, if an important keel exists and supporting bottom girders or longitudinals bulkheads do not exist,
- between side shell plating and keelson, side shell plating and bulkhead, or bulkhead and bulkhead, if longitudinal bulkheads or keelson exist, the scantlings and the span of which are such that they can be considered as a support.

.4 For ships with a rising of floors, the floor span is to be measured from the ship centreline, when the angle of the rising of floor is greater than:

- 20° in case of built-in floor at side,
- 10° in case of supported floor at side.

This being so, the floor bending stress is to be calculated in accordance with C3.8.4.5, with $\varepsilon = 1,1$.

.5 When the primary structure is made of a frame of crossed stiffeners with equivalent scantlings, a calculation of the totality of the stiffeners, taking relative stiffnesses into account, is to be submitted.

C3.8.5.5 Single-bottom structure

.1 Side girders are to be fitted. In general, their spacing is not to exceed 2,5 m.

.2 Centre and side girders are to be extended as far aft and forward as practicable.

.3 Where side girders are fitted in lieu of the centre girder, overlap is to be adequately extended, and additional stiffening of the centre bottom may be required.

.4 Flanges of bottom girders and floors are to be connected.

.5 For ships more than 40 m in length with transverse framed bottom, longitudinal stiffeners connected to floors are to be fitted between bottom girders, within the midship region. The mean spacing of longitudinal members is not to exceed 1,4 m.

C3.8.5.6 Double-bottom structure

.1 In general, the height of the double bottom is not to be less than:

$$0,1 \cdot \sqrt{L}$$

.2 Side girders are to be fitted. In general, their spacing is not to exceed 4,2 m.

.3 See also C3.8.5.5 above.

C3.8.6 Side shell structure

C3.8.6.1 Application

.1 The requirements of this sub-article apply to transversely or longitudinally framed side shell structure.

.2 The requirements of this sub-article are to be used for the scantlings of the main structural members located between the chine, as defined in C3.1.4, and the highest continuous deck.

.3 The requirements of this sub-article apply to structural members of inner walls of catamarans (see C3.8.4.1.6).

C3.8.6.2 General arrangements

.1 In case of longitudinal framing, the web frames are to be located in way of floors.

.2 In case of transverse framing, the section modulus of the web frames located in the engine room is not to be less than 4 times that of adjacent frames, and the cross-sectional area of these web frames is not to be less than twice that of adjacent frames.

.3 In case of transverse framing, frames are to be fitted at each frame. The scantlings of main and ’tween deck frames are not to be less than those of frames located immediately above.

.4 In general, stringers are required if the span of main and ’tween deck frames is greater than 4 m.

.5 Web frames are to be fitted in way of beams at hatch ends.

.6 The flanges of stringers and web frames are to be connected if necessary.

C3.8.6.3 Plating scantlings

.1 Plating scantlings are to be calculated in accordance with C3.8.4.3 and C3.8.4.4.

.2 The width of the sheerstrake, in m, is not to be less than:

$$b = 0,715 + 0,425 \cdot \frac{L}{100}$$

.3 Unless otherwise specified, the thickness of the sheerstrake is not to be less than that of the adjacent side shell plating.

.4 The thickness of the sheerstrake is to be increased by 40% in way of breaks in long superstructures occurring within the midship 0,5 L, over a length of about one sixth of the ship breadth on each side of the superstructure end.

.5 The thickness of the sheerstrake is to be increased by 30% in way of breaks in long superstructures occurring outside the midship 0,5 L, over a length of about one sixth of the ship breadth on each side of the superstructure end.

.6 The thickness of the sheerstrake is to be increased by 15% in way of breaks in short superstructures occurring within the midship 0,6 L, over a length of about one sixth of the ship breadth on each side of the superstructure end.

C3.8.6.4 Stiffener scantlings

.1 Stiffeners scantlings are to be calculated in accordance with C3.8.4.5.

.2 For the scantlings of a stringer, its span ℓ is to be measured:

- between transverse bulkheads if the stringer can be considered as a support or if there is no vertical web,
- between vertical webs if the stringer is intercostal and cannot be considered as a support between transverse bulkheads.

.3 For the scantlings of a vertical web frame, its span ℓ is to be measured:

- between decks or between deck and bottom, if there are no stringers or if stringers are intercostal,
- between deck and stringer, bottom and stringer or between stringers if stringers can be considered as a support between transverse bulkheads.

.4 When the primary structure is made of a frame of crossed stiffeners with equivalent scantlings, a calculation of the totality of stiffeners, taking relative stiffnesses into account, is to be submitted.

C3.8.7 Deck structure

C3.8.7.1 Application

.1 The requirements of this sub-article apply to transversely or longitudinally framed deck structure.

.2 The requirements of this sub-article are to be used for the scantlings of the main structural members of the strength deck, lower and platform decks, accommodation decks and the decks of superstructures and deckhouses.

C3.8.7.2 General arrangements

.1 In case of longitudinal framing, the beams are to be located in way of the vertical web frames of side shell.

.2 In case of transverse framing, the beams are to be, in general, fitted at every frame, in line with side shell stiffeners.

.3 In case of vertical break for the strength deck, the continuity of strength is to be ensured by a tapered structure of the two decks within a length equal to 2 to 5 frame spacing.

.4 The transverse strength of ships with large deck openings is to be individually considered.

.5 In the area of openings, the continuity of strength of longitudinal hatch coamings is to be ensured by underdeck girders.

.6 Hatch girders and reinforced beams are to be fitted in way of hatch openings.

.7 The flanges of girders and reinforced beams are to be connected, if necessary.

.8 In case of concentrated loads on decks (e.g. pillars, winches, davits), direct calculations are to be carried out taking account of simultaneous design pressure and concentrated loads.

C3.8.7.3 Plating scantlings

.1 Plating scantlings are to be calculated in accordance with C3.8.4.3 and C3.8.4.4.

.2 The width of the stringer plate, in m, is not to be less than:

$$b = 0{,}005\,(L + 70)$$

.3 Unless otherwise specified, the thickness of the stringer plate is not to be less than that of the adjacent plating.

.4 The thickness of the stringer plate is to be increased by 40% in way of breaks of long superstructures occurring within the midship 0,5 L, over a length of about one sixth of the ship breadth on each side of the superstructure end.

.5 The thickness of the stringer plate is to be increased by 30% in way of breaks of long superstructures occurring outside the midship 0,5 L, over a length of about one sixth of the ship breadth on each side of the superstructure end.

.6 The thickness of the stringer plate is to be increased by 15% in way of breaks of short superstructures occurring within the midship 0,6 L, over a length of about one sixth of the ship breadth on each side of the superstructure end.

C3.8.7.4 Stiffener scantlings

.1 Stiffener scantlings are to be calculated in accordance with C3.8.4.5.

.2 For the scantlings of a girder, its span l is to be measured:

- between transverse bulkheads, if the girder can be considered as a support, i.e. if its height is at least 1,5 times the height of the floors in the centreline, and its moment at least twice the moment of the floors in the centreline,
- between deck beams, if the girder is intercostal and used to prevent tripping instability of deck beams.

.3 For the scantlings of a deck beam, its span l is to be measured:

- between side shell platings, if there are no girders which can be considered as a support or if there are no longitudinal bulkheads,
- between side shell plating and bulkhead, side shell plating and girder, between bulkheads or girders if there are longitudinal bulkheads or girders, the scantlings and span of which are such that they can be considered as a support.

.4 Hatch beams and hatch girders are to be of reinforced scantlings, to take the interrupted stiffeners into account.

.5 The scantlings of hatch beams and girders is not to be less than those obtained in accordance with C3.8.4.5, changing s to take into account the effective supported areas.

.6 When the primary structure is made of a frame of crossed stiffeners with equivalent scantlings, a calculation of the totality of the stiffeners, taking relative stiffnesses into account, is to be submitted.

C3.8.7.5 Deck covers

.1 The scantlings of deck cover platings are to be determined in accordance with C3.8.4.3 and C3.8.4.4.

.2 The scantlings of the deck cover stiffeners are to be calculated in accordance with C3.8.4.5, the span l of the stiffener being measured:

- between the two edges of the cover, if the stiffener can be considered as a support for this dimension,
- between perpendicular stiffeners, if the stiffener is considered as intercostal.

.3 In case of deck cover with a frame of crossed stiffeners with equivalent scantlings, a calculation of the totality of the stiffeners, taking into account the relative stiffnesses, is to be submitted.

C3.8.8 Bulkhead structure

C3.8.8.1 Application

.1 The requirements of this sub-article are to be used for the scantlings of the main structural members of:

- watertight transverse or longitudinal bulkheads,
- transverse or longitudinal tank bulkheads,
- wash transverse or longitudinal bulkheads,
- cofferdam bulkheads,
- shaft tunnel bulkheads.

C3.8.8.2 General arrangements

.1 The scantlings of tank bulkheads which are also Rule bulkheads are not to be less than those required for a watertight bulkhead.

.2 Where bulkheads do not extend up to the uppermost continuous deck (such as the after peak bulkhead), suitable strengthening is to be provided in the extension of the bulkhead.

.3 Bulkheads are to be stiffened in way of deck girders.

.4 Floors are to be fitted in the double bottom, in way of plane transverse bulkheads.

.5 The scantlings of stiffeners on the horizontal part of stepped bulkheads are to be calculated as for beams.

.6 Where vertical stiffeners are cut in way of watertight doors, reinforced stiffeners are to be fitted on each side of the door and suitably overlapped; crossbars are to be provided to support the cut-off stiffeners.

.7 Arrangements are to be provided to avoid the buckling of large accommodation bulkheads without stiffeners.

C3.8.8.3 Plating scantlings

.1 Platings scantlings are to be calculated in accordance with C3.8.4.3 and C3.8.4.4.

C3.8.8.4 Stiffener scantlings

.1 Stiffeners scantlings are to be calculated in accordance with C3.8.4.5.

.2 For the scantlings of a stringer, its span l is to be measured:

- between side shell platings, between longitudinal bulkheads or between side shell plating and longitudinal bulkhead, for stringers of transverse bulkheads considered as a support,
- between transverse bulkheads, for stringers of longitudinal bulkheads considered as a support,
- between vertical webs, for stringers whose scantlings are such that they cannot be considered as a support.

.3 For the scantlings of a vertical web, its span l is to be measured:

- between decks or between deck and bottom, if the vertical web can be considered as a support,
- between horizontal stiffeners, if scantlings of the vertical web are such that it cannot be considered as a support.

.4 When the primary structure is made of a frame of crossed stiffeners with equivalent scantlings, a calculation of the totality of the stiffeners, taking relative stiffnesses into account, is to be submitted.

C3.8.8.5 Watertight doors

.1 The strength of a watertight door is not to be less than that of the adjacent bulkhead.

.2 In the calculation of the scantlings of stiffeners of watertight door, stiffeners are to be considered as supported at ends.

C3.8.9 Superstructure and deckhouse structures

C3.8.9.1 Application

.1 The requirements of this sub-article apply to the structure of superstructures and deckhouses framed transversely and longitudinally.

C3.8.9.2 General arrangements

.1 Reduction in scantlings may be granted for:

- deckhouses not protecting openings in the freeboard and superstructure decks,
- deckhouses located above the third tier.

These reductions are to be individually examined by the Society.

.2 Ends of superstructures and deckhouses are to be efficiently supported by bulkheads, pillars or other equivalent system.
Where hatchways are fitted close to the ends of superstructures, additional strengthening may be required.

.3 All openings cut in the sides or decks of superstructures and deckhouses are to be stiffened and have well rounded corners. Continuous stiffeners are to be fitted below and above doors or similar openings. Where necessary, compensation for large openings may be required.

.4 Side plating at the ends of superstructures is to be tapered into the bulwark or sheerstrake of the strength deck. Where a raised deck is fitted, this arrangement is to extend over a three-frame space.

.5 Access openings cut in sides of enclosed superstructures are to be fitted with watertight doors, permanently attached.
The structure and attachment system of these doors are to be arranged so that the strength remains equivalent to that of a non-pierced bulkhead.
Securing devices which ensure weathertightness are to include tight gaskets, clamping dogs or other similar appliances, and to be permanently attached to the bulkheads and doors. These doors are to be arranged for operation from both sides.

.6 As a rule, the spacing of stiffeners on sides of superstructures and deckhouses is to be the same as that of beams on supporting decks.

.7 Partial bulkheads or web are to be arranged to support the sides and ends of superstructures and deckhouses. Scantlings of these web frames are to be individually considered.

.8 Sides of deckhouses are to be strengthened in way of boats and the top plating is to be reinforced in way of boat davits.

.9 Special attention is to be paid to the transfer of vertical loads between decks.

C3.8.9.3 Plating scantlings

.1 Plating scantlings are to be calculated in accordance with C3.8.4.3 and C3.8.4.4.

.2 When the superstructure deck is the strength deck, the scantlings of the sides of superstructures are to be determined as for the side shell plating.

.3 The plating thickness of sides of long superstructures is to be increased by 25% over a length of about one sixth of the ship breadth on each end of the superstructure.

C3.8.9.4 Stiffener scantlings

.1 Stiffener scantlings are to be calculated in accordance with C3.8.4.5.

.2 Scantlings of side stiffeners of superstructures and deckhouses need not exceed those of side stiffeners of the tier immediately below, based on the same span and spacing.

.3 The Society reserves the right for a special examination of superstructure frames:

- where the decks at ends of the considered frame are not stiffened in the same way,
- where the frame span exceeds 4 m,
- for passenger ships.

.4 In the case of a superstructure or deckhouse contributing to the longitudinal strength, the vertical stiffeners between windows on the sides are to be individually examined.

C3.8.10 Principles of buildings

C3.8.10.1 Definition

.1 The stiffeners with the lower spacing are defined in this Section as ordinary stiffeners.

.2 Depending on the direction of ordinary stiffeners, a structure is made of one of the following systems:

- longitudinal framing,
- transverse framing.

.3 Ordinary stiffeners are supported by structural members, defined as primary stiffeners, such as:

- keelsons or floors,
- stringers or web frames,
- reinforced beams or deck stringers.

C3.8.10.2 General arrangements

.1 The purpose of this sub-article is to give some structural details which may be recommended. But they do not constitute a limitation; different details may be proposed by the builders and agreed upon by the Society, provided that builders give justifications, to be defined in each special case.

.2 Arrangements are to be made to ensure the continuity of longitudinal strength:

- in areas with change of stiffener framing,
- in areas with large change of strength,
- at connections of ordinary and primary stiffeners.

.3 Arrangements are to be made to ensure the continuity of transverse strength in way of connections between hulls of catamarans and axial structure.

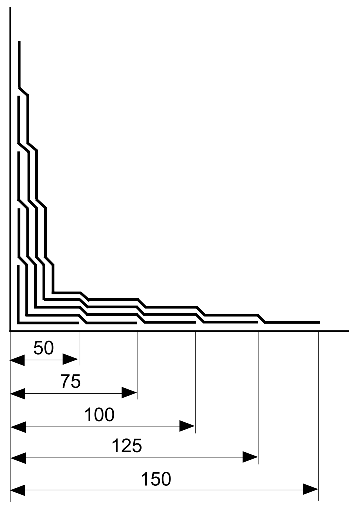
.4 Structure discontinuities and rigid points are to be avoided; when the strength of a structure element is reduced by the presence of an attachment or an opening, proper compensation is to be provided.

.5 Openings are to be avoided in highly stressed areas, in particular at ends of primary stiffeners, and, for webs of primary stiffeners, in way of pillars.
If necessary, the shape of openings is to be designed to reduce stress concentration.
In any case, the corners of openings are to be rounded.

.6 Connections of the various parts of a hull, as well as attachment of reinforcing parts or hull accessories, can be made by moulding on the spot, by bonding separately moulded, or by mechanical connections.

.7 Bulkheads and other important reinforcing elements are to be connected to the adjacent structure by corner joints (see Figure C3.8.4) on both sides, or equivalent joint.

Figure C3.8.4



The mass by m² of the corner joints is to be at least 50% of the mass of the lighter of the two elements to be fitted, and at least 900 g/m² of mat or its equivalent.
The width of the layers of the corner joints is to be worked out according to the principle given in Figure C3.8.4.

.8 The connection of the various parts of the hull, as well as connection of reinforcing members to the hull, can be made by adhesives, subject to special examination by the Society.

C3.8.10.3 Platings

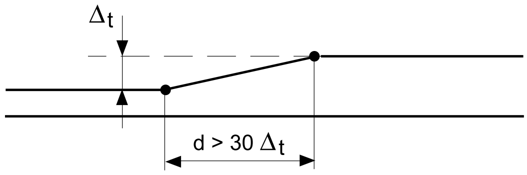
.1 **General**

(a) The edges of the reinforcements of one layer are not to be juxtaposed but to be overlapped of at least 50 mm; these overlaps are to be offset between various successive layers.

(b) Prefabricated laminates are fitted by overlapping the layers, preferably with chamfering of edges to be connected.
The thickness at the joint is to be at least 15% higher than the usual thickness.

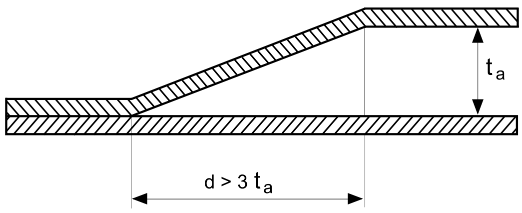
(c) Changes of thickness for a single-skin laminate are to be made as gradually as possible and over a width which is, in general, not to be less than thirty times the difference in thickness, as shown in Figure C3.8.5.

Figure C3.8.5



(d) The connection between a single-skin laminate and a sandwich laminate is to be carried out as gradually as possible over a width which is, in general, not to be less than three times the thickness of the sandwich core, as shown in Figure C3.8.6.

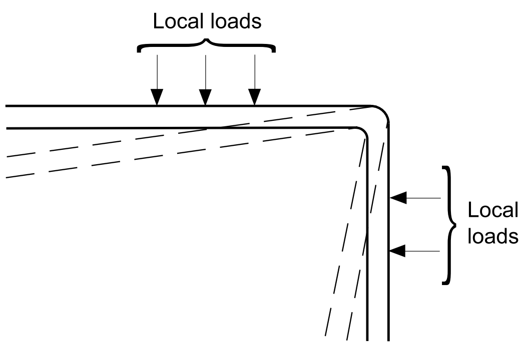
Figure C3.8.6



.2 Deck-side shell connection

(a) This connection is to be designed both for the bending stress shown on Figure C3.8.7, caused by vertical loads on deck and horizontal loads of seawater, and for the shear stress caused by the longitudinal bending.

Figure C3.8.7



(b) In general, the connection is to avoid possible loosening due to local bending, and ensure longitudinal continuity. Its thickness is to be sufficient to keep shear stresses acceptable.

(c) Figure C3.8.8 to Figure C3.8.11 give examples of deck-side shell connections.

Figure C3.8.8

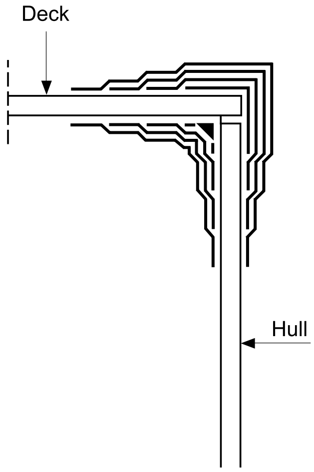


Figure C3.8.9

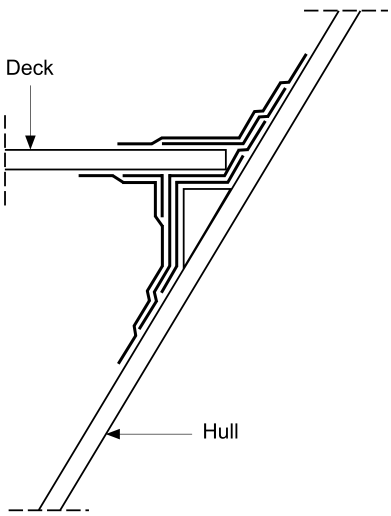


Figure C3.8.10

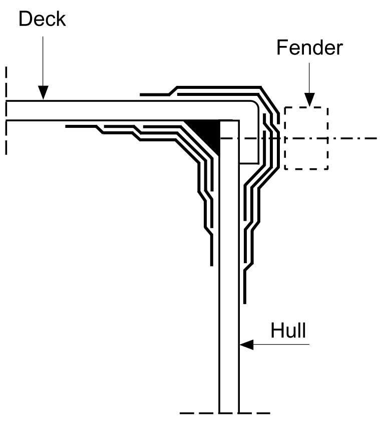
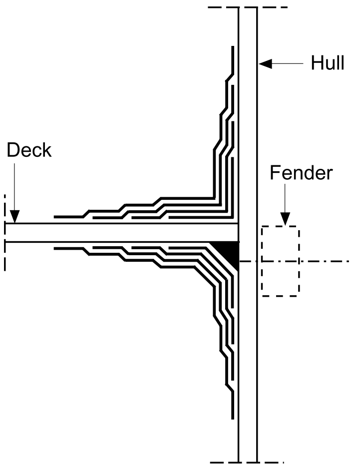


Figure C3.8.11



.3 **Bulkhead-hull connection**

(a) In some cases, this connection is needed to distribute the local load due to the bulkhead over a sufficient length of hull. Figure C3.8.12 and Figure C3.8.13 give possible solutions. The scantlings of corner joints are determined according to the loads acting upon the connections.

(b) The builder is to pay special attention to connections between bulkheads of integrated tanks and structural members.

Figure C3.8.12

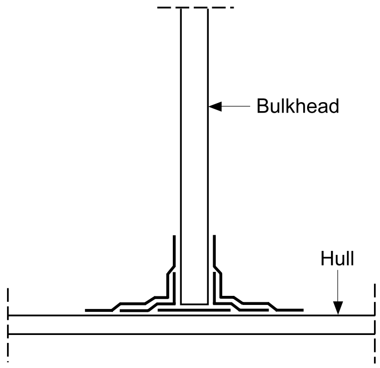
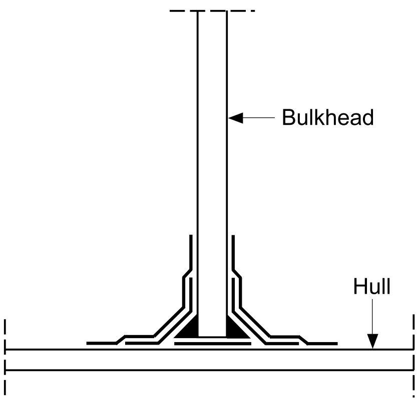


Figure C3.8.13



.4 **Passage through hull**

(a) Passages of metal elements through the hull, especially at the level of the rudder stock, shaft brackets, shaft-line, etc., are to be strongly built, in particular when subjected to alternating loads.

(b) Passages through hull should be reinforced by means of a plate and a counterplate connected to each other.

.5 **Passage through watertight bulkhead**

The continuous omega or rectangle stiffeners at a passage through a watertight bulkhead are to be watertight in way of the bulkhead.

.6 **Openings in deck**

The corners of deck openings are to be rounded in order to reduce local stress concentrations as much as possible, and the thickness of the deck is to be increased to maintain the stress at a level similar to the mean stress on the deck.

The reinforcement is to be made from a material identical to that of the deck.

C3.8.10.4 Stiffeners

.1 Primary stiffeners are to ensure structural continuity.

.2 Abrupt changes in web height, flange breadth, cross-section area of web and flange are to be avoided.

.3 In general, at the intersection of two stiffeners of unequal sizes (longitudinal with web frame, floor, beam or frame with stringer, girder or keelson), the smallest stiffener (longitudinal or frame) is to be continuous, and the connection between the elements is to be made by corner joints according to the principles defined in C3.8.10.2.

.4 Figure C3.8.14 to Figure C3.8.16 give various examples of stiffeners.

Figure C3.8.14

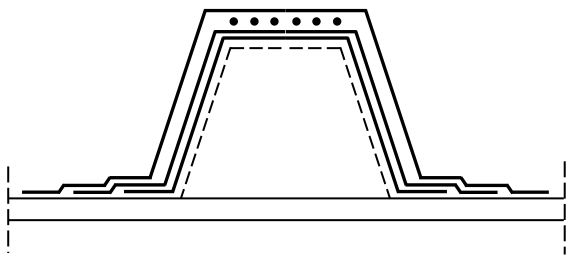


Figure C3.8.15

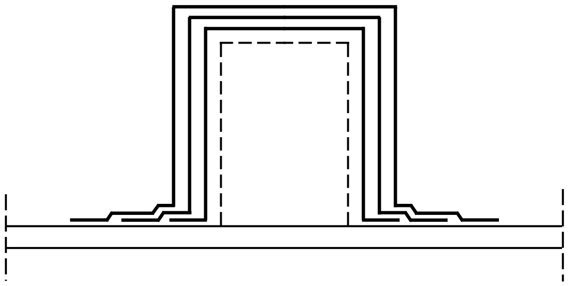
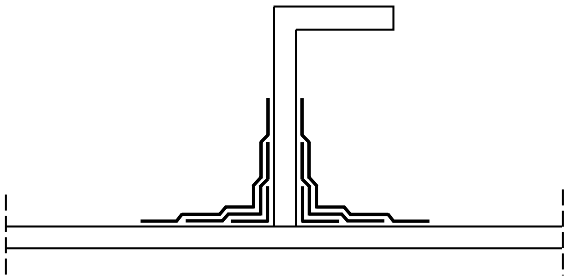


Figure C3.8.16



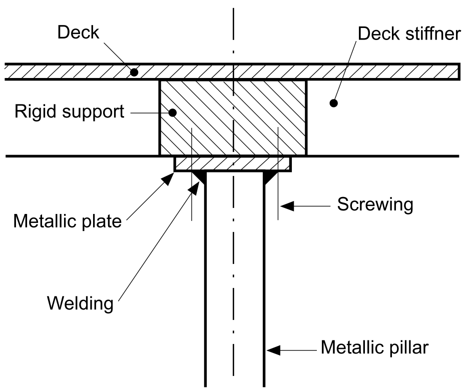
.5 Connections between stiffeners are to ensure good structural continuity. In particular, the connection between deck beam and frame is to be ensured by means of a flanged bracket. However, some types of connections without bracket may be accepted, provided that loads are light enough. In this case, stiffeners are to be considered as supported at their ends.

C3.8.10.5 Pillars

.1 Connections between metal pillars, subject to tensile loads, and the laminate structure are to be designed to avoid tearing between laminate and pillars.

.2 Connections between metal pillars, subject to compressive loads, and the laminate structure are to be carried out by means of intermediate metal plates. The welding of the pillar to the metal plate is to be carried out before fitting of the plate on board ship.
Figure C3.8.17 gives the principle for connection between the structure and pillars subject to compressive loads.

Figure C3.8.17

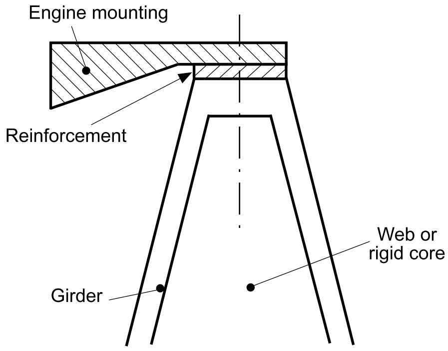


C3.8.10.6 Engine seating

.1 The engine seating is to be fitted on special girders suitably positioned between floors, which locally ensure sufficient strength with relation to pressure and weight loads.

.2 Figure C3.8.18 gives an example of possible seating.

Figure C3.8.18



C3.9 Hull appendages

C3.9.1. Propeller shaft brackets

C3.9.1.1 General

.1 For certain ships, the propeller shafting is extended to the propeller bearings clear of the main hull.
Propeller shafting is either enclosed in bossing or independent of the main hull and supported by shaft brackets.

C3.9.1.2 Shaft brackets

.1 The scantlings of bracket arms are to be calculated as indicated below. For high-powered ships, the Society may require direct calculations to be carried out.

.2 Bracket arms are to be attached to deep floors or girders of increased thickness, and the shell plating is to be increased in thickness and suitably stiffened, at the discretion of the Society. The thickness of the palm connecting the arms to the hull, if any, is to be not less than 0,2 d_S, where:

d_S : Rule diameter, in mm, of the propeller shaft, calculated with the actual mechanical characteristics,

and it is to be connected to the hull by means of through bolts, fitted with nut and lock nut, in way of the internal hull structures suitably stiffened.

.3 The arms of V-shaft brackets are to be perpendicular, as far as practicable.

.4 The bearing length of the shaft bracket boss, in mm, is to be not less than 3 d_S.

.5 The thickness, in mm, of the shaft bracket boss after boring operation is to be not less than:

$t_b = 0{,}2 \cdot d_S \cdot (k_1 + 0{,}25)$

where:

$k_1 = R_{ms} / R_{mb}$

R_{ms} : minimum tensile strength, in N/mm², of the propeller shaft,

R_{mb} : minimum tensile strength, in N/mm², of the shaft bracket boss, with appropriate metallurgical temper.

.6 Each arm of V-shaft brackets is to have a cross-sectional area, in mm², not less than:

$$S = 87{,}5 \cdot 10^{-3} \cdot d_{so}^2 \cdot \left(\frac{1600 + R_{ma}}{R_{ma}}\right)$$

where:

d_{so} : rule diameter, in mm, of the propeller shaft, for a carbon steel material,

R_{ma} : minimum tensile strength, in N/mm², of arms, with appropriate metallurgical temper.

.7 Single-arm shaft brackets are to have a section modulus at ship plating level, in cm³, not less than:

$$W = \frac{30}{R_{ma}} \cdot 10^{-3} \cdot \ell \cdot d_{so}^2 \cdot \sqrt{n \cdot d_{so}}$$

where:

ℓ : length of the arm, in m, measured from the shell plating to the centreline of the shaft boss,

n : shaft revolutions per minute.

Moreover, the cross-sectional area of the arm at the boss is not to be less than 60% of the cross-sectional area at shell plating.

C3.9.1.3 Plated bossing

.1 Where the propeller shafting is enclosed within a plated bossing, the aft end of the bossing is to be adequately supported.

.2 The scantlings of end supports are to be individually considered. Supports are to be designed to transmit loads to the main structure.

.3 End supports are to be connected to at least two deep floors of increased thickness, or connected to each other within the ship.

.4 Stiffening of the boss plating is to be individually considered. At the aft end, transverse diaphragms are to be fitted at every frame and connected to floors of increased scantlings. At the fore end, web frames spaced not more than four frames apart are to be fitted.

C3.9.2 Waterjets

.1 The supporting structures of waterjets are to be able to withstand the loads thereby generated in the following conditions:

- maximum ahead thrust,
- maximum thrust at maximum lateral inclination,
- maximum reversed thrust (going astern).

Information on the above loads is to be given by the waterjet manufacturer and supported by documents.

.2 For each waterjet, following loading cases are to be investigated:

LDC 1 : internal hydrodynamic pressure p_h in the built-in nozzle

LDC 2 : horizontal longitudinal force F_{x1} in normal service (ahead)

LDC 3 : horizontal transverse force F_y and associated moment M_z during steering operation

LDC 4 : horizontal longitudinal force F_{x2}, vertical force F_z and overturning moment M_y in crash-stop situation

.3 The actual location of the thrust bearing is to be adequately considered (either located aft of the stem in the stator bowl or inside the waterjet compartment)

.4 The scantlings are to be checked by direct calculations.

.5 Table C3.9.1 indicates the loading cases to be considered for the various components of the waterjet system. Other loading cases could be considered for specific or new design.

Table C3.9.1

Component	LDC 1	LDC 2	LDC 3	LDC 4
Built-in nozzle:				
- plating	X (1)	X (2)		
- bending behaviour				X (3)
Ship stem		X (2)	X	X (4)
Bolting on stem			X (5)	X (5)

(1) : to be checked under lateral pressure and against fatigue behaviour
(2) : buckling to be checked (100% of F_x transferred by built-in nozzle in case of thrust bearing aft of the stem)
(3) : ratio of M_y directly sustained by the built-in nozzle to be estimated on basis of relative stiffnesses
(4) : ratio of M_y directly sustained by the transom structure to be estimated on basis of relative stiffnesses
(5) : bolting calculation taking account of the actual pre-tension in bolts

.6 The stress criteria for static analysis may be taken as the following one, in N/mm²:

- bending stress:

$$\sigma_{am} = \frac{150}{K \cdot f'_m}$$

- shear stress:

$$\tau_{am} = \frac{90}{K \cdot f'_m}$$

- Von Mises equivalent bending stress:

$$\sigma_{eq,\,am} = \frac{190}{K \cdot f'_m}$$

where:

K : material factor defined in C3.2

f'_m : coefficient depending on the material:

- 1,00 for steel structures
- 2,15 for aluminium alloy structures

.7 The stress criteria for fatigue analysis are to be specified by the designer.

.8 The shell thickness in way of nozzles as well as the shell thickness of the tunnel are to be individually considered. In general, such thicknesses are to be not less than 1,5 times the thickness of the adjacent bottom plating.

.9 General principles to be followed for such structures subject to cyclic loadings are listed hereafter:

- continuous welding
- shear connections between stiffeners and transverse frames
- soft toe brackets
- no sniped ends
- no termination on plate fields
- no scallops in critical areas
- no start and stop of welding in corners or at ends of stiffeners and brackets
- possibly grinding of toes of critical welds

Note: As a guidance, the following criteria may be considered:

The bending natural frequency of plates and strength members of the hull in the area of waterjets should not be less than 2,3 times the blade frequency for structures below the design waterline and between transom and aft engine room bulkhead. Structural components (such as the casing of waterjet and accessory parts and the immersed shell area) which may transfer pressure fluctuations into the ship structure have to fulfill the requirements of the waterjet manufacturer. Especially with regard the grids installed in the inlet duct, the hydrodynamic design should assure an unproblematic operation with respect to cavitation phenomenon.

This checking is left to the manufacturers (see paragraph 3.4)

C3.10 Rudders

C3.10.1 General

.1 Rudders which are intended to be operated at the maximum angle of helm only during navigation at reduced speed are to comply with the provisions of this article.

.2 This article applies to rudders having a rectangular or trapezoidal blade contour without cutouts, of the types shown in Figure C3.10.1 and Figure C3.10.2. Rudders of different types is to be individually considered by the Society.

.3 Rudders which are intended to be operated at the maximum angle of helm during high speed navigation are to be designed on the basis of direct calculations to be performed by the designer. The acceptability of calculated results are to be individually considered by the Society in each separate case.

Figure C3.10.1

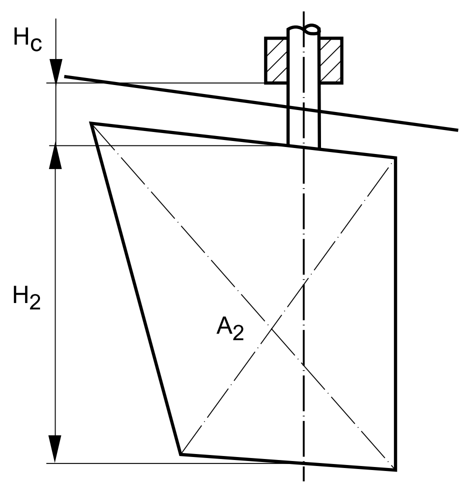
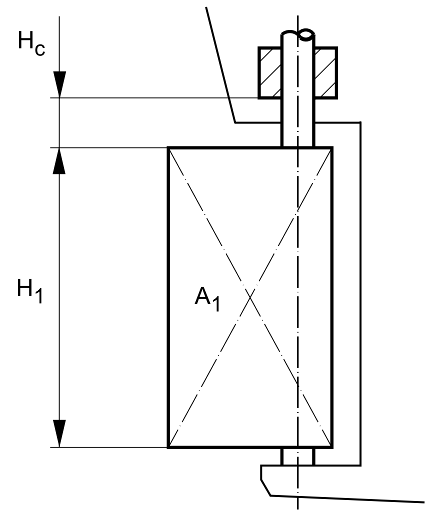


Figure C3.10.2



C3.10.2 Definitions and symbols

V_{AV} : maximum ahead service speed, in knots, at maximum displacement, in still water,

A : total area of rudder blade, in m^2, bounded by the blade external contour, including mainpiece and the part forward of the centreline of the rudder pintles, if any,

A_D : area, in m^2, of the rudder part abaft the centreline of rudder pintles,

X_G : distance, in m, from the centroid of area A to the centreline of pintles,

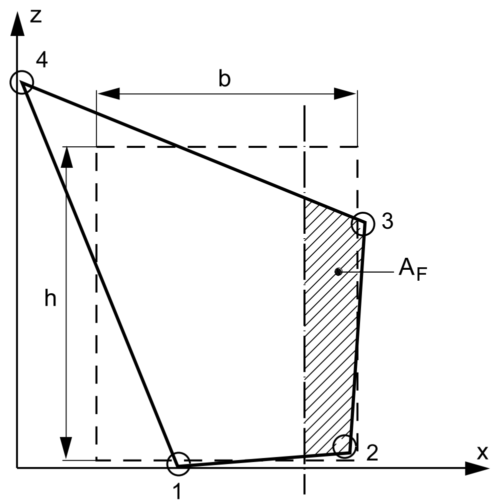
k_1 : shape factor, equal to:
$k_1 = (\Lambda + 2) / 3$

Λ : $\Lambda = h^2 / A_T$
where h is the mean height of the rudder area, in m. In no case is the value of Λ to be greater than 2. Mean height h and mean breadth b of rudder blade are to be calculated according to Figure C3.10.3,

A_T : area, in m^2, obtained by adding, to the rudder blade area, the area of rudder post or rudder horn, if any, up to height h,

k_2 : factor depending on rudder profile, the value of which is given in Table C3.10.1. For high-efficiency rudders, k_2 is to be equal to 1,7 for ahead condition and 1,2 for astern condition,

Figure C3.10.3



b : mean breadth of rudder, in m, equal to:

$$b = \frac{x_2 + x_3 - x_1}{2}$$

h : mean height of rudder, in m, equal to:

$$h = \frac{z_3 + z_4 - z_2}{2}$$

k_3 : factor equal to:

- k_3 = 0,8 for rudders outside the propeller jet
- k_3 = 1,15 for rudders behind a fixed propeller nozzle
- k_3 = 1,0 in other cases,

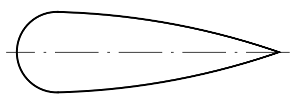
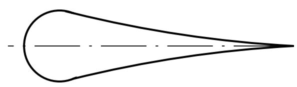
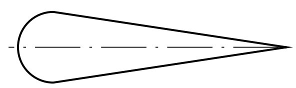
d_{TF} : rule diameter, in mm, of rudder stock subject to combined torque and bending,

d_T : rule diameter, in mm, of rudder stock subject to torque only,

C_R : rudder force, in N, i.e. force acting on the rudder blade, as defined in C3.10.5,

Q_R : rudder torque, in N · m, i.e. torque acting on the rudder stock, as defined in C3.10.5.

Table C3.10.1 - Factor k_2

Profile type	k_2	
	ahead condition	astern condition
NACA-00 – Göttingen profiles 	1,10	0,80
Hollow profiles 	1,10 - 1,35	0,90
Flat side profiles 	1,10	0,90

C3.10.3 Materials

.1 Rudder stocks, pintles, keys and bolts are to be made of rolled, forged or cast C-Mn steel, in accordance with the relevant requirements of the Rules.

.2 The material used for rudder stocks, pintles, keys and bolts is to have a minimum yield stress R_{eH} of not less than 200 N/mm².

.3 The requirements for the determination of scantlings contained in this article apply to steels having a minimum yield stress R_{eH} equal to 235 N/mm².

.4 In the case of steels with a yield stress R_{eH} other than 235 N/mm², the values of diameters and thicknesses calculated with the formulae contained in the following sub-articles are to be modified as indicated, depending on the factor K_1 obtained from the following formula:

$$K_1 = \left(\frac{235}{R_{eH}}\right)^y$$

where:

R_{eH} : minimum yield stress of steel employed, in N/mm²; in no case is R_{eH} to be greater than 450 N/mm² or 0,7 R_m, whichever is less,

R_m : minimum ultimate tensile strength of steel employed, in N/mm²,

- for R_{eH} > 235 N/mm²: y = 0,75
- for $R_{eH} \le$ 235 N/mm²: y = 1,0

.5 In general, significant reductions in rudder stock diameter for the application of steels with R_{eH} > 235 N/mm² may be accepted by the Society, subject to the results of a calculation to check rudder stock deformation.

.6 Significant rudder stock deformations are to be avoided so as not to create excessive edge pressures in way of bearings.

.7 Welded parts of rudders are to be made of rolled hull steels of a type approved by the Society.

C3.10.4 Arrangement

.1 Effective means are to be provided to support the weight of the rudder without excessive bearing pressure (e.g. by means of a rudder carrier attached to the upper part of the rudder stock). The hull structure in way of the rudder carrier is to be suitably strengthened.

.2 Suitable arrangements are to be made to prevent the rudder from accidental lifting.

.3 In addition, structural rudder stops of suitable strength are to be provided, except where the steering gear is provided with its own rudder stopping devices.

.4 In rudder trunks which are open to the sea, a seal or stuffing box is to be fitted above the deepest load waterline, to prevent water from entering the steering gear compartment and lubricant being washed away from the rudder carrier.

If the top of the rudder trunk is below the deepest waterline, two separate seals or stuffing boxes are to be provided.

C3.10.5 Determination of the force acting on the rudder blade and the torque acting on the rudder stock

.1 The rudder force C_R, in N, is to be calculated by the following formula:

$C_R = 132 \cdot A \cdot V^2 \cdot k_1 \cdot k_2 \cdot k_3$

where:

V : $\min[V_{AV}, 2/3 \cdot (V_{AV} + 2 \cdot L^{0,5})]$

.2 The rudder torque Q_R, in N · m, is to be calculated for both ahead and astern conditions according to the formula:

$Q_R = C_R \cdot r$

where:

r : distance, in m, equal to:
$r = b \cdot (\alpha - k_A)$
for the ahead condition, r is to be taken not less than 0,1 · b,

b : mean breadth of rudder area, in m, measured in accordance with Figure C3.10.3,

α :
- for ahead condition: α = 0,33
- for astern condition: α = 0,66

$k_A = A_F / A$

A_F being the area, in m², of the rudder blade portion afore the centreline of rudder pintles (see Figure C3.10.3).

C3.10.6 Rudder stock

C3.10.6.1 Rudder stock subject to torque

.1 Rudder stocks subject to torque are to have scantlings such that the torsional stress, in N/mm², does not exceed the following value:

$\tau_{T\,ALL} = 68/K_1$

.2 The rudder stock diameter is therefore to be not less than d_T, in mm, calculated by the following formula:

$d_T = 4{,}2 \cdot (Q_R \cdot K_1)^{1/3}$

C3.10.6.2 Rudder stock subject to combined torque and bending

.1 Rudder stocks subject to combined torque and bending are to have scantlings such that their equivalent stress σ_e, in N/mm², does not exceed the value determined by the formula:

$\sigma_{e\,ALL} = 118 / K_1$

.2 σ_e is given by the formula:

$$\sigma_e = \sqrt{\sigma_B^2 + 3 \cdot \tau_T^2}$$

where:

σ_B : bending stress component, in N/mm², given by the formula:

$$\sigma_B = \frac{10,2 \cdot M}{d_{TF}^3} \cdot 10^3$$

τ_T : torsional stress component, in N/mm², given by the following formula:

$$\tau_T = \frac{5,1 \cdot Q_R}{d_{TF}^3} \cdot 10^3$$

.3 The rudder stock diameter, in mm, is therefore to be not less than the value d_{TF}, in mm, calculated according to the formula:

$$d_{TF} = d_T \cdot \left(1 + \frac{4}{3} \cdot \left(\frac{M}{Q_R}\right)^2\right)^{1/6}$$

where:

M : bending moment, in N · m, which may be expressed as:

$M = 0,866 \cdot (C_R / A) \cdot H$

H :
- for spade rudders (see Figure C3.10.1):

  $H = A_2 \cdot (H_C + H_2 / 2)$

- for rudders with 2 bearings (with solepiece) (see Figure C3.10.2):

  $H = A_1 \cdot a_1 \cdot u \cdot H1$

A_1, A_2, H_C, H_1 and H_2 are shown in Figure C3.10.1 and Figure C3.10.2.

The values of the coefficients a_1 and u are given in Table C3.10.2 as a function of the ratio c, where:

$c = H_1 / (H_C + H_1)$

Table C3.10.2 - Coefficients a_1 and u

c	u	a_1	c	u	a_1
1,00	0,2490	1,000	0,74	0,2694	1,266
0,98	0,2370	1,000	0,72	0,2784	1,302
0,96	0,2294	1,000	0,70	0,2881	1,336
0,94	0,2256	1,000	0,68	0,2984	1,370
0,92	0,2242	1,000	0,66	0,3094	1,403
0,90	0,2248	1,000	0,64	0,3212	1,435
0,88	0,2270	1,000	0,62	0,3336	1,467
0,86	0,2303	1,017	0,60	0,3468	1,499
0,84	0,2348	1,064	0,58	0,3608	1,531
0,82	0,2402	1,109	0,56	0,3757	1,563
0,80	0,2464	1,151	0,54	0,3915	1,596
0,78	0,2534	1,191	0,52	0,4084	1,629
0,76	0,2610	1,229	0,50	0,4264	1,662

.4 The Society may accept bending moments, shear forces and support reaction forces determined by a direct calculation to be performed with reference to the static schemes and loading conditions set out in Figure C3.10.4 and Figure C3.10.5.

For the rudder in Figure C3.10.4, the load per unit length P_R, in kN/m, is given by:

$$P_R = C_R \cdot \frac{10^{-3}}{\ell_{10}}$$

For the rudder in Figure C3.10.5, the maximum bending moment M_B, in N · m, and support forces B_3 and B_2, in N, may be determined by the formulae:

$$M_B = C_R \cdot \left(\ell_{20} + \frac{\ell_{10} \cdot (2C_1 + C_2)}{3 \cdot (C_1 + C_2)}\right)$$

$B_3 = M_B / l_{30}$

$B_2 = C_R + B_3$

.5 In general, the diameter of a rudder stock subject to torque and bending may be gradually tapered above the upper stock bearing, so as to reach the value of d in way of the quadrant or tiller.

Figure C3.10.4

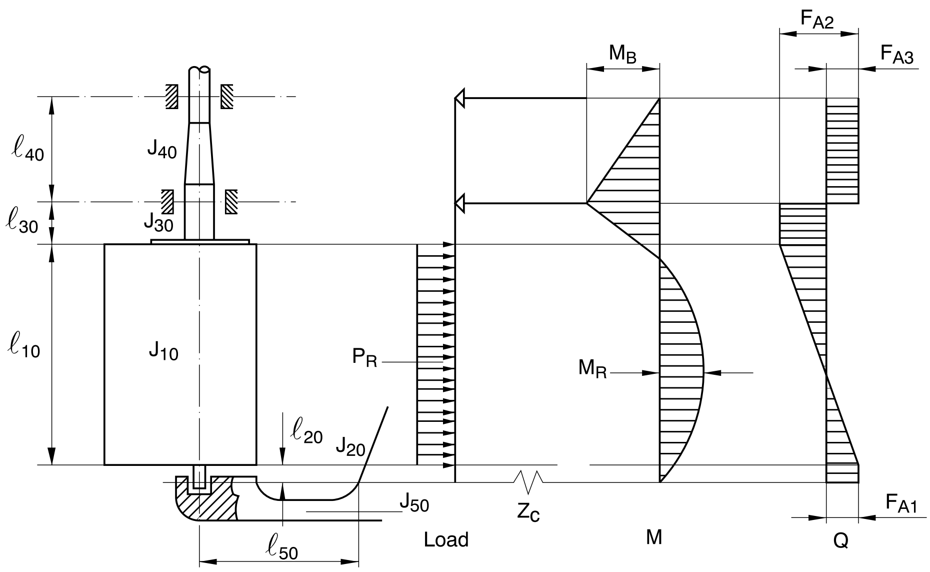
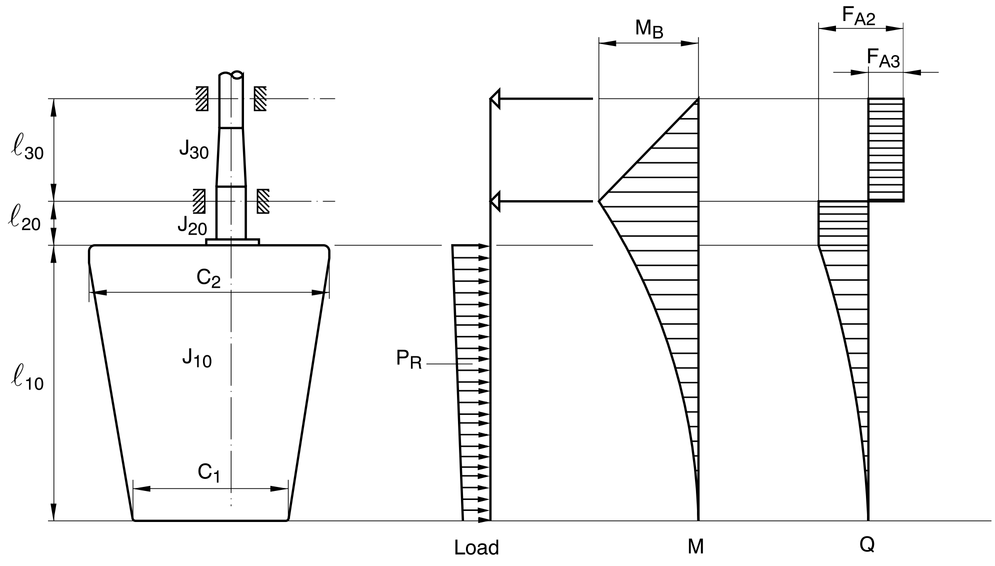


Figure C3.10.5



C3.10.7 Rudder plating

.1 Double-plating rudders consist of a welded plating box, stiffened by horizontal and vertical webs, which may or may not incorporate the mainpiece.

.2 The generic horizontal cross-section of the rudder plating is to be such that stress components, in N/mm², do not exceed the following values:

- normal bending stress:

  $\sigma_{Fl} = 110 / K_1$

- shear stress:

  $\tau = 50 / K_1$

- equivalent stress:

  $$\sigma_e = \sqrt{\sigma_{Fl}^2 + 3 \cdot \tau^2} = \frac{120}{K_1}$$

.3 The thickness of each rudder plate panel is to be not less than t_F, in mm, calculated by the following formula:

$$t_F = \left(5,5 \cdot s \cdot \beta \cdot \sqrt{d + \frac{C_R \cdot 10^{-4}}{A}} + 2,5\right) \cdot \sqrt{K_1}$$

where:

d : draught at summer load waterline, in m,

$$\beta = \sqrt{1,1 - 0,5 \cdot \left(\frac{s}{b_L}\right)^2}$$

which need not be greater than 1,

with:

s : minor side of the plating panel, in m,

b_L : major side of the plating panel, in m.

.4 Vertical webs with spacing greater than twice that of horizontal webs are not acceptable.

.5 Web thickness is to be at least 70% of that required for rudder plating, and in no case is it to be less than 8 mm, except for the upper and lower webs. The thickness of any of these webs is to be uniform and not less than that of the web panel having the greatest thickness t_F as calculated with the above formula. In any case the thickness is not required to be increased by more than 20% compared with normal webs.

.6 When the design of the rudder does not incorporate a mainpiece, this is to be replaced by two vertical webs closely spaced and in general not less than 1,5 times the thickness of normal webs. In rudders with an area A smaller than 5 m², one vertical web may be accepted, provided its thickness is in general at least twice that of normal webs. As a rule, the increased thickness of such webs need not exceed 30 mm, unless otherwise required in special cases to be individually considered by the Society.

The thickness of the side plating between the two vertical webs replacing the mainpiece, or in way of the single web, is to be increased by at least 20%.

.7 The welded connections of blade plating to vertical and horizontal webs are to comply with the requirements of C3.2.

Where internal access to the rudder is not practicable, connections are to be made by slots on a supporting flat welded to the webs, to be cut on one side of the rudder only, in accordance with C3.2.

.8 Rudder nose plates are to have a thickness not less than 1,25 t_F. In general this thickness need not exceed 22 mm, unless otherwise required in special cases to be individually considered by the Society.

C3.10.8 Rudder pintles

.1 Rudder pintles are to have a diameter not less than the value d_A, in mm, calculated by the formula:

$d_A = 0{,}35 \cdot (F_A \cdot K_1)^{1/2}$

where:

F_A : force, in N, acting on the pintle, calculated as specified in C3.10.8.7.

.2 Provision is to be made for a suitable locking device to prevent the accidental loosening of pintles.

.3 The pintle housings are in general to be tapered with the taper ranging:

- from 1:12 to 1:8 for pintles with non-hydraulic assembly and disassembly arrangements,
- from 1:20 to 1:12 for pintles with hydraulic assembly and disassembly arrangements.

The housing height is to be not less than the pintle diameter d_A.

.4 The maximum value of the pressure acting on the gudgeons, in N/mm², calculated by the formula:

$$p_F = \frac{F_A}{d_A \cdot h_A}$$

is not to exceed the values given in Table C3.10.3, where h_A is the length of contact between pintle and housing, taken to be not greater than 1,2 d_A.

Values in excess of those given In Table C3.10.3 may be accepted by the Society on the basis of specific tests.

Table C3.10.3

Bearing material	q_a (N/mm²)
Lignum vitae	2,5
White metal, oil lubricated	4,5
Synthetic material with hardness between 60 and 70 Shore D (1)	5,5
Steel, bronze and hot-pressed bronze-graphite materials (2)	7,0
(1) Indentation hardness test at 23°C and with 50% moisture to be performed according to a recognised standard. Type of synthetic bearing materials to be approved by the Society. (2) Stainless and wear-resistant steel in combination with stock liner approved by the Society.	

.5 The thickness of the pintle housing in the gudgeon is to be not less than 0,25 d_A.

.6 The manufacturing tolerances, in mm, on the diameter of metal supports are to be less than:

$d_A / 1000 + 1{,}0$

In the case of non-metal supports, tolerances are to be evaluated carefully on the basis of the thermal and distortion properties of the materials employed; the tolerance on the support diameter is in no case to be less than 1,5 mm.

.7 Where direct calculation is used to obtain the rudder stock stress components, the value F_A is also to be derived from the same calculation.

Otherwise, F_A is to be calculated from the following formula:

$$F_A = \frac{C_R}{A} \cdot A_G$$

where:

C_R : force, in N, acting on the rudder blade, determined as specified in C3.10.5,

A_G : part of the rudder blade area A, in m², supported by the pintle. A_G is to be not lower than:

$$A_G = A \cdot \frac{H_C + 0{,}5 \cdot H_1}{H_C + H_1}$$

C3.10.9 Rudder couplings

C3.10.9.1 Horizontal flange couplings

.1 Horizontal flange couplings are to be connected by a number n_B of fitted bolts not fewer than 6, and the diameter of which, in mm, is not less than d_B given by the formula:

$$d_B = 0{,}62 \cdot \frac{K_{1B}}{K_{1A}} \cdot \sqrt{\frac{d_1^3}{n_B \cdot e_M}}$$

.2 The thickness of the coupling flange is to be not less than the value t_p, in mm, calculated by the following formula:

$$t_p = d_B \cdot \sqrt{\frac{K_{1P}}{K_{1B}}}$$

In any case $t_p \geq 0{,}9\ d_B$,

with d_B calculated for a number of bolts not exceeding 8.

The symbols used above have the following meaning:

d_1 : rule diameter d_T or d_{TF}, in mm, of the rudder stock, in compliance with the requirements in C3.10.6,

K_{1B}, K_{1A}, K_{1P}: coefficients depending on the high-strength steel used for bolts, rudder stock and coupling flange, respectively, whose values are defined in C3.10.3,

e_M : mean distance, in mm, of the bolt axes from the longitudinal axis through the coupling centre.

.3 The distance from the bolt axes to the external edge of the coupling flange is generally to be not less than 1,2 d_B.

.4 A suitable locking device is to be provided to prevent accidental loosening of nuts.

.5 Non-fitted bolts may be used provided that, in way of the mating plane of the coupling flanges, a key is fitted with a section of 0,25 d_Tx 0,10 d_T and keyways in both the coupling flanges, and provided that at least two of the coupling bolts are fitted bolts.

C3.10.9.2 Vertical flange couplings

.1 Vertical flange couplings are to be connected by a number n_B of fitted bolts not fewer than 8, and the diameter of which, in mm, is not less than d_B given by the formula:

$$d_B = 0,81 \cdot d_1 \cdot \sqrt{\frac{K_{1B}}{n_B \cdot K_{1A}}}$$

d_1, K_{1B} and K_{1A} being defined in C3.10.9.1.2 above.

.2 The first moment of area of the sectional area of bolts about the vertical axis through the centre of the coupling is to be not less than the value M_s, in cm^3, obtained by the formula:

$M_s = 0,43\ d_1^3\ 10^{-6}$

.3 The thickness of the coupling flange is generally to be not less than d_B.

.4 The distance of the bolt axes from the external edge of the coupling flange is generally to be not less than 1,2 d_B.

.5 A suitable locking device is to be provided to prevent the accidental loosening of nuts.

C3.10.9.3 Cone couplings

.1 Cone couplings of the shape shown in Figure C3.10.6 (with explanations of symbols in (a) and (b) below) are to be secured by a slugging/hydraulic nut, as the case may be, provided with an efficient locking device, and with the following dimensions:

(a) Cone couplings with hydraulic arrangements for assembling and disassembling the coupling:

Taper: $1/20 \leq (d_1 - d_0) / t_S \leq 1/12$

$t_S \geq 1,5 \cdot d_1$

$d_G \geq 0,65 \cdot d_1$

$t_N \geq 0,60 \cdot d_G$

$d_N \geq 1,2 \cdot d_0$ and, in any case, $d_N \geq 1,2 \cdot d_G$

A washer is to be fitted between the nut and the rudder gudgeon not less than $0,13 \cdot d_G$ in thickness, and with an outer diameter not less than $1,3 \cdot d_0$ or $1,6 \cdot d_G$, whichever is greater.

(b) Cone couplings without hydraulic arrangements for assembling and disassembling the coupling:

Taper: $1/12 \leq (d_1 - d_0) / t_S \leq 1/8$

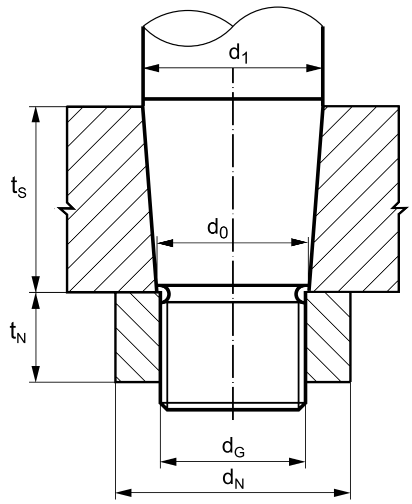
$t_S \geq 1,5 \cdot d_1$

$d_G \geq 0,65 \cdot d_1$

$t_N \geq 0,60 \cdot d_G$

$d_N \geq 1,2 \cdot d_0$ and, in any case, $d_N \geq 1,2 \cdot d_G$.

Figure C3.10.6



.2 The dimensions of the locking nut, in both (a) and (b) above, are given purely for guidance, the determination of adequate scantlings being left to the responsibility of the designer.

.3 In cone couplings of type (b) above, a key is to be fitted with a cross-section $0,025 \cdot d_T^2$ and keyways in both the tapered part and the rudder gudgeon.
In cone couplings of type (a) above, the key may be omitted. In this case, the designer is to provide the Society with shrinkage calculations supplying all data necessary for the appropriate check.

.4 All necessary instructions for hydraulic assembly and disassembly of the nut, including indications of the values of all relevant parameters, are to be available on board.

C3.10.10 Single plate rudders

.1 The mainpiece diameter is to be calculated according to C3.10.4.2.

.2 The mainpiece diameter is to be not less than the stock diameter. For spade rudders, the lower third may taper down to 0,75 times the stock diameter.

.3 The blade thickness t_B, in mm, is to be not less than:
$t_B = (1,5 \cdot s \cdot V_{AV} + 2,5) \cdot K_1^{1/2}$
where:

s : spacing of stiffening arms, in m, in no case to be more than 1 m.

.4 The thickness of the arms is to be not less than the blade thickness; the section modulus, in cm^3, of the generic cross-section is to be not less than:
$Z_A = 0,5 \cdot s \cdot C_1^2 \cdot V_{AV}^2 \cdot K_1$
where:

C_1 : horizontal distance, in m, from the aft edge of the rudder to the cross-section.

C3.11 Stabilisation means

C3.11.1 General

.1 Two different situations are to be considered for the purpose of Section 3, depending on the main function of the stabilisation system:

Situation 1: The stabilisation system is associated with the safe operation of the craft as described in 16.1.1. In that case, the system is covered by the present Rules.

Situation 2: The stabilisation system is only a motion reduction or a ride control system. In such a situation, the system is not covered by the present Rules.

C3.11.2 Classification process

.1 For situation 1, the structural design assessment process in scope of classification is given hereafter:

- the following structural parts are reviewed, on basis of design loads and safety criteria indicated by the supplier:
  - structure of the stabilisation devices: foils, trim, tabs or interceptors
  - ship structure supporting the stabilisation devices
- Only power activated items such as foils, trims, tabs or interceptors are assessed. The following parts are reviewed:
  - hydraulic system used for activation of stabilisation system
  - associated electrical devices

.2 For situation 2, the structural design assessment process in scope of classification is given hereafter:

- only the ship strength in way of stabilisation devices is assessed. Ship structure supporting these devices is reviewed, on basis of design loads and safety criteria indicated by the supplier:
- Only possible interferences between hydraulic installation and the safety of the craft are of concern. The applicable regulations depend on the location of the hydraulic power pack. The working principles are not checked. However, the hydraulic system documentation is to be submitted.

APPENDIX C3A1 SPECIAL REQUIREMENTS FOR SCANTLINGS OF HYDROFOIL HULL STRUCTURES

C3A1.1 Foreword

.1 The requirements of this Appendix apply to hydrofoils, i.e. craft which can sail both at high speed, with the hull emerging from the water surface, supported by the hydrodynamic lift of a system of connected underwater foil planes (foils), and as conventional floating craft during manoeuvring operations or in emergency conditions.

.2 Where not expressly specified, the symbols used here are those already defined in this Section

.3 This Appendix generally covers hydrofoils with a length $L \leq 35$ m and fitted with two foils, a bow and an after foil, and a screw propeller, having a maximum sailing speed on foils of 40 knots, and intended for the carriage of passengers and, if applicable, of cargo.

.4 Hydrofoils with characteristics other than those above, or which are not designed in accordance with these Rules, are to be individually considered.

C3A1.2 General

.1 The hull is to be designed with the aim of achieving safe navigation of the hydrofoil, both when emerging on foils and when floating under the different displacement, trim and stability conditions, in still water and in sea waves, which are expected in service.
The designer is to establish, by calculations and, if necessary, tank tests on models, hull shapes, weights and their distribution, the position, shape and type of foils and the thrust of the propulsion system in order to ensure suitable structural strength of the hull and safe transverse and longitudinal stability of the hydrofoil, with particular reference to transient conditions of lifting from water, alighting on water and turning.

.2 Hydrofoils covered by this Appendix generally have hard chine hulls as well as bottoms presenting a significant deadrise, bow foil within 1/3 L of the bow and after foil within 1/3 L of the stern.
Foils may be of the partially submerged Vee (narrow or wide) self-stabilizing type, or of the completely submerged, horizontal non-self-stabilizing type fitted with automatic stabilizing devices; foils may be of the fixed or lifting type.

.3 In the case of hydrofoils with general characteristics substantially different from those above or having special arrangements, the Society reserves the right to require appropriate additional calculations as well as tank tests on models, followed, if necessary, by exhaustive sea trials before entry into service.

C3A1.3 Definitions and symbols

L : Rule length, in m (see C3.1),

L_a : longitudinal distance, in m, between mid bow foil and mid after foil, measured parallel to L,

L_{ft} : overall length, in m,

B : moulded breadth, in m (see C3.1),

B_a : greatest foil breadth, in m,

D : depth, in m (see C3.1),

D_a : greatest depth, in m, measured vertically from the lower side of the more deeply submerged foil to the corresponding top of the deck beam, at the side of the main deck,

T : draught, in m (see C3.1),

T_a : greatest draught, in m, of the more deeply submerged foil, measured vertically with craft at rest,

T'_a : greatest draught, in m, of the more deeply submerged foil, measured vertically with full load craft on sailing trim on foils,

f_m : coefficient depending on the material:

- 1,00 for steel structures
- 1,45 for aluminium alloy structures,

f'_m : coefficient depending on the material:

- 1,00 for steel structures
- 2,15 for aluminium alloy structures.

C3A1.4 Documents to be submitted

.1 In addition to the plans and information listed in C3.0, the following calculations, specifications and plans (in triplicate) are to be submitted to the Society for approval, together with the following information:

(a) outer shell expansion, including stiffeners in way of foils, rudder, stern tubes and propeller shaft brackets;

(b) structure of foils and relevant hull connection stiffeners as well as quality of materials employed, with specification of intended heat treatments and non-destructive tests;

(c) calculations and diagrams relevant to the longitudinal strength of the hull;

(d) calculation of foil structure strength, including the specification of the loading conditions considered and restraints assumed.

.2 Any other documents, calculations and plans deemed useful by the Society for the purpose of classification are also to be submitted.

C3A1.5 Longitudinal strength

C3A1.5.1 General

.1 The longitudinal strength of the hull is to be calculated for at least the two conditions specified below, adopting the more severe of the resulting scantlings.

(a) Floating hydrofoil
Hydrofoil floating in still water,

(b) Emerging hydrofoil on foils

(1) Emerging hydrofoil supported by its foils and considered on its sailing trim in still water without any additional motion, taking account, in the acting forces diagram, of the vertical components (lift) of hydrodynamic forces on the foils,

(2) Hydrofoil in the conditions specified in (1) but in sea waves, taking account of pitching, rolling and heaving motions, and of consequent acceleration and forces of inertia.

.2 The calculation of the hull cross-section modulus is to include the shells and associated stiffeners which, due to their longitudinal continuity, effectively contribute to longitudinal strength.

.3 As regards the acceleration values and wave characteristics to be assumed in the calculations, they are to include the severest sea conditions expected for the hydrofoil in service, according to the provisions in C3.3.

C3A1.5.2 Allowable stresses
Rule values of midship section modulus
Section modulus calculation

.1 The maximum allowable bending stresses σ at deck and bottom and shear stress τ at sides are generally not to exceed the values given in Table C3A1.1.

Table C3A1.1 - Maximum allowable stresses

Hydrofoil under conditions specified in:	σ at bottom (N/mm^2)	σ at deck (N/mm^2)	τ at sides (N/mm^2)
C3A1.5.1.1 (a) C3A1.5.1.1 (b) (1)	$45 / (K \cdot f'_m)$	$45 / (K \cdot f'_m)$	$40 / (K \cdot f'_m)$
C3A1.5.1.1 (b) (2)	$85 / (K \cdot f'_m)$	$85 / (K \cdot f'_m)$	$70 / (K \cdot f'_m)$

In general, maximum σ stresses occur at about 0,5 L_a, and maximum τ stresses in way of the bow foil.

.2 Attention is to be paid to scantling distribution for structures contributing to the longitudinal strength of the different hull zones, so as to avoid structural discontinuities, which would give rise to peaks in the diagrams of moments of inertia and of section moduli, with consequent abrupt variations in stresses. The structures constituting the hull are also to comply with the requirements for local hull strength, set out below.

.3 For hydrofoils with length $L \leq 35$m, the Rule midship section moduli at bottom Z_b and at deck Z_d, in cm^3, are given by the formula:

$$Z_b = Z_d = (6{,}3 \cdot L_a - 60) \cdot 10^3$$

.4 The section modulus is, in any case, to be such as to comply with the allowable stresses given in Table C3A1.1.

.5 The section moduli of the cross-sections W_b at bottom and W_d at deck are conventionally obtained by dividing the moment of inertia of the cross-section under consideration by the vertical distance between the horizontal neutral axis and the base line, and by the distance between this axis and the top of the deck beam, at the side, of the strength deck, respectively.

.6 To calculate the moment of inertia of the above cross-sections, the net cross-section of continuous elements contributing to longitudinal strength, and therefore reduced for openings, manholes and other holes which are not completely compensated, is to be taken into account; in the case of riveted structures, in contrast, rivet holes in shells and bars are not required to be deducted from the strength cross-section.

C3A1.6 Local strength

C3A1.6.1 General

.1 Hull structure dimensions are to comply with the relevant requirements of this Section considering the craft as floating, and neglecting dynamic effects due to accelerations, impact and wave loads.

.2 The structural arrangements to be adopted in these craft are specified below, together with minimum scantlings to be satisfied in any case.

.3 The scantlings of the outer shell, decks and relevant stiffeners contributing to local hull strength are to comply with the requirements of this Appendix. They are to be increased, if necessary, depending on the longitudinal strength as required in C3A1.5.

.4 The spacing of secondary stiffeners is, in general, not to exceed 300 mm, at least in way of foils, the machinery space and forward of the bow foil.

.5 Primary transverse frames, consisting of floors, side transverses and deck transverses, are to be fitted both where the structure of ordinary stiffeners is of the transverse type and where it is of the longitudinal type.

In the first case, the frames give support to bottom girders, side stringers and deck girders, which in turn, support the ordinary shell stiffeners, i.e., floors, webs and beams, respectively; in the second case they support the longitudinals directly.

Structures different from the above are to be individually considered in each case.

C3A1.6.2 Bottom shell plating

.1 The thickness t_b, in mm, of the bottom shell, in the area from the bow foil to the stern, is in no case to be less than:

$3 \cdot f_m \cdot \sqrt{K}$

.2 The thickness t_k of the keel strake is to be, in general, at least equal to 1,2 times the thickness adopted for the bottom and in no case less than 4 mm.

.3 The bottom thickness t_{bf} in the area forward of the bow foil is to be at least 1,2 t_b, provided that the take-off speed of the hydrofoil is not greater than approximately 20 knots and the maximum sailing speed on foils is not greater than approximately 40 knots. For greater speeds, the thickness t_{bf} is to be individually considered in each case, depending on the results of calculations and, if necessary, experiments to be performed by the designer, to assess the hydrodynamic force on the shell due to water in the takeoff stage and the wave action on the shell in the sailing condition on foils at maximum service speed.

.4 Takeoff speed is intended as the minimum speed necessary to lift the hull on foils in still water.

.5 In way of foils, the bottom thickness is to be increased appropriately and in no case is it to be less than, in mm:

$5 \cdot f_m \cdot \sqrt{K}$

C3A1.6.3 Side shell plating

.1 The thickness t_s, in mm, of the side shell is to be not less than:

$3 \cdot f_m \cdot \sqrt{K}$

.2 The thickness t_s, in mm, from 0,1 L aft the bow foil to 0,1 L forward of such foil is to be not less than:

$5 \cdot f_m \cdot \sqrt{K}$

.3 The thickness t_{sh} of the sheerstrake, for the whole hull length, is to be at least equal to that of the corresponding side.

.4 Where, on the sheerstrake, side ports or side scuttles or other large openings are fitted, the thickness is to be increased such as to compensate these openings.

.5 The thickness t_{sh} is also to be increased in way of end bulkheads of any castles, or, in any case, in way of steps in the strength deck.

.6 In way of foils, the side thickness is to be suitably increased and is, in no case, to be less than, in mm:

$5 \cdot f_m \cdot \sqrt{K}$

C3A1.6.4 Deck and flat plating

.1 The thickness t_d, in mm, of the deck plating is to be not less than:

$3 \cdot f_m \cdot \sqrt{K}$

.2 The thickness t_{st} of the stringer plate of the strength deck is to be at least equal to that adopted for the sheerstrake or for the remaining deck plating, whichever is greater.

.3 The thickness, in mm, of decks below the strength deck, generally consisting of flats, is to be not less than:

- if the ’tween deck is intended for accommodation or similar:

  $2 \cdot f_m \cdot \sqrt{K}$

- if the deck forms a tank bottom or tank top:

  $2,5 \cdot f_m \cdot \sqrt{K}$

C3A1.6.5 Bottom structure

.1 For the bottom, longitudinal framing extending through the whole length is generally required, except for extreme stern and extreme bow areas, where the framing is generally transverse.

.2 In way of the bow foil and after foil, ordinary floors of suitable scantlings, to be individually considered in each case, are to be fitted. In way of the fore foil, the floor spacing is generally to be one half the frame spacing.

.3 In the machinery space, at least two girders on each side are to be fitted, at least one of which is to be fitted in way of one of the engine seating girders.

.4 In the area forward of the bow foil, at least one girder on each side is to be fitted. The height, in general, is to be at least equal to that of the bottom transverses, and preferably located in the same plane as a deck girder, if fitted. The girder thickness is to be not less than, in mm:

$3 \cdot f_m \cdot \sqrt{K}$

.5 At the bow foil and after foil, the number and scantlings of the floors are to be individually considered in each case, depending on the type of structure proposed. In any case, two floors belonging to complete transverse rings (side and deck transverses) are to be fitted, and located one forward and the other aft of the hull penetrations of the bow foil bearing arm.

Intermediate floors in this area are to be positioned, between those usually fitted at each frame spacing, and all such bottom transverses are to have a section modulus of at least 1,25 times that required for the area aft of the engine room.

.6 In the area forward of the bow foil, the floors are generally to have a section modulus of at least 1,8 times that required for the area aft of the engine room and a spacing not greater than four web spacings. In the usual case of bottoms presenting forward a deadrise angle greater than approximately 25°, the floors are to have a horizontal upper edge and a height of at least $0,2 \cdot D$ in the centreline.

.7 In the case the takeoff and sailing speed of the hydrofoil are greater than those specified in C3A1.6.2.3, the scantlings of the forward floors are to be individually considered in each case.

C3A1.6.6 Side structure

.1 This structure may be of the transverse type, i.e. consisting of ordinary webs, supported by stringers (or flats) and side transverses belonging to the primary transverse rings, or, for hydrofoils with length L greater than approximately 20 m, of the longitudinal type, i.e. consisting of longitudinals supported by side transverses belonging to these rings.

.2 Continuity of the longitudinals is to be ensured, considering their contribution to the longitudinal strength of the hull.

.3 Side transverses are to be fitted for the purpose of supporting the longitudinals, and side stringers (or flats), to be individually considered in each case, are to be fitted in way of and forward of the machinery space.

.4 In way of foils, scantlings are to be individually considered in each case.

.5 The section modulus of the side transverses forward of the bow foil is to be individually considered in each case: in any event, two side transverses are to be fitted in way of the floors located forward and aft of the hull penetrations of the bow foil bearing arm, for which in general:

$h / S \geq 0,25$

where h is the web height and S is the conventional span of the side transverse.

.6 In way of the bow and after foils and in the case of side transverses supporting deck bracket-transverses, the provisions of C3A1.6.5.5 to C3A1.6.5.7 apply.

.7 In the area forward of the bow foil, the side transverses are preferably to have an h/S ratio of at least 0,2. As regards the case of high hydrofoil speeds, the provisions of C3A1.6.5.5 to C3A1.6.5.7 are to be complied with.

C3A1.6.7 Deck structure

.1 Strength deck stiffeners may be of the transverse type where constituted by beams supported by girders which are in turn supported by deck transverses belonging to the primary transverse rings, which may or may not be associated with pillars; such stiffeners are of the longitudinal type where they consist of longitudinals supported by the deck transverses.

The latter structure is recommended where L > 20 m.

.2 Stiffeners of decks below the strength deck and stiffeners of flats intended for passenger accommodation or forming the top of the machinery space are to have a section modulus not less than, in cm^3:

$4 \cdot f_m \cdot K$

.3 Where the deck or flat forms the top of a tank for liquids, the provisions of C3.7 or C3.8 are to be complied with.

.4 The scantlings of stiffeners fitted on account of special structural requirements, for example in way of foils, are to be individually considered in each case.

.5 Deck transverses are to be fitted in way of side transverses, so as to constitute members of complete transverse rings.

.6 They may instead be of the bracket type in the general case of hydrofoils for which L is less than approximately 15 m, and fitted with long deck openings; in such case, deck transverses, continuous from side to side, are to be fitted at least immediately aft and forward of the machinery space and forward of the bow foil. An intermediate flat, between bottom and deck, is to be fitted at least in the area aft of the machinery space.

.7 The scantlings of deck transverses in way of foils and the scantlings of panting deck transverses fitted in the fore peak, at approximately mid-depth between bottom and deck, are to be individually considered in each case.

.8 Owing to their span (roughly 0,3 to 0,5 m), deck transverses of the bracket type are generally composed of wide brackets connected to the web frame and the side stringer of the deck opening. The scantlings of such deck transverses are to be individually considered in each case.

C3A1.6.8 Watertight bulkheads

.1 For the hydrofoils considered in this Appendix, four watertight subdivision bulkheads are generally required to be fitted as follows:

- watertight collision bulkhead, located not less than 0,05 · L from the forward perpendicular and, in general, not more than 0,08 · L from the same perpendicular,
- fore and after watertight bulkhead of the machinery space,
- after watertight bulkhead, located, in general, about 0,05 · L from the aft perpendicular, but in no case more than 0,08 · L from the same perpendicular.

.2 In the case of hydrofoils intended for the carriage of passengers, the watertight subdivision bulkheads are also to satisfy the relevant requirements of Section 2.

C3A1.7 Foils

C3A1.7.1 General

.1 The type, shape and location of foils is to be determined by the designer based upon the general design provisions specified in C3A1.2, taking account of the fact that the essential function of foils is to support the hull, emerging at a sufficient height above the water surface so as to allow sailing even in waves, while ensuring the stability of the hydrofoil at the same time.

After determining these characteristics, the strength calculations for foils and relevant hull supporting connections are to be performed.

.2 In the case of hydrofoils with foil types other than those considered below, the Society reserves the right, after examining the calculations, to require special checks and tests, as specified in C3A1.2.

.3 The foil profile and shape are to comply with the provisions of the present article and, even when sailing in waves, to avoid cavitation phenomena dangerous for the stability of the hydrofoil.

.4 Calculation of the forces acting on the hydrofoil may be performed by considering the craft in sailing condition on foils in still water.

.5 The following acting forces are assumed:

- hydrofoil weight, at least in the two conditions of full load and without passengers,
- hydrodynamic resistance of the bow foil and after foil and associated lift,
- thrust of propellers.

.6 For the equilibrium, the algebraic sum of the acting forces and relevant moments with respect to the hydrofoil's centre of gravity is obviously to be equal to zero.

.7 In addition, the hydrofoil is to be considered during its turning manoeuvres. This means that water thrust on the rudder, whose action gives rise to variations in the hydrodynamic resistance and in the lift distribution on foils, as well as the forces generated by balancing flaps, are to be added to the forces above.

.8 Moreover, taking into account the most severe dynamic conditions expected for the hydrofoil in service, the above forces and, in addition, forces of inertia generated by rolling, pitching and heaving, including those during takeoff from the water and alighting on the water, are to be considered in the designer's calculations.

The characteristics of such motions, i.e. oscillation amplitude and period, and the consequent acceleration from which the forces of inertia originate, are to be considered individually by the Society in each case, based upon the experience already gained, if the hydrofoil under consideration is similar to previous ones which have given good results in service, or, otherwise, upon the results of exhaustive tank tests on models, as well as sea trials on the hydrofoil itself, before entry into service.

C3A1.7.2 Foil strength calculations

.1 In the case of V-type or W-type foils, each is usually connected, by quasi-vertical or vertical arms, to a horizontal member, fitted transversely with respect to the hull, and supported by special hull structures.

The foils and arms may therefore in such cases be considered, overall, as a system consisting of beams and joints supported by the hull structures.

.2 The forces acting on the foils consist of hydrodynamic resistance and lift, as well as the reactions of the structures mentioned above which balance such forces.

.3 Strength calculations are therefore to take account of the nature of the restraints from the hull on the reticular system and acting forces, in the loading conditions specified above, as well as of the mechanical properties of the materials employed, which are generally high-strength welding steels.

.4 In particular, diagrams of bending moments and axial and shear forces acting on the foils are to be plotted and the stresses deriving from them are to be calculated.

C3A1.7.3 Foil construction

.1 The foil joints are generally constituted of forged or cast steel, or are obtained from plate, while the beams are to be made of fabricated plating, and connections are to be welded.

.2 Since, due to the shape and dimensions of the foil profile, the foils themselves are not internally accessible, and therefore back-welding of all welded joints is not possible, the constructional plan is to specify special types of edge preparation, welding sequence and performance, to ensure the absence of defects and minimise internal stresses due to shrinkage at welds.

In particular, the number of slot-welded joints on plating is to be minimised.

.3 Materials are to be tested by the Society, and electrodes and welding processes are to be recognised as suitable in accordance with the Rules.

.4 Butt-joints are to be subjected to radiographic examination and, if inaccessible from one side, to magnetic particle or dye-penetrant examination.

.5 Depending on the quality of the material adopted and on welding processes, the Society reserves the right to require thermal stress-relieving in the furnace after welding.

APPENDIX C3A2 SPECIAL REQUIREMENTS FOR SCANTLINGS OF AIR-CUSHION VEHICLE HULL STRUCTURES

C3A2.1 Foreword

.1 The requirements of this Appendix apply to "flexible skirt hovercraft", i.e. air-cushion vehicles with a downwardly-extending flexible structure used to contain or divide the air cushion.

This type of air-cushion vehicle is amphibious.

.2 Unless otherwise specified, the symbols used here are those already defined in C3.1.

C3A2.2 General

C3A2.2.1 Definitions and symbols

.1 Weight and masses

Light weight: the weight of the craft without cargo, fuel, lubricating oil and water in tanks, without consumable stores, passengers, crews or personal effects.

Light mass: the mass of the craft under the same conditions.

Maximum operational weight: the overall weight at which the craft is permitted to operate under normal conditions.

Maximum operational mass: the mass of the craft under the same conditions.

.2 Dimensions

The main dimensions of an hovercraft are determined for the following situations:

- stationary,
- under maximum load,
- afloat.

L : length, in m, equal to the length of the rigid hull measured on the waterline at draught T, and not to be less than 95% of the air cushion longitudinal connection,

B : breadth, in m, equal to the broadest part of the rigid hull measured on the waterline at draught T. B is not to be less than 95% of the air cushion transverse connection,

T : draught, in m, (see C3.1),

D : depth, in m, (see C3.1).

The structure is divided into several substructures depending on the type of supported loads (overall forces, local forces, concentrated loads, etc.) and design methods.

C3A2.2.2 Main structure

.1 The main structure comprises all structural members which contribute to overall strength, i.e. members which support the overall longitudinal and transverse bending forces as well as overall torsional forces resulting from asymmetrical loads (e.g. craft in flying or floating situation on diagonal wave).

.2 Besides its resistance to overall forces, this structure is to be capable of supporting certain local forces exerted by local loads, or loads distributed in areas of limited dimensions.

.3 It generally includes:

- platform above the air-cushion with its primary and secondary, transverse, longitudinal and diagonal stiffeners,
- watertight compartments giving buoyancy,
- decks, floors, bulkheads as well as side walls, superstructure and deckhouse shell plating rigidly connected to the platform and for buoyancy compartments.

C3A2.2.3 Secondary structures

.1 The secondary structure completes the main structure by contributing to the safety and the protection of the craft against bad weather and wave impacts.

They are designed to support only local stresses.

.2 These secondary structures comprise all members not rigidly connected to the main structure such as certain platforms, internal or external bulkheads and walls or access doors.

C3A2.2.4 Additional structures

.1 Additional structures cover all arrangements attached to the main structure and taking a prominent part in the craft's operation and safety.

They generally create concentrated stresses in the main structure, and possibly, secondary structures.

.2 These structures mainly comprise:

- skirt connections to the structure,
- seatings and foundations for propelling unit, ventilating plants and associated auxiliaries,
- supporting brackets for steering and trim control apparatus, which can be aerial or submerged,
- onshore or offshore anchoring and mooring as well as towing arrangements,
- landing and ground support arrangements for amphibious air-cushion vehicles,
- wheelhouse, if not integrated in the structure.

C3A2.3 Documents to be submitted

C3A2.3.1 Documents submitted for information

.1 The designer is to provide a general arrangement drawing showing the general structural layout, intended use of different spaces and tanks, and location of propelling, lifting and operating installations.

.2 In addition to the information stipulated in C3.0, weight balances are to be provided for the following cases:

- light weight air-cushion vehicle,
- air-cushion vehicle at operating full load.

.3 In addition, for air-cushion vehicles carrying cargo, weight balances are to be submitted for all intermediate loading cases considered by the designer and indicated in the operating manual.

.4 Each loading case is to be indicated with the relevant position of the main masses.

C3A2.3.2 Justification of scantlings

.1 Scantlings are to be justified by calculation notes indicating relevant loads, calculation methods and computation results.

.2 When computer calculations are carried out, the software is to be indicated, and indications are to be communicated with regard to structure description, boundary conditions and the way loads are introduced.
The results of these calculations are to be submitted to the Society.

.3 Justification can be based on recognised experimental results: recorded for similar structures and corrected, if required, to allow for minor variations of certain parameters, the effects of which have been suitably evaluated.
In that case, tested structures, test conditions, methods and results, as well as variations in the parameters and their effects on the structure in question, are to be clearly defined.

C3A2.3.3 Drawings for approval

.1 In addition to the plans listed in Table C3.0.1, the following drawings are to be submitted to the Society for approval:

- bottoms and walls limiting air cushion,
- side shell and side walls,
- air-cushion lining and subdivision arrangements,
- seatings, foundations, supporting brackets and air pipes of lifting plant,
- skegs, rudders and control systems,
- landing, ground supporting and mooring arrangements, if any, including handling equipment,
- details of all types of assembling arrangements and scantlings of connections,
- hoisting and handling equipment, if any, used on board.

.2 This is not an exhaustive list; other drawings may be required.

C3A2.4 Scantlings criteria

C3A2.4.1 General

.1 Each constituent part of the structure is to be designed to withstand a combination of loads which constitute the scantling criteria, without sustaining damage or distortions likely to affect the good working order of the air-cushion vehicle.

.2 These criteria are determined on the basis of the craft's characteristics, its performances, and operational restrictions dictated by the intended type of service.

C3A2.4.2 Types of stresses

.1 General stresses

General stresses result from the overall forces applied to the structure in order to maintain the air-cushion vehicle in balance in a given situation.
These loads are, on the one hand, loads due to masses (forces of inertia) and, on the other hand, external loads created by environmental conditions, as defined in C3A2.4.3.
General stresses induce distortions and overall stresses in the main structure.

.2 Local stresses

Local stresses are created by masses which are directly supported by internal forces and external loads applied locally.
They modify the stress values resulting from general stresses for a specific component of the main structure.
They are used as a basis for the scantlings of the components of secondary and additional structures.

C3A2.4.3 Calculation of external loads

.1 Air-cushion vehicle flying on waves

(a) An air-cushion vehicle operating on rough seas, passing over a wave, is subjected to an overall force of impact, due to a combination of pressure variation and impact of green seas, whose basic value can be expressed by the formula:

$F = C \cdot M \cdot g$

where:

M : mass of the air-cushion vehicle, in kg,

g : acceleration of gravity, equal to 9,81 m/s²,

$$C = \frac{K_x \cdot K_j \cdot V_v \cdot V}{M^{1/3} \cdot (1 + r_G^{\,2})^{2/3}}$$

with:

K_x : coefficient depending on position x of spot of the impact and determined according to Figure C3A2.1,

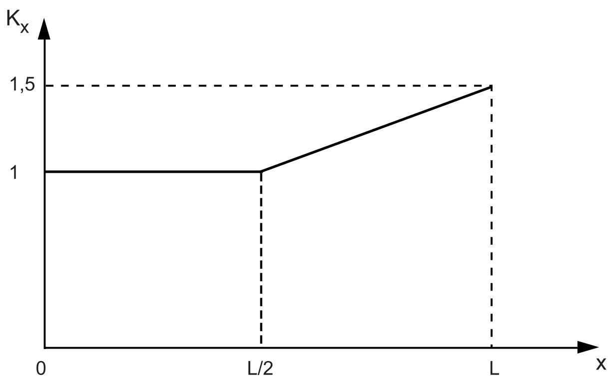
K_j : reduction factor depending on the type of cushion and defined in (b),

V_v : vertical speed of impact, in m/s, as defined in (c),

V : maximum speed of air-cushion vehicle, in m/s, for the wave height H considered. The relation between V and H is to be provided by the designer as a function of the vertical acceleration in the centre of gravity (see also C3.3.1 and C3.3.4),

r_G : distance from spot of impact to centre of gravity, divided by the radius of gyration.

Figure C3A2.1 Coefficient K_x



(b) In the absence of more accurate information, K_j is considered to be 0,7 for flexible skirt air-cushion vehicles. For side-wall craft, K_j can be determined only by model tests and is to be confirmed by prototype tests.

(c) The speed V_v is given by the formula:

$$V_v = 0,6 + H \cdot \sqrt{\frac{\pi \cdot g}{2 \cdot A}}$$

where:

H : wave height, in m,

A : wave length, in m.

Values of A and H are defined in C3A2.4.3.2 below.

(d) The rigid structure can be subjected to direct wave impact under the following circumstances:

- craft in flying situation under worst intended conditions,
- plough-in of cushion system,
- craft afloat, at rest or not.

The basic value of the maximum impact pressure, referred to as local pressure (governing scantlings of a secondary stiffener or shell on a frame space), in kN/m², can be evaluated by the formula:

$p_{loc} = 2,4 \cdot K'_x \cdot K_f \cdot V_v \cdot V$

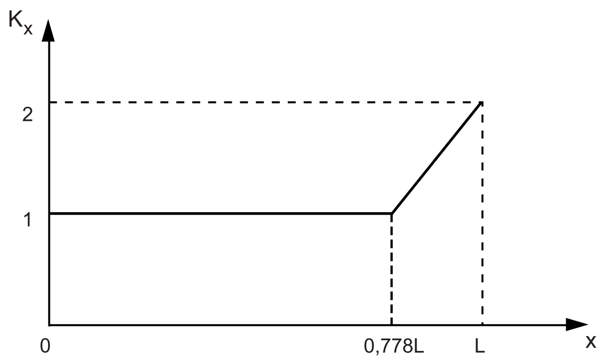
where:

K'_x : coefficient depending on position x of spot of the impact and determined according to Figure C3A2.2,

K_f : coefficient depending on the shape of bottoms, defined in (f),

V_v and V: values defined in (a) above.

Figure C3A2.2 Coefficient K_x



(e) The average pressure, in N/m², corresponding to the local pressure (distributed pressure determining scantlings of main stiffeners) is given by the formula:

$p_{moy} = 1,06 \cdot K'_x \cdot K_f \cdot V_v \cdot V$

(f) K_f is determined by means of model tests and has to be confirmed by prototype tests. In the absence of the necessary data, K_f is considered to be equal to 1.

.2 Air-cushion vehicles afloat

(a) The wave considered for scantling calculations of flexible skirt craft afloat is a sinusoidal wave of height H and length A, in metres, and confirming the following equations:

- for A ≤ 41,50 m:
  H = A / 10
- for A > 41,50 m:

$$H = 6,51 - 0,57 \cdot \left(\frac{300 - A^{3/2}}{100}\right)$$

(b) The value H is defined by the designer on the basis of the limit operating conditions indicated in the Enclosure of the Class Certificate and on the midship section drawing (see C3.3.1 and C3.3.4).

The worst conditions are generally encountered when A is approximately equal to:

- L for head wave,
- B for beam wave.

.3 Wind effects

(a) Two cases are to be considered, depending on whether the craft is at rest or in operation.

(b) When the craft is moored to the ground or afloat, each component of the entire structure has to be able to withstand the pressure and/or vacuum forces produced by a steady wind, blowing horizontally, depending on the worst direction for each component considered, at a speed of 70 knots.

More severe conditions may be required for air-cushion craft intended to operate in particularly exposed areas.

Less severe conditions can be accepted for small or medium-size craft which can easily be wind-screened.

(c) During navigation under the worst intended conditions, it is to be checked that each constituent part of the air-cushion vehicle is capable of withstanding the pressure and vacuum forces produced by gusts increasing the true wind speed by at least 30% of its nominal value (mean value observed during 10 minutes).

This horizontal component is to obtain the most unfavourable direction for the particular constituent part.

These forces are, if applicable, to be considered together with the forces in C3A2.4.3.1 and C3A2.4.3.2 above.

(d) If no other indications are available, the dynamic pressures, exerted by the wind on a vertical element, can be estimated by means of the following formulae, in kN/m², depending on the altitude above sea level of the element and wind speed v_w, in knots:

- between 0 and 5 m above the sea level:

  $q_1 = 1{,}50 \cdot 10^{-3} \cdot v_w^2$

- at 10 m or more:

  $q_2 = 0{,}16 \cdot 10^{-3} \cdot v_w^2$

Between 5 m and 10 m, there is a linear variation of q between the two preceding values.

Note: These pressure variations depending on altitude take account of the degree of seawater saturation of the sea-air. Other corrections are to be made to these values to account for the type of forces (pressure or vacuum), the lines of the air-cushion vehicle, etc. These corrections are to be justified by the designer.

.4 Other meteorological conditions

(a) Besides the loads mentioned in C3A2.4.3.1 to C3A2.4.3.3, and according to the navigation area, loads resulting from the accumulation of snow and ice on certain parts such as roofs, side walls, steering and propelling installations, are to be accounted for, if applicable.

(b) Generally, for air-cushion vehicles built in series, the most severe conditions are to be considered depending on various intended navigation areas.

C3A2.4.4 Calculation of internal loads

.1 Loads on flooring (decks)

(a) Normal static loads on various floorings are to be indicated in the builder's technical specifications.

(b) Scantlings of floorings in compartments intended for carriage of passengers are calculated on the basis of 0,75 kN per passenger.

However, this value may be reduced to 0,60 kN if it can be justified.

(c) For guidance, the following values can be adopted for flooring scantlings, depending on use:

- flooring of passenger compartment: even load of 2,50 kN/m² (or loads indicated in (b) with no more than 4 passengers per square metre),
- flooring of luggage compartments: density 150 kg/m³ (load evenly distributed),
- flooring supporting miscellaneous cargoes: density 700 kg/m³ (load evenly distributed),
- flooring supporting cars: 3,0 kN per wheel (load locally distributed on the surface on tyre tracks),
- flooring supporting commercial vehicles: 65,0 kN per wheel.

These preceding loads are nominal static loads.

(d) When the air-cushion vehicle is afloat on waves, and a flooring is exposed to green seas, its strength is also to be checked with regard to hydrostatic pressure, according to the parameters defined in C3A2.4.3.2.

.2 Loads due to propelling and steering installations

(a) These loads are applied to the structure through the connections of foundations, seatings, gantries, etc. supporting the propelling engine, the lifting installation, their auxiliaries as well as steering gear such as rudders and skegs.

(b) For propelling and lifting plants, loads are calculated on the basis of the most critical situations to be expected (e.g. breakdowns, sudden changes in engine speed, reverse propeller pitch).

(c) For steering arrangements, loads are either contractual loads (power rudders) or loads actually encountered. The latter can be deduced from calculations or tests. The basic contractual loads applied by the pilot on the controls are as follows:

- 0,46 kN on a control stick or control wheel ahead or reverse gear,
- 0,28 kN on a control stick - laterally,
- 0,185 kN on a control wheel - tangential action,
- 0,60 kN on pedals or levers.

(d) See also C3A2.7.8.

.3 Loads due to tests

(a) Tests are to be carried out to check the tightness of integrated buoyancy compartments, fuel tanks and various liquid tanks.

Scantlings are to be such that no permanent distortion will remain after tests at the pressures indicated in (b) and (c) below (verification at yield stress).

(b) Buoyancy compartments are generally tested with compressed air at a pressure of not more than 0,2 bar (pressure is controlled by means of a U-shape standpipe), after application of sealing material, if required.

(c) Fuel tanks and liquid tanks are tested with water at a pressure equal to a stand-pipe of 2,40 m above the uppermost point of the compartment.

Fuel and liquid tanks are also to be able, without breaking, to withstand the forces produced by the movement of liquids in case of collision as mentioned in C3A2.7.8.

C3A2.5 Load factors

C3A2.5.1 General

.1 Load factors are increasing coefficients used to determine, on the basis of nominal static loads, the dynamic forces supported by the structure, referred to as basic loads.

.2 These coefficients depend on actual movements of air-cushion vehicle, speed, acceleration, turning, etc. and on movements imposed on the craft due to external factors such as wave, wave impact or gusts of wind.

.3 Load factors are estimated on the basis of various accelerations for which reference values are specified in C3A2.5.2 and C3A2.5.3 below.

C3A2.5.2 Accelerations under normal service conditions

.1 For the calculation of local forces, including those resulting from liquid loads, acceleration can be at least any of the values between the following limits:

- from 0,7 g upwards to 0,8 g downwards in addition with gravity,
- from 0,5 g afterwards to 1,0 g forwards,
- from 0,5 g on one side to 0,5 g on the other side.

.2 The preceding values apply to air-cushion vehicles for “open sea” or “restricted open sea” service.

.3 Reductions may be allowed for craft for “moderate environment” or “smooth sea” service (see C3.3.1).

C3A2.5.3 Accelerations in the event of collision

.1 The relevant authorities require certain installations and connections to be capable of withstanding the forces resulting from such more severe accelerations than the preceding in C3A2.5.2.

.2 The values to be taken into account are:

- from 3 g upwards to 4 g downwards,
- from 0 g to 6 g forwards,
- from 0 g to 3 g afterwards,
- from 0 g to 3 g sideways.

C3A2.5.4 Application procedure

.1 For certain calculations, a combination of accelerations in several directions needs to be considered, but the final acceleration value is not to exceed:

- 1 g for horizontal accelerations in normal service,
- 6 g for accelerations in the event of collision.

.2 The directions mentioned in C3A2.5.2, C3A2.5.3 and C3A2.5.4 refer to inertia forces which tend to displace each mass in relation to the entire air-cushion vehicle.

.3 The vertical and transverse accelerations indicated in C3A2.5.2 can, if necessary, be modified in agreement with the Society, at the designer’s request, provided that a complete file is submitted with sufficient experimental justifications.
These values can also vary depending for which part the scantlings are to be calculated and its location in relation to the craft’s centre of gravity.

.4 In certain specific cases, the load factor can be considered as equal to 1, for example when the forces applied are constant or vary slowly (jacking operations, traversing operations at low speed, etc.).

.5 The basic loads due to dynamic forces are loads which easily occur in service under the worst intended conditions.

They are deducted from nominal static loads by means of the appropriate load factors.

C3A2.6 Strength limits and safety coefficients

C3A2.6.1 General

.1 Strength limits

(a) Strength limits are increasing factors applied to basic loads, to account for exceptional overloads incurred by the structure under critical foreseen conditions.

(b) Strength limits also help to provide for part of the doubt inherent in calculation theories or methods.

(c) Basic loads multiplied by strength limits give the maximum loads that the structure has to withstand without incurring permanent distortions.

.2 Safety coefficients

(a) Safety coefficients take into account:

- uncertainties inherent in certain assumptions,
- more or less accurate calculation methods,
- flaws and allowances accepted for materials and assembling procedures,
- residual manufacturing stresses,
- variations, in time, in the characteristics of certain materials,
- strength reductions due to corrosion or scoring caused by the surrounding environment.

(b) Maximum loads multiplied by relevant safety coefficients define the most extreme loads that the structure is to be capable of withstanding without breaking or collapsing, while incurring possible permanent distortions.

C3A2.6.2 Summary table

.1 Table C3A2.1 summarises the methods for load calculations.

Table C3A2.1 - Load calculation methods

1 - Nominal static load x Load factor	= basic load
2 - Basic load x Strength limit	= maximum load
3 - Maximum load x Safety coefficient	= extreme load

.2 The basic load corresponds to the worst intended conditions. The maximum load corresponds to the critical design conditions.

C3A2.6.3 Numerical values

.1 Values of strength limits and safety coefficients are determined by the designer in agreement with the Society.

.2 Strength limits may vary depending on the importance of the part for which scantlings are to be calculated, and the type of loads applied.

In general, strength limits may not exceed 1,5.

.3 In general, the safety coefficients are considered as equal to 1,5.

However, the accelerations indicated in C3A2.5.3, in the event of collisions, are the most extreme values, so that the resulting loads are also extreme loads (safety coefficient equal to 1).

Higher values may, nevertheless, be required (recommended value: 2) for parts subject to extremely concentrated forces such as hoisting, trucking, towing and anchoring points.

C3A2.7 Cases of scantlings

C3A2.7.1 General

.1 Loads to be applied to the structure are determined by considering the air-cushion vehicle in the situations outlined in C3A2.7.1.2 and C3A2.7.1.3.

.2 Situations corresponding to normal service under specific limit conditions determine general structure scantlings.

.3 Exceptional situations are taken into account only to determine scantlings of parts which are directly involved, and their connections to the structures.

.4 Depending on the scantling case, the resulting loads are either basic loads or maximum loads (extreme loads in collision situations).

C3A2.7.2 Flying situation

.1 The different flying situations are:

- on still water,
- on head waves,
- on abeam waves,
- on diagonal waves.

.2 The transient stages, involving a changeover from one of the preceding elementary situations to another, are also to be considered.
The flying situation on still water is, in particular, to make it possible to determine the forces generated by operations under the most severe conditions, as a result of:

- speed,
- accelerations or decelerations,
- lifting height,
- turning and yawing characteristics,
- trim and heeling variations.

.3 The envelope of maximum forces is obtained by considering all loading cases defined on the operating manual, as well as maximum speeds authorised, depending on various wave heights up to the maximum design height.

.4 The different cases above determine:

- general forces of overall longitudinal and transverse bending, as well as overall tension and corresponding shear forces,
- local forces produced by wave impacts, gusts of wind, propelling machinery, skirt connections, etc.

C3A2.7.3 Floating situation

.1 The different floating situations to be considered are:

- on still water,
- on head waves,
- on abeam waves,
- on diagonal waves (line of wave crests almost parallel to one of the craft's diagonals).

.2 All loading cases defined in the operating manual are to be considered, as for flying situations.

.3 The speed to be considered is either the maximum self-propelling speed, if this possibility exists, or else the maximum towing speed.

.4 The above cases determine both general and corresponding local forces.

C3A2.7.4 Landing

.1 This refers to amphibious air-cushion vehicles normally parking on land.

.2 The worst landing case is defined by the following parameters:

- maximum lifting height,
- highest possible descending speed,
- worst mass, trim, heeling and horizontal speed conditions (e.g. asymmetrical landing supports, gusts of wind).

.3 This case determines local forces applied to landing-gear connecting points.
It can also determine certain general forces, in particular for torsion resulting from asymmetrical landing supports.

C3A2.7.5 Hoisting

.1 This case affects the scantlings of hoisting points and their connections to the structure (distribution of concentrated forces).

.2 It also to be checked that this case does not generate general bending or torsional forces (asymmetrical hoisting) leading to stresses that exceed allowable values.

.3 The maximum authorized mass for hoisting is to be determined by the designer and indicated in the maintenance manual.

C3A2.7.6 Trucking

.1 This case determines the scantlings of the trucking contact pieces and their attachments to the structure (local forces).

.2 The verification required in C3A2.7.5 is also to be carried out.

.3 The maximum authorized mass for trucking is to be determined by the designer and indicated in the maintenance manual.

C3A2.7.7 Anchoring - Mooring - Towage

.1 These situations determine the concentrated forces applied to points of ground or quay anchoring and mooring, together with towage.

.2 They can also affect the scantlings of some parts of the structure subjected to aerodynamic forces, and loads, if any, due to accumulated snow and/or ice (see C3A2.4.3.3 and C3A2.4.3.4).

.3 The maximum authorized forces to be applied at the preceding points are equal to the respective breaking loads of anchor, mooring and towing cable lines.

C3A2.7.8 Collisions

.1 It is to be checked that certain parts of the structure, equipment and components are capable of withstanding the exceptional dynamic forces resulting from a collision.

.2 These verifications comprise, without being confined, to:

- scantlings of engine foundations, seatings and gantries of propelling installation,
- structure at connecting points of these parts,

- cargo and luggage lashing points,
- vehicle wedging and securing points,
- securing arrangements of passenger seats,
- fuel and lube oil tanks, integrated or not (motions of liquids).

.3 The forces are deduced from the accelerations mentioned in C3A2.5.3. They correspond to extreme loads.

C3A2.8 Allowable stresses

C3A2.8.1 General

.1 The maximum allowable stresses for a specific material or construction are deduced from the minimum corresponding mechanical properties, determined through tests.

.2 The strength of the various parts of the structure and associated connections is checked by means of static strength calculations, according to yield stress, tensile strength or buckling, whichever is the most severe.

.3 Computer calculations are to satisfy the indications in C3A2.3.2.

.4 The various stresses in a structural part are calculated on the basis of the different cases of scantlings defined in C3A2.7.

Suitable combinations are to be operated at each point. In particular, stresses due to both general and local forces are to be considered.

.5 Resulting stress values are to be corrected to account for:

- stress concentration around cutouts and discontinuities in plates and stiffeners,
- local deterioration of mechanical properties around connections (e.g. welded or glued joints).

C3A2.8.2 Verifications based on extreme loads

.1 Breaking

(a) Application of extreme loads to the structure allows maximum elementary stresses at each point of a structural part or a construction to be calculated.

(b) If the total stress resulting from the appropriate combination of elementary stresses at any point is a pulling force, it may not, under any circumstances, exceed the minimum breaking load at this point.

.2 Bucking

(a) If the total stress resulting from the appropriate combination of elementary stresses at any point is a compressive force, it may not, under any circumstances, exceed the collapse limit (general buckling) at this point.

(b) The collapse limit is to be determined, if required, on the basis of reduced elasticity modulus values of materials (corrected accordingly to the corresponding Poisson's ratio).
The moments of inertia are, themselves, to be reduced, to take into account only the "equivalent width" of plates (width capable of bearing the general buckling rate without local buckling).

C3A2.8.3 Verification based on maximum loads

.1 Application of maximum loads to the structure allows corresponding elementary stresses at each point of a structural part or a construction to be calculated.

.2 The total stress resulting from the appropriate combination of elementary stresses at any point may not be more that the least of the following values:

- minimum conventional yield stress of the material or construction,
- minimum breaking load of the material or construction divided by 1,5.

C3A2.8.4 Verification based on basic loads

.1 No systematic verification is made for basic loads.

.2 However, since these loads are supported by the structure in normal service, they can be used to check the fatigue strength of certain components or constructions.

C3A2.9 Distortions

C3A2.9.1 Distortions under maximum loads

.1 No permanent distortions are to remain after application of maximum loads.

.2 Each structural component is to be so designed that the distortions sustained can in no way affect the good working order of the other components of the air-cushion vehicle.

C3A2.9.2 Distortions under extreme loads

.1 Permanent distortions under extreme loads may be accepted, provided that neither the craft's safety nor proper operation of its main components is affected.

ANNEX 7 STABILITY OF MULTIHULL CRAFT

1 Stability criteria in the intact condition

A multihull craft, in the intact condition, shall have sufficient stability when rolling in a seaway to successfully withstand the effect of either passenger crowding or high-speed turning as described in 1.4. The craft's stability shall be considered to be sufficient provided compliance with this paragraph is achieved.

1.1 Area under the GZ curve

The area (A_1) under the GZ curve up to an angle θ shall be at least:

$A_1 = 0.055 \times 30° / \theta$ (m.rad)

where θ is the least of the following angles:

.1 the downflooding angle;

.2 the angle at which the maximum GZ occurs; and

.3 30°

1.2 Maximum GZ

The maximum GZ value shall occur at an angle of at least 10°.

1.3 Heeling due to wind

The wind heeling lever shall be assumed constant at all angles of inclination and shall be calculated as follows:

$HL_1 = P_i\, A\, Z\, /\, (9800\, \Delta)$ (m)

$HL_2 = 1.5\, HL_1$ (m) (see figure 1)

where:

$P_i = 500\, (V_W / 26)^2$ (N/m²)

where:

V_W	:	wind speed corresponding to the worst intended conditions (m/s)
A	:	projected lateral area of the portion of the craft above the lightest service waterline (m²)
Z	:	vertical distance from the centre of A to a point one half the lightest service draught (m)
Δ	:	displacement (t).

1.4 Heeling due to passenger crowding or high-speed turning

Heeling due to the crowding of passengers on one side of the craft or to high-speed turning, whichever is the greater, shall be applied in combination with the heeling lever due to wind (HL_2).

1.4.1 Heeling due to passenger crowding

When calculating the magnitude of the heel due to passenger crowding, a passenger crowding lever shall be developed using the assumptions stipulated in 2.10 of this Code.

1.4.2 Heeling due to high-speed turning

When calculating the magnitude of the heel due to the effects of high-speed turning, a high-speed turning lever shall be developed using either the following formula or an equivalent method specifically developed for the type of craft under consideration, or trials or model test data:

$$TL = \frac{1}{g} \cdot \frac{V_o^2}{R} \cdot \left(KG - \frac{d}{2}\right)$$

where:

TL	:	turning lever (m)
V_o	:	speed of craft in the turn (m/s)
R	:	turning radius (m)
KG	:	height of vertical centre of gravity above keel (m)
d	:	mean draught (m)
g	:	acceleration due to gravity.

1.5 Rolling in waves (figure 1)

The effect of rolling in a seaway upon the craft's stability shall be demonstrated mathematically. In doing so, the residual area under the GZ curve (A_2), i.e. beyond the angle of heel (θ_h), shall be at least equal to 0.028 m.rad up to the angle of roll θ_r. In the absence of model test or other data θ_r shall be taken as 15° or an angle of ($\theta_d - \theta_h$), whichever is less.

Figure 1 Intact stability

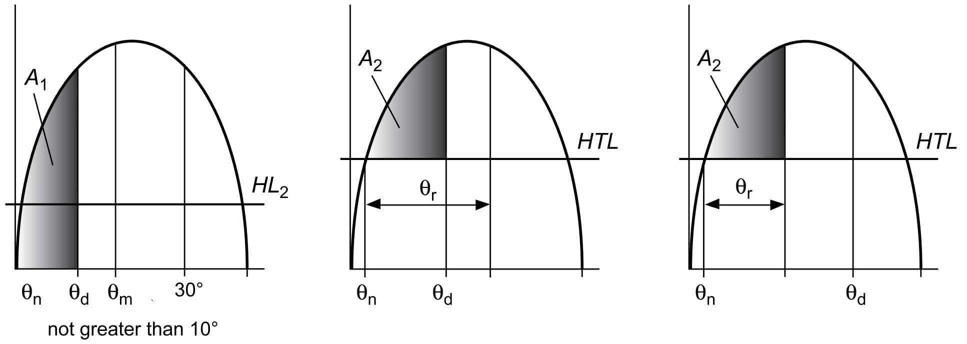
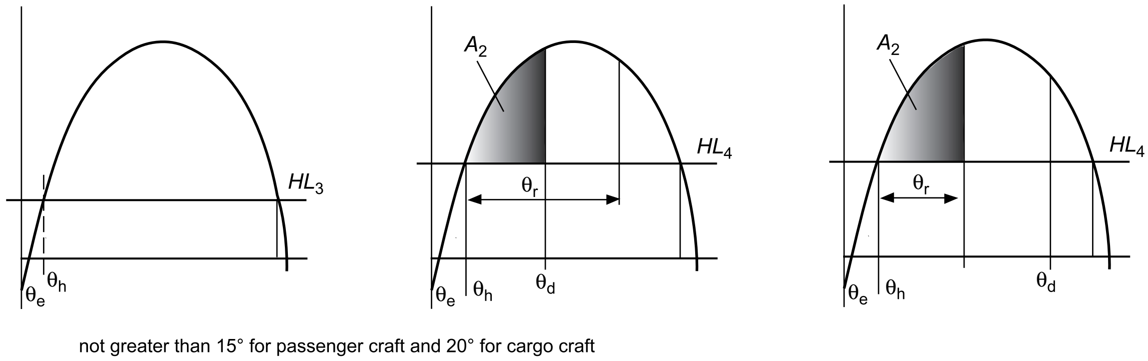


Figure 2 Damage stability



2 *Criteria for residual stability after damage*

2.1 *The method of application of criteria to the residual stability curve is similar to that for intact stability except that the craft in the final condition after damage shall be considered to have an adequate standard of residual stability provided:*

.1 *the required area A_2 shall be not less than 0.028 m.rad (figure 2 refers); and*

.2 *there is no requirement regarding the angle at which the maximum GZ value shall occur.*

2.2 *The wind heeling lever for application on the residual stability curve shall be assumed constant at all angles of inclination and shall be calculated as follows:*

$HL_3 = P_d A Z / (9800 \Delta)$

where:

$P_d = 120 (V_w / 26)^2$ (N/m²)

V_w : *wind speed corresponding to the worst intended conditions (m/s)*

A : *projected lateral area of the portion of the ship above the lightest service waterline* (m^2)

Z : *vertical distance from the centre of A to a point one half of the lightest service draught (m)*

Δ : *displacement (t).*

2.3 *The same values of roll angle shall be used as for the intact stability.*

2.4 *The downflooding point is important and is regarded as terminating the residual stability curve. The area A_2 shall therefore be truncated at the downflooding angle.*

2.5 *The stability of the craft in the final condition after damage shall be examined and shown to satisfy the criteria, when damaged as stipulated in 2.6 of this Code.*

2.6 *In the intermediate stages of flooding, the maximum righting lever shall be at least 0.05 m and the range of positive righting lever shall be at least 7°. In all cases, only one breach in the hull and only one free surface need to be assumed.*

3 Application of heeling levers

3.1 *In applying the heeling levers to the intact and damaged curves, the following shall be considered:*

3.1.1 *for intact condition:*

.1 *wind heeling lever (including gusting effect) (HL_2); and*

.2 *wind heeling lever (including gusting effect) plus either the passenger crowding or speed turning levers whichever is the greater (HTL).*

3.1.2 *for damage condition:*

.1 *wind heeling lever–steady wind (HL_3); and*

.2 *wind heeling lever plus heeling lever due to passenger crowding (HL_4)*

3.2 Angles of heel due to steady wind

3.2.1 *The angle of heel due to a wind gust when the heeling lever HL_2, obtained as in 1.3, is applied to the intact stability curve shall not exceed 10°.*

3.2.2 *The angle of heel due to a steady wind when the heeling lever HL_3, obtained as in 2.2, is applied to the residual stability curve after damage, shall not exceed 15° for passenger craft and 20° for cargo craft.*

Abbreviations used in figures 1 and 2

A_1	:	*≥ Area required by 1.1*
A_2	:	*≥ 0.028 m.rad.*
HL_2	:	*Heeling lever due to wind + gusting*
HTL	:	*Heeling lever due to wind + gusting + (passenger crowding or turning)*
HL_3	:	*Heeling lever due to wind*
HL_4	:	*Heeling lever due to wind + passenger crowding*
θ_m	:	*Angle of maximum GZ*
θ_d	:	*Angle of downflooding*
θ_r	:	*Angle of roll*
θ_e	:	*Angle of equilibrium, assuming no wind, passenger crowding or turning effects*
θ_h	:	*Angle of heel due to heeling lever HL_2, HTL, HL_3 or HL_4*

2.3 *The test referred to in 2.1.3 shall document that the accelerations do not exceed safety level 2 in annex 3 when control levers of automatic modes are used in a manner which will give the highest accelerations. If safety level 2 is exceeded then the craft operating manual shall include a warning that it is a risk to passengers being injured, if a crash stop is performed.*

2.4 *Other tests shall be repeated during craft turning to establish the need or otherwise to impose any speed-related restrictions during manoeuvres.*

3 Cruise performance

3.1 *This test is to establish the craft performance and accelerations experienced during cruise modes with no passenger load or cargo load during the following conditions:*

.1 *normal operation conditions are those in which the craft will safely cruise at any heading while manually operated, auto-pilot assisted operated or operated with any automatic control system in normal mode; and*

.2 *worst intended conditions, referred to in 1.4.57 of this Code, are those in which it shall be possible to maintain safe cruise without exceptional piloting skill. However, operations at all headings relative to the wind and sea may not be possible. For type of craft having a higher performance standard in non-displacement mode, the performance and accelerations shall also be established at displacement mode during operation in the worst intended condition.*

3.2 *Operation levels, as defined in 3.1, shall be established and documented by full-scale tests in at least two relevant sea conditions and in head, beam and following seas. It shall be shown that the period of every test (run) and the number of series are sufficient for achieving reliable measurements. In every sea state tested, the aggregate time in each direction shall not be less than 15 min. Model tests and mathematical simulations could be used to verify the performance in the worst intended conditions.*

Limits for normal operation condition shall be documented by measurements of craft speed, heading to the wave and interpolation of measurements of maximum horizontal accelerations in accordance with 2.4 of annex 3. Measurement of wave height and period shall be made to the maximum extent practicable.

Limits for worst intended condition shall be documented by measurements of craft speed, wave height and period, heading to the wave and by root mean square (RMS) values of horizontal accelerations in accordance with 2.4 of annex 3 and of vertical accelerations close to the craft longitudinal centre of gravity. RMS values could be used for extrapolation of peak values. To obtain the expected peak values related to structural design load and safety levels (one per 5-min exceedance), multiply the RMS values by 3.0 or

$$C = \sqrt{2 \cdot \ln N}$$

where:

N : is the number of successive amplitudes within the relevant period.

If not otherwise verified by model tests or by mathematical calculations, it might be assumed a linear relation between wave height and accelerations based on measurements in the two sea conditions. Limits for worst intended condition shall be documented both related to passenger safety in accordance with 2.4 of annex 3 and related to the actual structural design load of the craft.

3.3 *The tests and verification process shall document the limiting seas for safe operation of the craft:*

.1 *in normal operation at maximum operational speed the accelerations shall not exceed safety level 1 in annex 3 with an average of one per 5-min period. The craft operating manual shall include detailed description of the effects of speed reduction or change of heading to the waves in order to prevent exceedance;*

.2 *in the worst intended conditions, with reduced speed as necessary, the accelerations shall not exceed safety level 2 in annex 3 with an average of one per 5-min period, nor shall any other craft characteristic motion as pitch, roll and yaw exceed levels that could impede the safety of passengers. In worst intended conditions, with reduced speed as necessary, craft shall be safely manoeuvrable and provide adequate stability in order that the craft can continue safe operation to the nearest place of refuge, provided caution is exercised in handling. Passengers shall be required to be seated when safety level 1 in annex 3 is exceeded; and*

.3 *within the actual structural design load for the craft, with reduced speed and change of heading, as necessary.*

3.4 Turning and manoeuvrability

The craft shall be safely controllable and manoeuvrable during:

.1 *hull-borne operation;*

.2 *operation in non-displacement mode;*

.3 *take-off, landing;*

.4 *any intermediate or transition modes, as applicable; and*

.5 *berthing operations, as applicable.*

4 Effects of failures or malfunction

4.1 General

The limits of safe operation, special handling procedures and any operational restrictions shall be examined and developed as a result of full-scale trials conducted by simulating possible equipment failures.

The failures to be examined shall be those leading to major or more severe effects as determined from evaluation of FMEA or similar analysis.

Failures to be examined shall be agreed between the craft manufacturer and the Administration and each single failure shall be examined in a progressive manner.

4.2 Objects of tests

Examination of each failure shall result in:

.1 determining safe limits of craft operation at the time of failure, beyond which the failure will result in degradation beyond safety level 2;

.2 determining crew member's actions, if any, to minimize or counter the effect of the failure; and

.3 determining craft or machinery restrictions to be observed to enable the craft to proceed to a place of refuge with the failure present.

4.3 Failures to be examined

Equipment failures shall include, but not be limited to, the following:

.1 total loss of propulsion power;

.2 total loss of lift power (for ACV and SES);

.3 total failure of control of one propulsion system;

.4 involuntary application of full propulsion thrust (positive or negative) on one system;

.5 failure of control of one directional control system;

.6 involuntary full deflection of one directional control system;

.7 failure of control of trim control system;

.8 involuntary full deflection of one trim control system element; and

.9 total loss of electrical power.

Failures shall be fully representative of service conditions and shall be simulated as accurately as possible in the most critical craft manoeuvre where the failure will have maximum impact.

4.4 "Dead ship" test

In order to establish craft motions and direction of laying to wind and waves, for the purposes of determining the conditions of a craft evacuation, the craft shall be stopped and all main machinery shut down for sufficient time that the craft's heading relative to wind and waves has stabilized. This test shall be carried out on an opportunity basis to establish patterns of the design's "dead ship" behaviour under a variety of wind and sea states.

ANNEX 10 CRITERIA FOR TESTING AND EVALUATION OF REVENUE AND CREW SEATS

1 Purpose and scope

The purpose of these criteria is to provide requirements for revenue and crew seats, seat anchorage and seat accessories and their installation to minimize occupant injury and/or disruption of egress/ingress if the craft suffers a collision.

2 Static seat tests

2.1 *The requirements of this section are applicable to all crew and revenue seats.*

2.2 *All seats to which this paragraph applies, along with their supports and deck attachments, shall be designed to withstand at least the following static forces applied in the direction of the craft:*

.1 *Forward direction: a force of 2.25 kN,*

.2 *After direction: a force of 1.5 kN,*

.3 *Transverse direction: a force of 1.5 kN,*

.4 *Vertically downward: a force of 2.25 kN, and*

.5 *Vertically upward: a force of 1.5 kN.*

A seat shall comprise a frame, bottom and back. Forces applied in the fore or aft direction of the seat shall be applied horizontally to the seat back 350 mm above the seat bottom. Forces applied in the transverse seat direction shall be applied horizontally to the seat bottom. Vertical upward forces shall be evenly distributed to the corners of the seat bottom frame. Vertical downward forces shall be uniformly distributed over the seat bottom.

If a seating unit consists of more than one seating position, these forces shall be applied at each seating position concurrently during the tests.

2.3 *When the forces are applied to a seat, consideration shall be given to the direction in which the seat is to face in the craft. For example, if the seat faces sideways, the transverse craft force would be applied fore and aft on the seat and the forward craft force would be applied transversely on the seat.*

2.4 *Each seating unit to be tested shall be attached to the support structure similar to the manner in which it will be attached to the deck structure in the craft. Although a rigid support structure can be used for these tests, a support structure, having the same strength and stiffness as the support structure in the craft, is preferred.*

2.5 *The forces described in 2.2.1 to 2.2.3 shall be applied to the seat through a cylindrical surface having a radius of 80 mm and a width at least equal to the width of the seat. The surface shall be equipped with at least one force transducer able to measure the forces applied.*

2.6 *The seat shall be considered acceptable if:*

.1 *under the influence of the forces referred to in 2.2.1 to 2.2.3, the permanent displacement measured at the point of application of the force is not more than 400 mm;*

.2 *no part of the seat, the seat mountings or the accessories become completely detached during the tests;*

.3 *the seat remains firmly held, even if one or more of the anchorages is partly detached;*

.4 *all of the locking systems remain locked during the entire test but the adjustment and locking systems need not be operational after the tests; and*

.5 *rigid parts of the seat with which the occupant may come into contact shall present a curved surface with a radius of at least 5 mm.*

2.7 *The requirements of section 3 may be used in lieu of the requirements of this section provided that the accelerations used for the tests are at least 3 g.*

3 Dynamic seat tests

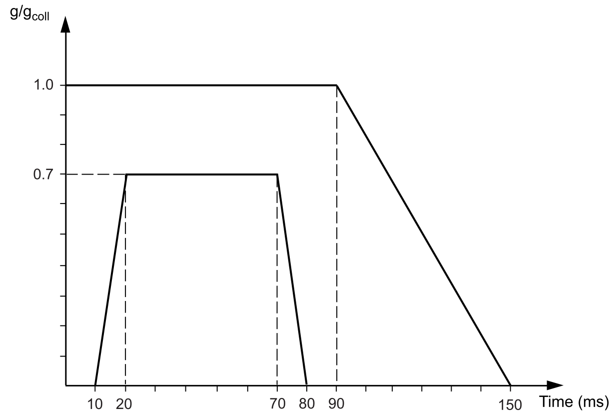
3.1 *The requirements of this section are applicable in addition to those in 2.1 for crew and revenue seats in craft having a design collision load of 3 g or greater.*

3.2 *All seats for which this section applies, the seat supporting structure, the attachment to the deck structure, the lap belt, if installed, and shoulder harness, if installed, shall be designed to withstand the maximum acceleration force that can be imposed upon them during a design collision. Consideration shall be given to the orientation of the seat relative to the acceleration force (i.e. whether the seat is forward-, aft-, or side-facing).*

3.3 *The acceleration pulse to which the seat is subjected shall be representative of the collision time-history of the craft. If the collision time-history is not known, or cannot be simulated, the acceleration time-history envelope shown in the figure can be used.*

3.4 *In the test frame, each seat unit and its accessories (e.g., lap belts and shoulder harnesses) shall be attached to the support structure similar to the manner in which it will be attached in the craft. The support structure can be a rigid surface; however, a support structure having the same strength and stiffness as the support structure in the craft is preferred. Other seats and/or tables with which an occupant may come in contact during a collision shall be included in the test frame in an orientation and with a method of attachment typical of that in the craft.*

Figure 1 Acceleration time-history envelope



3.5 *During the dynamic seat test, a fiftieth percentile anthropomorphic test dummy, suitable for the test being conducted, shall be placed in the seat in an upright seating position. If a typical seating unit is composed of more than one occupant seat, a test dummy shall be placed in each occupant seat in the unit. The dummy, or dummies, shall be secured in the seat unit in accordance with procedures of recognized national standards (see note) and be secured using only the lap belt and shoulder harness if they are installed. Tray tables and other such devices shall be placed in the position that would cause the greatest potential for an occupant to become injured.*

Note: Refer to ECE 80 with addendum 79. Other national standards may be acceptable.

3.6 *The test dummy shall be instrumented and calibrated, in accordance with the requirements of a recognized national standard, so as to permit, as a minimum, calculation of the head injury criterion, calculation of the thoracic trauma index, measurement of force in the femur, and measurement, if possible, of extension and flexion of the neck.*

3.7 *If more than one dummy is used in the tests, the dummy located in the seat having the highest potential for an occupant to be injured shall be the one instrumented. The other dummy or dummies need not be instrumented.*

3.8 *The tests shall be conducted and the instrumentation shall be sampled at a rate sufficient to reliably show response of the dummy in accordance with the requirements of a recognized national standard.*

Note: Refer to the specifications of International Standard ISO 6487–Technique of measurement in impact tests (1987) or SAE J211–Instrumentation.

3.9 *The seat unit tested in accordance with the requirements of this section shall be considered acceptable if:*

.1 *the seat unit and tables installed in the seat unit or area do not become dislodged from the supporting deck structure and do not deform in a manner that would cause the occupant to become trapped or injured;*

.2 *the lap belt, if installed, remains attached and on the test dummy's pelvis during the impact. The shoulder harness, if installed, remains attached and in the immediate vicinity of the test dummy's shoulder during the impact. After the impact, the release mechanisms of any installed lap belt and shoulder harness shall be operative;*

.3 *the following acceptability criteria are met:*

.3.1 *the head injury criterion (HIC), calculated in accordance with the formula, does not exceed 500*

$$HIC = (t_2 - t_1)\left[\frac{1}{t_2 - t_1}\int_{t_1}^{t_2} a(t)\,dt\right]^{2,5}$$

where:

t_1 and t_2 are the beginning and ending times (in seconds) of the interval in which the HIC is a maximum. The term a(t) is the resultant measured acceleration in the head of the dummy in g;

.3.2 *the thoracic trauma index (TTI), calculated in accordance with the formula, does not exceed 30 g except for periods totalling less than 3 ms*

$TTI = (g_R + g_{LS}) / 2$ or acceleration at the centre of gravity

where:

g_R : *is the acceleration in g of either the upper or lower rib;*

g_{LS} : *is the acceleration in g of the lower spine; and*

.3.3 *the force in the femur does not exceed 10 kN except that it cannot exceed 8 kN for periods totalling more than 20 ms; and*

.4 *loads on the upper torso harness straps do not exceed 7.8 kN or a total of 8.9 kN if dual straps are used.*

ANNEX 11 OPEN REVERSIBLE LIFERAFTS

1 General

1.1 *All open reversible liferafts shall:*

.1 *be constructed with proper workmanship and materials;*

.2 *not be damaged in stowage throughout the air temperature range of -18 °C to +65 °C;*

.3 *be capable of operating throughout an air temperature range of –18 °C to +65 °C and a seawater temperature range of –1 °C to +30 ° C;*

.4 *be rot-proof, corrosion-resistant and not be unduly affected by seawater, oil or fungal attack;*

.5 *be stable and maintain their shape when inflated and fully laden; and*

.6 *be fitted with retro-reflective material, where it will assist in detection, and in accordance with the recommendations adopted by the Organization.*

Note: Refer to the Recommendation on the Use and Fitting of Retro-Reflective Materials on Life-Saving Appliances, adopted by the Organization by resolution A.658(16).

2 Construction

2.1 *The open reversible liferaft shall be so constructed that when it is dropped into the water in its container from a height of 10 m, the liferaft and its equipment will operate satisfactorily. If the open reversible liferaft is to be stowed at a height of more than 10 m above the waterline in the lightest seagoing condition, it shall be of a type which has been satisfactorily drop-tested from at least that height.*

2.2 *The open reversible floating liferaft shall be capable of withstanding repeated jumps on to it from a height of at least 4.5 m.*

2.3 *The open reversible liferaft and its fittings shall be so constructed as to enable it to be towed at a speed of 3 knots in calm water when loaded with its full complement of persons and equipment, with the sea-anchor deployed.*

2.4 *The open reversible liferaft when fully inflated shall be capable of being boarded from the water whichever way up it inflates.*

2.5 *The main buoyancy chamber shall be divided into:*

.1 *not less than two separate compartments, each inflated through a nonreturn inflation valve on each compartment; and*

.2 *the buoyancy chambers shall be so arranged that in the event of one of the compartments being damaged or failing to inflate, the intact compartment shall be able to support, with positive freeboard over the open reversible liferaft's entire periphery, the number of persons which the liferaft is permitted to accommodate, each having a mass of 75 kg and seated in their normal positions.*

2.6 *The floor of the open reversible liferaft shall be waterproof.*

2.7 *The open reversible liferaft shall be inflated with a non-toxic gas by an inflation system complying with the requirements of paragraph 4.2.2 of the LSA Code. Inflation shall be completed within the period of one minute at an ambient temperature of between 18 ° C and 20 ° C and within a period of three minutes at an ambient temperature of –18 ° C. After inflation the open reversible liferaft shall maintain its form when loaded with its full complement of persons and equipment.*

2.8 *Each inflatable compartment shall be capable of withstanding a pressure equal to at least three times the working pressure and shall be prevented from reaching a pressure exceeding twice the working pressure either by means of relief valves or by a limited gas supply. Means shall be provided for fitting the topping-up pump or bellows.*

2.9 *The surface of the buoyancy tubes shall be of non-slip material. At least 25% of these tubes shall be of a highly visible colour.*

2.10 *The number of persons which an open reversible liferaft shall be permitted to accommodate shall be equal to the lesser of:*

.1 *the greatest whole number obtained by dividing by 0.096 the volume, measured in cubic metres, of the main buoyancy tubes (which for this purpose shall not include the thwarts, if fitted) when inflated; or*

.2 the greatest whole number obtained by dividing by 0.372 the inner horizontal cross-sectional area of the open reversible liferaft measured in square metres (which for this purpose may include the thwart or thwarts, if fitted) measured to the innermost edge of the buoyancy tubes; or

.3 the number of persons having an average mass of 75 kg, all wearing lifejackets, that can be seated inboard of the buoyancy tubes without interfering with the operation of any of the liferaft's equipment.

3 Open reversible liferaft fittings

3.1 *Lifelines shall be securely becketed around the inside and outside of the open reversible liferaft.*

3.2 *The open reversible liferaft shall be fitted with an efficient painter of a length suitable for automatic inflation on reaching the water. For open reversible liferafts accommodating more than 30 persons an additional bowsing-in line shall be fitted.*

3.3 *The breaking strength of the painter system, including its means of attachment to the open reversible liferaft, except the weak link required by paragraph 4.1.6.2 of the LSA Code, shall be:*

.1 7.5 kN for open reversible liferafts accommodating up to 8 persons;

.2 10.0 kN for open reversible liferafts accommodating 9 to 30 persons; and

.3 15.0 kN for open reversible liferafts accommodating more than 30 persons.

3.4 *The open reversible liferaft shall be fitted with at least the following number of inflated ramps to assist boarding from the sea whichever way up the raft inflates:*

.1 one boarding ramp for open reversible liferafts accommodating up to 30 persons; or

.2 two boarding ramps for open reversible liferafts accommodating more than 30 persons; such boarding ramps shall be 180° apart.

3.5 *The open reversible liferaft shall be fitted with water pockets complying with the following requirements:*

.1 the cross-sectional area of the pockets shall be in the shape of an isosceles triangle with the base of the triangle attached to the buoyancy tubes of the open reversible liferaft;

.2 the design shall be such that the pockets fill to approximately 60% of capacity within 15 s to 25 s of deployment;

.3 the pockets attached to each buoyancy tube shall normally have aggregate capacity of between 125 l and 150 l for inflatable open reversible liferafts up to and including the 10-person size;

.4 the pockets to be fitted to each buoyancy tube on liferafts certified to carry more than 10 persons shall have, as far as practicable, an aggregate capacity of 12 N litres, where N is the number of persons carried;

.5 each pocket on a buoyancy tube shall be attached so that when the pocket is in the deployed position it is attached along the full length of its upper edges to, or close to, the lowest part of the lower buoyancy tube; and

.6 the pockets shall be distributed symmetrically round the circumference of the liferaft with sufficient separation between each pocket to enable air to escape readily.

3.6 *At least one manually controlled lamp complying with the requirements shall be fitted on the upper and lower surfaces of the buoyancy tubes.*

3.7 *Suitable automatic drain arrangements shall be provided on each side of the floor of the liferaft in the following manner:*

.1 one for open reversible liferafts accommodating up to 30 persons; or

.2 two for open reversible liferafts accommodating more than 30 persons.

3.8 *The equipment of every open reversible liferaft shall consist of:*

.1 one buoyant rescue quoit, attached to not less than 30 m of buoyant line with a breaking strength of at least 1 kN;

.2 two safety knives of the non-folding type, having a buoyant handle, shall be fitted attached to open reversible liferaft by light lines. They shall be stowed in pockets so that, irrespective of the way in which the open reversible liferaft inflates, one will be readily available on the top surface of the upper buoyancy tube in a suitable position to enable the painter to be readily cut;

.3 one buoyant bailer;

.4 two sponges;

.5 one sea-anchor permanently attached to the open reversible liferaft in such a way as to be readily deployable when the open reversible liferaft inflates. The position of the sea-anchor shall be clearly marked on both buoyancy tubes;

.6 two buoyant paddles;

.7 one first-aid outfit in a waterproof case capable of being closed tightly after use;

.8 one whistle or equivalent sound signal;

.9 two hand flares;

.10 one waterproof electric torch suitable for Morse signalling together with one spare set of batteries and one spare bulb in a waterproof container;

.11 one repair outfit for repairing punctures in buoyancy compartments; and

.12 one topping-up pump or bellows.

3.9 The equipment specified in 3.8 is designated an HSC Pack.

3.10 Where appropriate, the equipment shall be stowed in a container which, if it is not an integral part of, or permanently attached to, the open reversible liferaft, shall be stowed and secured to the open reversible liferaft and be capable of floating in water for at least 30 min without damage to its contents. Irrespective of whether the equipment container is an integral part of, or is permanently attached to, the open reversible liferaft, the equipment shall be readily accessible irrespective of which way up the open reversible liferaft inflates. The line which secures the equipment container to the open reversible liferaft shall have a breaking strength of 2 kN or a breaking strength of 3:1 based on the mass of the complete equipment pack, whichever is the greater.

4 Containers for open reversible inflatable liferafts

4.1 The open reversible liferafts shall be packed in a container that is:

.1 so constructed as to withstand conditions encountered at sea;

.2 of sufficient inherent buoyancy, when packed with the liferaft and its equipment, to pull the painter from within and to operate the inflation mechanism shall the craft sink; and

.3 as far as practicable, watertight, except for drain holes in the container bottom.

4.2 The container shall be marked with:

.1 maker's name or trademark;

.2 serial number;

.3 the number of persons it is permitted to carry;

.4 non-SOLAS reversible;

.5 type of emergency pack enclosed;

.6 date when last serviced;

.7 length of painter;

.8 maximum permitted height of stowage above waterline (depending on drop-test height); and

.9 launching instructions.

5 Markings on open reversible inflatable liferafts

The open reversible liferafts shall be marked with:

.1 maker's name or trademark;

.2 serial number;

.3 date of manufacture (month and year);

.4 name and place of service station where it was last serviced; and

.5 number of persons it is permitted to accommodate on the top of each buoyancy tube, in characters not less than 100 mm in height and of a colour contrasting with that of the tube.

6 Instructions and information

Instructions and information required for inclusion in the craft's training manual and in the instructions for on-board maintenance shall be in a form suitable for inclusion in such training manual and instructions for on-board maintenance. Instructions and information shall be in a clear and concise form and shall include, as appropriate, the following:

.1 general description of the open reversible liferaft and its equipment;

.2 installation arrangements;

.3 operational instructions, including use of associated survival equipment; and

.4 servicing requirements.

7 Testing of open reversible inflatable liferafts

7.1 *When testing open reversible liferafts in accordance with the recommendations of resolution MSC.81(70), part 1:*

.1 *tests No. 5.5, 5.12, 5.16, 5.17.2, 5.17.10, 5.17.11, 5.17.12, 5.18 and 5.20 may be omitted;*

.2 *the part of test No. 5.8 regarding closing arrangement may be omitted,*

.3 *the temperature -30° C in test No. 5.17.3 and 5.17.5 may be substituted with -18° C; and*

.4 *the drop height of 18 m in test No. 5.1.2 may be substituted with 10 m.*

Omittances and substitution, as described above, shall be reflected in the type approval certificate.