SECTION 4 STRUCTURE CALCULATION PRINCIPLES

1 Hull girder - Structural continuity

1.1 General principles

1.1.1 Attention is to be paid to the structural continuity:

- in way of changes in the framing system
- at the connections of primary or ordinary stiffeners.

1.1.2 Longitudinal members contributing to the hull girder longitudinal strength are to extend continuously for a sufficient distance towards the ends of the ship.

Ordinary stiffeners contributing to the hull girder longitudinal strength are generally to be continuous when crossing primary supporting members. Otherwise, the detail of connections is considered by the Society on a case by case basis.

1.1.3 Where stress concentrations may occur in way of structural discontinuity, adequate compensation and reinforcements are to be provided.

1.1.4 Openings are to be avoided, as far as practicable, in way of highly stressed areas.

Where necessary, the shape of openings is to be specially designed to reduce the stress concentration factors.

Openings are to be generally well rounded with smooth edges.

1.1.5 Primary supporting members are to be arranged in such a way that they ensure adequate continuity of strength. Abrupt changes in height or in cross-section are to be avoided.

2 Strength characteristics of hull girder transverse sections

2.1 Hull girder transverse sections

2.1.1 General

Hull girder transverse sections are to be considered as being constituted by the members contributing to the hull girder longitudinal strength, i.e. all continuous longitudinal members below the strength deck defined in [2.2].

For the catamaran, the members of each float as well as superstructure contributing to the hull girder longitudinal strength are to be taken into account.

2.1.2 Members of various metallic materials

Where the members contributing to the longitudinal strength are made in materials not having one single value of Young's modulus E, the equivalent sectional area that may be included in the hull girder transverse sections is obtained, in m², from the following formula:

$$A_{SE} = \frac{E_{REF}}{E_M} A_M$$

where:

E_{REF} : Reference Young's modulus, in N/mm², considered for the whole transverse section

E_M : Actual Young's modulus, in N/mm², of the considered member

A_M : Sectional area, in m², of the member under consideration.

2.1.3 Members in composite materials

Where the members contributing to the longitudinal strength are made in various composite materials, the neutral axis and the inertia of the hull girder transverse sections are calculated on the same basis as explained in Ch 12, Sec 4, [6.2] for stiffeners.

In this case, the value of Z_{Xi} to take into account is the distance between the baseline of the transverse section and the neutral axis of each sub-element of the hull.

2.1.4 The transverse sectional areas of openings such as hatch covers, sideshell ports, sideshell doors, in the members contributing to the longitudinal hull girder strength, are to be deduced from the considered transverse section.

2.1.5 Lightening holes, draining holes and single scallops

Lightening holes, draining holes and single scallops in longitudinals need not be deducted if their height is less than 0,25 h_W, without being greater than 75 mm, where h_W is the web height, in mm, of the considered longitudinal.

2.2 Strength deck

2.2.1 The strength deck is, in general, the uppermost continuous deck.

In the case of a superstructure or deckhouses contributing to the longitudinal strength, the strength deck is the deck of the superstructure or the deck of the uppermost deckhouse.

2.2.2 A superstructure extending at least 0,4 L may generally be considered as contributing to the longitudinal strength.

The presence of openings in the side shell and longitudinal bulkheads is to be taken into account in the analysis of the transverse sections of the hull girder.

2.2.3 When the analysis of the hull girder strength is performed with a Finite Elements Analysis, the presence of large openings in side shell, decks and longitudinal bulkheads is to be taken into account in the analysis. This may be done in two ways:

- by including these openings in the finite element model

- by assigning to the plate panel between the side frames beside each opening an equivalent thickness, in mm, obtained from the following formula:

$$t_{EQ} = 10^3\left[\ell_P\left(\frac{Gh^2}{12EI_J} + \frac{1}{A_J}\right)\right]^{-1}$$

where according to Fig 1:

ℓ_P : Longitudinal distance, in m, between the frames beside the opening

h : Height, in m, of openings

I_J : Moment of inertia, in m^4, of the opening jamb about the transverse axis y-y

A_J : Shear area, in m^2, of the opening jamb in the direction of the longitudinal axis x-x

G : Coulomb's modulus, in N/mm^2, of the material used for the opening jamb, to be taken equal to:

- for steels:

  $G = 8{,}0 \cdot 10^4$ N/mm^2

- for aluminium alloys:

  $G = 2{,}7 \cdot 10^4$ N/mm^2.

2.3 Section modulus

2.3.1 The section modulus in any point of a transverse section is given, in m^3, by the following formula:

$$Z_A = \frac{I_Y}{|z - N|}$$

where:

I_Y : Moment of inertia, in m^4 of the transverse section

z : Z co-ordinate, in m, of the point above base line

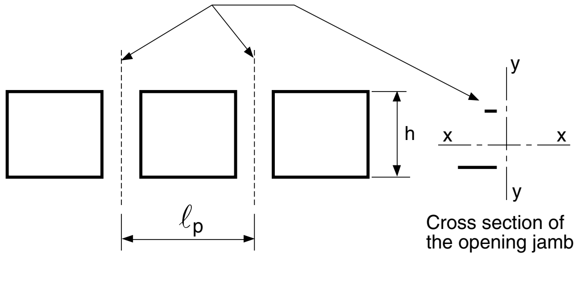
N : Z co-ordinate, in m, of the centre of gravity of the transverse section, above base line.

2.3.2 The section moduli at bottom and at deck are given, in m^3, by the following formulae:

- at bottom:

$$Z_{AB} = \frac{I_Y}{N}$$

Figure 1 : Side openings



- at deck

$$Z_{AB} = \frac{I_Y}{V_D}$$

where:

I_Y, N : Defined in [2.3.1]

V_D : Vertical distance, in m, equal to $V_D = z_D - N$, where:

z_D : z co-ordinate, in m, of the strength deck, above the base line.

2.4 Moments of inertia

2.4.1 The moment of inertia I_Y, in m^4, is calculated with respect to the horizontal neutral axis.

2.5 First moments

2.5.1 The first moment S, in m^3, at a level z above the baseline is that, calculated with respect to the horizontal neutral axis, of the portion of the hull transverse sections defined in [2.1] located above the z level.

2.6 Overall longitudinal strength

The overall longitudinal strength in any point of a transverse section, in N/mm^2, is obtained as:

$$\sigma_A = \frac{M_V}{Z_A}$$

where:

M_V : Overall bending moment of combination global loads calculated as indicated in Ch 6, Sec 4

Z_A : Section modulus calculated according to [2.3.1].

3 Stiffener calculation

3.1 Span of stiffeners

3.1.1 General

The span ℓ of stiffeners is to be measured as shown in Fig 2 to Fig 5.

Figure 2 : Stiffener without brackets

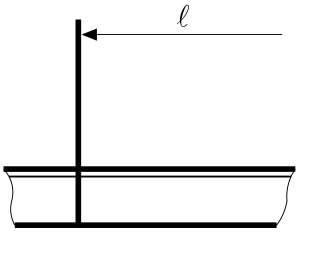


Figure 3 : Stiffener with a stiffener at one end

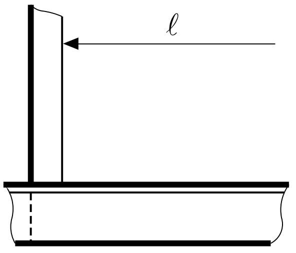


Figure 4 : Stiffener with end bracket

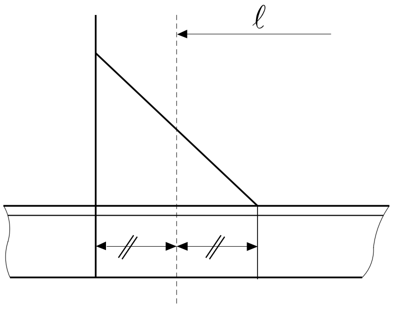


Figure 5 : Stiffener with a bracket and a stiffener at one end

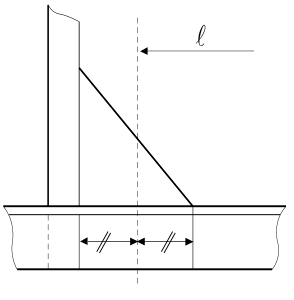
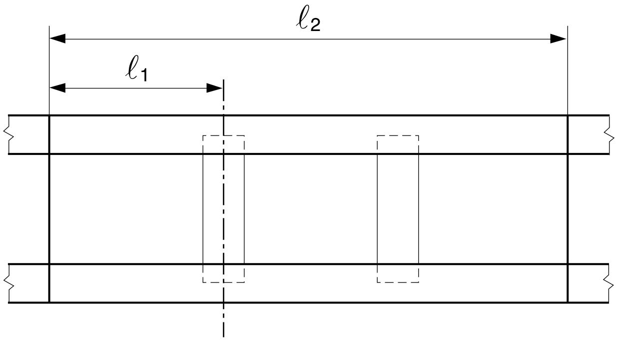


Figure 6 : Span of stiffeners in the case of open floors



3.1.2 Open floors

The span ℓ of transverse ordinary stiffeners connected by one or two struts is to be taken as the greater of 1,4 ℓ_1 and 0,7 ℓ_2, where ℓ_1 and ℓ_2 are the spans defined in Fig 6.

3.2 Scantling of a stiffener made of steel or aluminium

3.2.1 For each structural member, the scantling of stiffeners is obtained by considering successively the loads sustained by the structure under consideration, and the relevant associated admissible stress levels.

When the structural member under consideration is sustaining compressive load, actual stress level is to be checked against buckling stress as given in Ch 4, Sec 3.

3.2.2 For steel and aluminium structural members, the Rules scantlings are directly given by the Rules formulae.

3.2.3 The Society may also consider direct calculations based on actual geometry, Rules loads and admissible stress.

3.2.4 Special attention is to be paid to connection of ordinary stiffeners and surrounding supporting structure.

3.2.5 As a rule, the design section modulus Z, in cm^3, and the shear area A_{sh}, in cm^2, calculated according in Ch 8, Sec 4, for a stiffener sustaining lateral pressure are obtained from typical formulae, as follows:

$$Z = 1000 \cdot coeff \cdot \frac{p \cdot s \cdot l^2}{m \cdot \sigma_{ad}}$$

$$A_{sh} = 10 \cdot coeff \cdot \frac{p \cdot s \cdot l}{\tau_{ad}}$$

where:

10, 1000: Unit coefficient

coeff : This reduction coefficient may be of two different types:

- $(1 - s / 2\ell)$ in case of a load uniformly distributed over the full span of the stiffener. In such a case, this reduction coefficient express the load directly transferred to the primary supporting members at end of the stiffener
- $(3\ell^2 - 0{,}36) \cdot 0{,}3/\ell^3$ in case of impact pressure applied on side shell as defined in Ch 7, Sec 1, [2.3]. In that formula, ℓ is to be taken not less than 0,6 m

p : Local pressure, in kN/m^2, which may be a uniform load applied over the the full span of the stiffener or a uniform load applied on a part of the span only

s : Loaded width supported by the siffener, in m

ℓ : Span of the stiffener, in m

σ_{ad}, τ_{ad} : Rule admissible stresses, in N/mm^2, as defined in Ch 4, Sec 3, Tab 2 or Ch 4, Sec 3, Tab 4 and depending on the type of materials and on the type of load (hydrodynamic load, slamming, impact load, test load or exceptional load in damage situation) m : Coefficient depending on end conditions of the stiffener. This coefficient m may be taken as:

- 12, when the cross section at the end of the stiffener cannot rotate under the effect of the lateral load (fixed end)
- 8, when the cross section at the end of the stiffener can rotate freely under the effect of the lateral load (simply supported end)
- 10, when the cross section at the end of the stiffener is in an intermediate condition between fixed end-condition and simply supported end-condition.

As a rule, m is taken equal to 12 when:

- the stiffener is supported at end with a constant load either side of the support, making the rotation of the cross section impossible (case of an outside shell longitudinals)
- the stiffener is attached to a supporting structure with a significantly higher stiffness than the one of the stiffener.

As a rule, m is taken equal to 8 when:

- the stiffener is snipped at end.

3.3 Scantling of a stiffener made of composite

3.3.1 For each structural member, the scantling of stiffeners is obtained by considering successively the loads sustained by the structure under consideration, and the relevant associated safety factors.

3.3.2 For composite structural members, the calculation of stresses is directly given by the Rules formulae Ch 12, Sec 4, [6] and compared to the theoritical breaking stresses, estimated in Ch 12, Sec 3, [5], taking into account the safety factors as defined in Ch 4, Sec 3, [5.4].

The calculation of the stiffeners flexural moment and shear force are given in Ch 9, Sec 4.

3.3.3 Special attention is to be paid to connection of ordinary stiffeners and surrounding supporting structure. As a general rule, the scantling coefficient "m" taking into account the end conditions of the stiffener is to be taken as given in [3.2.5].

4 Plating calculation

4.1 General

4.1.1 Plating thicknesses are calculated with consideration given to elementary plate panel between secondary stiffeners and primary supporting members.

4.1.2 Steel and aluminium alloys

As a rule, for steel and aluminium plates sustaining lateral pressure, rule thickness, in mm, given by typical scantling formulae indicated in Ch 8, Sec 3 are as follows:

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

where:

22,4 : Unit coefficient, allowing to express directly the thickness from the ratio of the bending moment of the elementary plate panel with fixed boundaries and the corresponding section modulus

μ : Coefficient for the aspect ratio of the elementary plate panel, taking account of the stress distribution along the larger side and the smaller side of the panel

p : Local pressure, in kN/m^2, which may be a uniform load applied over the full span of the plate or a uniform load applied on a part of the span only (impact pressure on side shell)

s : Smaller side, in m, of the elementary plate panel

σ_{ad} : Rule permissible stress, in N/mm^2, depending on the type of material and on the type of load, as defined in Ch 4, Sec 3, Tab 2 or Ch 4, Sec 3, Tab 4

coeff : Coefficient equal to:

- In case of uniformly distributed hydrodynamic loads, as given in:

  coeff = 1

- In case of impact pressure on side shells (loads distributed on a part only of the elementary plate panel), as given in Ch 7, Sec 1, [2.3]:

  - coeff = 1, if

    $$\frac{\ell}{0,6} \le 1 + s$$

  - coeff = $(1+s)^{-1/2}$, if

    $$\frac{\ell}{0,6} > 1 + s$$

4.1.3 Composites

As a rule, for composite materials, scantling formulae are expressed as a function of the bending moment and the shear force on the edges of the elementary plate panel, as defined in Ch 9, Sec 3, [7].

The dimensions of elementary plate panel is to be considered as shown on Fig 7.

The calculation of stresses in each elementary layers is given in Ch 12, Sec 4 and compared to the theoretical breaking stresses estimated in Ch 12, Sec 3, [5], taking into account the safety factors as defined in Ch 4, Sec 3, [5.4].

Figure 7 : Composite elementary plate panel