SECTION 4 STIFFENERS

1 General

1.1 Geometric and rigidity calculation of a stiffener

1.1.1 The mechanical characteristics of a stiffener made up of composite is to be estimated as defined in Ch 12, Sec 4, [6].

1.2 Ordinary stiffeners

1.2.1 Span

The span ℓ, in m, of ordinary stiffeners is to be taken as indicated in Ch 4, Sec 4, [3].

1.2.2 Laminate attached plating for lateral loading

The width of the laminate attached plating to be considered for the yielding check of ordinary stiffeners is to be obtained, in m, from the following formulae, where s is the spacing between ordinary stiffeners, in m:

- where the laminate attached plating extends on both sides of the ordinary stiffener:

  $b_P = s$

- where the laminate attached plating extends on one side of the ordinary stiffener (i.e. ordinary stiffeners bounding openings):

  $b_P = 0{,}5s$.

1.2.3 Where ordinary stiffeners are continuous through primary supporting members, their connection to the web of the primary supporting member is to be in accordance with [1.5.1].

1.2.4 As a rule, where ordinary stiffeners are cut at primary supporting members, brackets are to be fitted to ensure the structural continuity of the ordinary stiffeners by ensuring the continuity of the longitudinal fibres located in the ordinary stiffener flange.

1.3 Primary supporting members

1.3.1 Span

The span ℓ , in m, of primary supporting members is to be taken as indicated in Ch 4, Sec 4, [3].

1.3.2 Laminate attached plating

The width of the laminate attached plating to be considered for the yielding check of primary supporting members analysed through beam structural models is to be obtained, in m, from the following formulae, where s is the spacing of the primary supporting members:

- where the laminate plating extends on both sides of the primary supporting member:

  $b_P = \min (s; 0{,}2\ell)$

- where the laminate plating extends on one side of the primary supporting member (i.e. primary supporting members bounding openings):

  $b_P = 0{,}5 \min (s; 0{,}2\ell)$

1.3.3 The web shear area of primary supporting members is to take into account the section reduction due to cut-outs provide for the ordinary stiffeners passage through the primary supporting members, if relevant.

1.3.4 In general, the depth of cut-outs is to be not greater than 50% of the depth of the primary supporting member.

1.3.5 Where openings such as duct routing for pipes, electrical cable..., are cut in primary supporting members, they are to be equidistant from the face plate and the attached plate. As a rule, their height is not to be more than 20% of the primary supporting member web height.

1.3.6 Openings may not be fitted in way of toes of end brackets.

1.3.7 Over half of the span in the middle of the primary supporting members, the length of openings is to be not greater than the distance between adjacent openings.

At the ends of the span, the length of openings is to be not greater than 25% of the distance between adjacent openings.

1.4 Large openings in primary supporting members

1.4.1 In the case of large openings as shown in Fig 1, the secondary stresses in primary supporting members are to be considered for the reinforcement of the openings.

The secondary stresses may be calculated in accordance with the following procedure:

- Members (1) and (2) are subjected to the following forces and moments:

$$F = \frac{M_A + M_B}{2d}$$

$$m_1 = \left|\frac{M_A - M_B}{2}\right| K_1$$

$$m_2 = \left|\frac{M_A - M_B}{2}\right| K_2$$

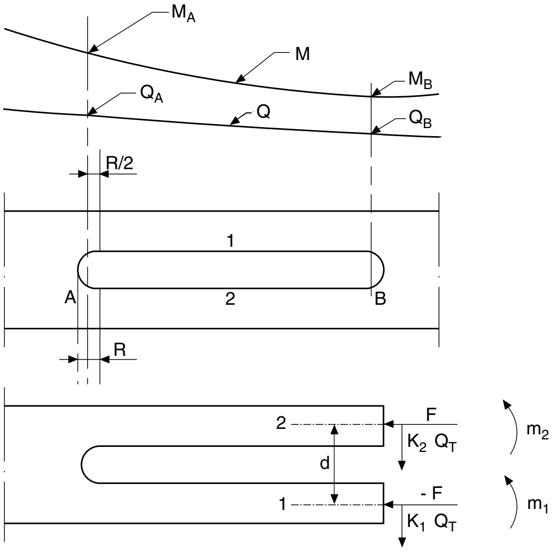
where:

M_A, M_B: Bending moments, in kN.m, in sections A and B of the primary supporting member

m_1, m_2: Bending moments, in kN.m, in (1) and (2)

d : Distance, in m, between the neutral axes of (1) and (2)

Figure 1 : Large openings in primary supporting members - Secondary stresses



I_1, I_2 : Moments of inertia, in cm^4, of members (1) and (2) with attached plating, as defined in Ch 12, Sec 4, [6.2]

$$K_1 = \frac{I_1}{I_1 + I_2}$$

$$K_2 = \frac{I_2}{I_1 + I_2}$$

- Members (1) and (2) are subjected to a uniforme compressive or tensile strain, in percent, equal to:

$$\varepsilon_{F1} = 10\frac{F}{\sum_i (S_i E_{Xi})_1}100$$

$$\varepsilon_{F2} = 10\frac{F}{\sum_i (S_i E_{Xi})_2}100$$

with $\Sigma(S_iE_i)_1$ and $\Sigma(S_iE_i)_2$, respectively the sum of the product of the section, in cm^2, and the Young modulus, in N/mm^2, of each element (laminate attached plating, web stiffener and flange stiffener) of the stiffener 1 and the stiffener 2.

- Members (1) and (2) are subjected to a flexural strain induced by secondary flexural moments m_1 and m_2.

The longitudinal strain, in percent, of each element of members (1) and (2) induced by m_1 and m_2 are:

$$\varepsilon_{Xi(1)} = \frac{m_1 d_{i(1)}}{10 E_{Xi(1)} I_1}100$$

$$\varepsilon_{Xi(2)} = \frac{m_2 d_{i(2)}}{10 E_{Xi(2)} I_2}100$$

as defined in Ch 12, Sec 4, [6.2.3].

Note: The suffix (1) and (2) are only used to differentiate the members (1) and (2).

- The web of members (1) and (2) are subjected to a shear strain, in percent, induced by the shear force Q_T equal to:

$$\gamma_{XY(1)} = 10\frac{Q_T}{\sum_i (S_i G_i)_{(1)}}100$$

$$\gamma_{XY(2)} = 10\frac{Q_T}{\sum_i (S_i G_i)_{(2)}}100$$

where Q_T is the shear force, in kN, applied to members (1) and (2), equal to Q_A or Q_B, whichever is greater.

$\Sigma(S_iG_i)$ as defined in Ch 12, Sec 4, [6.2.5], is the sum of the product of the section, in cm^2, and the Coulomb modulus, in N/mm^2, of each element (laminate attached plating, web stiffener and flange stiffener) of the stiffener 1 and the stiffener 2.

The suffix (1) and (2) being only used to differentiate the members (1) and (2).

- The local stresses in way of large openings are to be examined in each composite element making up the members (1) and (2) as defined in Ch 12, Sec 4, [6] in the two following cases:
  - stresses induced by force F and secondary flexural moment m_1 and m_2. In this case, the global strain is to be equal to the sum of the strains induced by F and m_1 and m_2;
  - shear stress induced by Q_T.
- The stresses estimated are to comply with the safety factors defined in Ch 4, Sec 3, [5.4].

1.4.2 When stresses do not comply with safety factors defined in Ch 4, Sec 3, [5.4], the number of elementary layers in web members (1) and (2) and/or the number of elementary layers provided to edge the large opening are to be increased.

1.5 Connections of primary stiffeners and primary supporting member

1.5.1 Where ordinary stiffeners are continuous through primary supporting members, they are to be connected to the web plating so as to ensure proper transmission of loads, e.g. by means of the principal connection details shown in Fig 2.

Other principal connection may be considered by the Society on a case by case basis.

1: a local reinforcement of primary stiffener web can be necessary if (h_P - h_S) is not sufficient.

2: a local laminate connection between the ordinary stiffener and the primary structure is to be provided as follows:

- laminate connection (number of elementary layer) is to be defined according to shear stress defined in Ch 12, Sec 4, [6.2.5] (where T is the shear force in the ordinary stiffener at its ends) and safety factor defined in Ch 4, Sec 3, [5.4].
- laminate connection surface on ordinary stiffener and primary structure is to be defined taking into account the previous shear force T, the structural adhesive characteristics defined in Ch 12, Sec 2, [5.2] and safety factor defined in Ch 4, Sec 3, [5.4].

Figure 2 : Connection detail

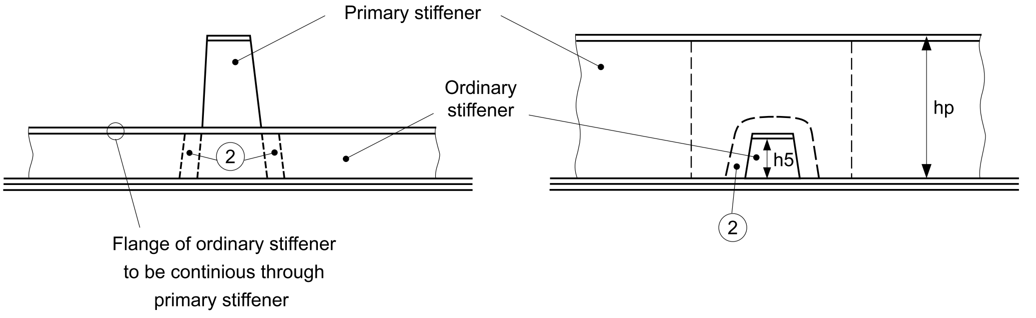
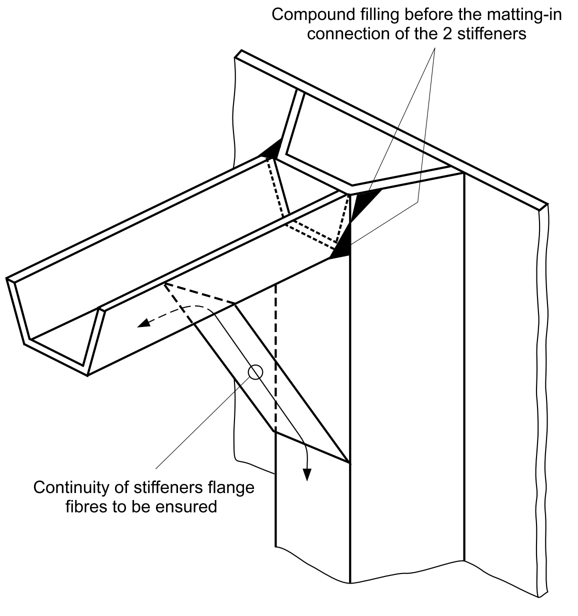


Figure 3 : Principal bracket arrangement



1.5.2 Where ordinary stiffeners are cut at primary supporting members, the ordinary flange stiffeners continuity is to be ensured by bracket or equivalent arrangement.

1.5.3 Bracket arrangement

As a general rule, the main principal bracket arrangement is to be based on the design shown on Fig 3, ensuring the continuity of the longitudinal fibres of stiffener flanges.

1.5.4 Cut-outs in stiffening structure

As a general rule, all openings carried out in a laminate panel (bulkhead, stiffener web...) are to be protected against damage caused by water and/or humidity.

This protection can be ensured by one or more laminate product laminated on the opening edge.

The location of cut-outs in secondary and/or primary structure are to be located in area where the shear forces are minimum.

The cut-outs in some area such as, for example, intersection between primary stiffeners, are to be avoided.

2 Ordinary stiffeners sustaining lateral pressure

2.1 Load point

2.1.1 Lateral pressure for longitudinal stiffener

Unless otherwise specified, lateral pressure is to be calculated at mid-span of the ordinary stiffener considered.

2.1.2 Lateral pressure for transversal stiffener

Unless otherwise specified, lateral pressure is to be calculated at the lower point and at the upper point of the ordinary stiffener considered.

2.2 Bending and shear check

2.2.1 As a general rule, the bending check of ordinary stiffeners sustaining lateral pressure is carried out according to the following process:

- Estimation of the flexural bending moment M induced by lateral pressure, in kN.m, and shear force T in kN, at the edges:

$$M = coeff\frac{p_M \cdot s \cdot \ell^2}{m}$$

$$T = coeft\frac{p_T \cdot s \cdot \ell}{2}$$

where

ℓ : Span of the stiffener, in m, measured as indicated in Ch 4, Sec 4, [3]

s : Spacing between stiffeners, in m

p_M : Lateral pressure, in kN/m², as given

1) For hydrodynamic loads

a) For longitudinal stiffeners,

$p_M = p_S$

as defined in Ch 7, Sec 1 taken into account [2.1.1]

b) For transversal stiffeners,

$p_M = 3\ p_{S\ lower} + 2\ p_{S\ upper}$

where $p_{S\ lower}$ and $p_{S\ upper}$ are defined in Ch 7, Sec 1, taken into account [2.1.2]

2) For bottom slamming loads

$p_M = p_{sl}$, as defined in Ch 7, Sec 2

3) For impact pressure on side shell

$p_M = p_{Smin}$, as defined in Ch 7, Sec 1, [2.3]

p_T : Lateral pressure, in kN/m^2, as given

1) For hydrodynamic loads

a) For longitudinal stiffeners,

$p_T = p_S$

as defined in Ch 7, Sec 1 taken into account [2.1.1]

b) For transversal stiffeners,

$p_T = (0{,}7\ p_{S\ lower} + 0{,}3\ p_{S\ upper})$

where $p_{S\ lower}$ and $p_{S\ upper}$ are defined in Ch 7, Sec 1 , taken into account [2.1.2]

2) For bottom slamming loads

$p_T = p_{sl}$, as defined in Ch 7, Sec 2

3) For impact pressure on side shell

$p_T = p_{Smin}$, as defined in Ch 7, Sec 1, [2.3]

m : Coefficient depending on load type and/or end conditions :

- m = 60 for load type p_M as defined in 1) b)
- m = 12, 10 or 8 for types p_M as defined in 1) a), 2), 3), and depending on end conditions, as defined in Ch 4, Sec 4, [3.3.3].

coeff : Reduction coefficient equal to:

- $(1 - s/2\ell) \geq 0$ in general case
- $(3\ell^2 - 0{,}36)\cdot 0{,}3/\ell^3$ for ordinary side shell stiffeners in the case where p is taken equal to the impact pressure on side shell p_{Smin} as defined in Ch 7, Sec 1, [2.3], with ℓ being taken not less than 0,6 m
- 1 for decks ordinary stiffener

coeft : Reduction coefficient equal to:

- $(1 - s/2\ell) \geq 0$ in general case
- $0{,}6/\ell$, without being taken superior to 1, for ordinary side shell stiffeners in the case where p is taken equal to the minimum pressure on side shell as defined in Ch 7, Sec 1, [2.3]
- 1 for decks ordinary stiffener

- Estimation of the neutral axis and the inertia of the stiffener as defined in Ch 12, Sec 4, [6.2.1] and Ch 12, Sec 4, [6.2.2]
- Estimation of the strains and the stresses induced by the moment M and by the shear force T, as defined in Ch 12, Sec 4, [6.2.3] to Ch 12, Sec 4, [6.2.5]
- Estimation of tensile or compressive stresses and shear stresses in each individual layer of each element of the stiffener, as defined in Ch 12, Sec 4, [6.2.4] and Ch 12, Sec 4, [6.2.5]
- Examination of safety factor for each element of the stiffener (composite attached plating, web and flange) in relation to minimum safety factors defined in Ch 4, Sec 3, [5.4].

2.2.2 Attention is to be particularly paid on the location where the strains are calculated. For an analysis at the edges:

- the flange is to be in compression (negative strain)
- the attached plating is to be in traction (positive strain).

3 Primary supporting members sustaining lateral pressure

3.1 General

3.1.1 The primary supporting members are designed as indicated in [2] for ordinary stiffeners, without taking into account the coefficients coeff and coeft, with lateral loads depending on primary member under consideration:

- bottom primary members: hydrodynamic loads as given in Ch 7, Sec 1, [2.2] and Ch 7, Sec 2.
- side primary members: hydrodynamic loads as given in Ch 7, Sec 1, [2.2]
- decks primary members: minimum sea loads as given in Ch 7, Sec 1, [3].

For deck primary structure exposed to sea pressure, the lateral loads taken into account can be reduced by the following coefficients:

- 0,8 for primary structure of exposed superstructure deck;
- $(1 - 0{,}05\ell) > 0{,}8$ for primary structure of exposed deck.

4 Curved primary supporting members

4.1 General

4.1.1 The curvature of primary supporting members may be taken into account by direct analysis.

4.1.2 Model principles

In case of 2-D or 3-D beam structural model, the curved primary supporting members are to be represented by a number N of straight beams, N being adequately selected to minimize the spring effect in way of knuckles.

The stiffness of knuckles equivalent springs is considered as unaffecting the local bending moment and shear forces distribution where the angle between two successive beams is not more than 3°.

5 Calculation program

5.1 Stiffener analysis

5.1.1 The stiffener analysis can be carried out with Bureau Veritas program defined in Ch 1, Sec 4.

5.2 Curvate primary stiffener analysis

5.2.1 The curvate primary stiffener analysis can be carried out with Bureau Veritas program defined in Ch 1, Sec 4.