Common Structural Rules for Bulk Carriers, January 2006

Corrigenda 5
Rule Editorials

Notes: (1) These Rule Corrigenda enter into force on 1 April 2006

(2) This document contains a copy of the affected rule along with the editorial change or clarification noted as applicable.

(3) Users are reminded that the formula in Chapter 5, Appendix 1, 2.2.8, was corrected by Rule Change Notice No.1, November 2007.

- Details about the IACS CSR Knowledge Centre (KC) ID Numbers can be found on the IACS CSR web site (www.iacs.org.uk) under the headings of 'Questions and Answers and Common Interpretations'.

CHAPTER 1 – GENERAL PRINCIPLES

SECTION 4 SYMBOLS AND DEFINITIONS

2. Symbols

2.1 Ship's main data

2.1.1

V : Maximum ahead service speed, in knots, means the greatest speed which the ship is designed to maintain in service at her deepest seagoing draught at the maximum propeller RPM and corresponding engine MCR (Maximum Continuous Rating).

Reason for the Rule Clarification:
This editorial correction is made to be in line with the definition in the IACS Common Structural Rules for Double Hull Oil Tankers.
(Refer to KC ID 514)

CHAPTER 2 – GENERAL ARRANGEMENT DESIGN

SECTION 3 ACCESS ARRANGEMENT

2. Technical provisions for means of access

2.3 Construction of ladders

2.3.2 Inclined ladders

Ref. IMO Technical Provisions, 3.6 (Resolution MSC.158(78))

The width of inclined ladders between stringers is to be not less than 400 mm. The treads are to be equally spaced at a distance apart, measured vertically, of between 200 mm and 300 mm. When steel is used, the treads are to be formed of two square bars of not less ~~that~~ than 22 mm by 22 mm in section, fitted to form a horizontal step with the edges pointing upward. The treads are to be carried through the side stringers and attached thereto by double continuous welding. All inclined ladders are to be provided with handrails of substantial construction on both sides, fitted at a convenient distance above the treads.

Reason for the Rule Clarification:
Editorial correction.

CHAPTER 3 – STRUCTURAL DESIGN PRINCIPLES

SECTION 1 MATERIAL

2. Hull structural steel

2.3 Grades of steel

2.3.7

In specific cases, such as ~~[2.3.6]~~ [2.3.8], with regard to stress distribution along the hull girder, the classes required within 0.4L amidships may be extended beyond that zone, on a case by case basis.

Reason for the Rule Clarification:
Editorial correction.

Table 4 Application of material classes and grades

Structural member category	Material class	
	Within 0.4*L* amidship	**Outside 0.4*L* amidship**
SECONDARY		
Longitudinal bulkhead strakes, other than that belonging to the Primary category	I	*A/AH*
Deck Plating exposed to weather, other than that belonging to the Primary or Special category		
Side plating (7)		
PRIMARY		
Bottom plating, including keel plate	II	*A/AH*
Strength deck plating, excluding that belonging to the Special category		
Continuous longitudinal members above strength deck, excluding hatch coamings		
Uppermost strake in longitudinal bulkhead		
Vertical strake (hatch side girder) and uppermost sloped strake in top wing tank		
SPECIAL		
Sheer strake at strength deck (1), (6)	III	II (I outside 0.6*L* amidships)
Stringer plate in strength deck (1), (6)		
Deck strake at longitudinal bulkhead (6)		
Strength deck plating at corners of cargo hatch openings in bulk carriers, ore carriers, combination carriers and other ships with similar hatch openings configuration (2)		
Bilge strake (3), (4), (6)		
Longitudinal hatch coamings of length greater than 0.15*L* (5)		
Web of lower bracket of side frame of single side bulk carriers having additional service feature **BC-A** or **BC-B** (5)		
End brackets and deck house transition of longitudinal cargo hatch coamings (5)		

Notes:

(1) Not to be less than grade *E/EH* within 0.4*L* amidships in ships with length exceeding 250 m.

(2) Not to be less than class III within 0.6*L* amidships and class II within the remaining length of the cargo region.

(3) May be of class II in ships with a double bottom over the full breadth and with length less than 150 m.

(4) Not to be less than grade *D/DH* within 0.4*L* amidships in ships with length exceeding 250 m.

(5) Not to be less than grade *D/DH*.

(6) Single strakes required to be of class III or of grade *E/EH* and within 0.4*L* amidships are to have breadths, in m, not less than $0.8 + 0.005L$, need not be greater than 1.8 m, unless limited by the geometry of the ship's design.

(7) For **BC-A** and **BC-B** ships with single side skin structures, side shell strakes included totally or partially between the two points located to 0.125ℓ above and below the intersection of side shell and bilge hopper sloping plate are not to be less than grade *D/DH*, ℓ being the frame span.

Reason for the Rule Clarification:

The editorial correction is made to clarify the application of structural members. (Refer to KC ID 502)

SECTION 6 STRUCTURAL ARRANGEMENT PRINCIPLES

8. Single side structure

8.3 Side frames

8.3.1 General

Frames are to be built-up symmetrical sections with integral upper and lower brackets and are to be arranged with soft toes.

The side frame flange is to be curved (not knuckled) at the connection with the end brackets. The radius of curvature is not to be less than r, in mm, given by:

~~$r = \frac{0.3 b_f^2}{t_f + t_C}$~~

$$r = \frac{0.4 b_f^2}{t_f + t_C}$$

where:

t_C : Corrosion addition, in mm, specified in Ch 3, Sec 3

b_f and t_f : Flange width and net thickness of the curved flange, in mm. The end of the flange is to be sniped.

In ships less than 190 m in length, mild steel frames may be asymmetric and fitted with separate brackets. The face plate or flange of the bracket is to be sniped at both ends. Brackets are to be arranged with soft toes.

The dimensions of side frames are defined in Fig 19.

Reason for the Rule Clarification:

This correction is made to be in line with IACS UR S12. (Refer to KC ID 564)

10. Bulkhead structure

10.4 Corrugated bulkhead

10.4.4 Span of corrugations

The span ℓ_C of the corrugations is to be taken as the distance shown in Fig 29.

For the definition of ℓ_C, ~~the height of the upper and lower stools may not be taken smaller than the values specified in [10.4.7] and [10.4.8]~~ the internal end of the upper stool is not to be taken more than a distance from the deck at the centre line equal to:

- 3 times the depth of corrugation, in general
- 2 times the depth of corrugation, for rectangular stool

Reason for the Rule Clarification:

This correction is made to be in line with IACS UR S18. (Refer to KC ID 424 & 445)

10.4.7 Lower stool

The lower stool, when fitted, is to have a height in general not less than 3 times the depth of the corrugations.

The net thickness and material of the stool top plate are to be not less than those required for the bulkhead plating above. The thickness and material properties of the upper portion of vertical or sloping stool side plating within the depth equal to the corrugation flange width from the stool top are to be not less than the required flange plate thickness and material to meet the bulkhead stiffness requirement at the lower end of the corrugation.

The ends of stool side ordinary stiffeners, when fitted in a vertical plane, are to be attached to brackets at the upper and lower ends of the stool.

The distance *d* from the edge of the stool top plate to the surface of the corrugation flange is to be in accordance with Fig 30.

The stool bottom is to be installed in line with double bottom floors or girders as the case may be, and is to have a width not less than 2.5 times the mean depth of the corrugation.

The stool is to be fitted with diaphragms in line with the longitudinal double bottom girders or floors as the case may be, for effective support of the corrugated bulkhead. Scallops in the brackets and diaphragms in way of the connections to the stool top plate are to be avoided.

Where corrugations are cut at the lower stool, corrugated bulkhead plating is to be connected to the stool top plate by full penetration welds. The stool side plating is to be connected to the stool top plate and the inner bottom plating by either full penetration or deep penetration welds. The supporting floors are to be connected to the inner bottom by either full penetration or deep penetration weld. ~~The weld of corrugations and stool side plating to the stool top plate are to be full penetration one. The weld of stool side plating and supporting floors to the inner bottom plating are to be full penetration or deep penetration welds~~.

Reason for the Rule Clarification:

This correction is made to be in line with IACS UR S18. (Refer to KC ID 337)

CHAPTER 4 – DESIGN LOADS

SECTION 5 EXTERNAL PRESSURES AND FORCES

3. External pressures on superstructures and deckhouses

3.2 Exposed wheel house tops

3.2.1

The lateral pressure for exposed wheel house tops, in kN/m2, is not to be taken less than:

~~$p = 2.5$~~ $p = 12.5$

Reason for the Rule Clarification:

Editorial correction regarding the minimum pressure for superstructures, etc. is made because it is a typo (Refer to KC ID 478).

3.4 End ~~Superstructure end~~ bulkhead~~s~~ of superstructure and deckhouse

3.4.1

The lateral pressure, in kN/m^2, for determining the scantlings is to be obtained from the greater of the following formulae:

$$p_A = nc[bC - (z - T)]$$

$$p_A = p_{A\,min}$$

where:

n : Coefficient defined in Tab 7, depending on the tier level.

The lowest tier is normally that tier which is directly situated above the uppermost continuous deck to which the depth D is to be measured. However, where the actual distance (D-T) exceeds the minimum non-corrected tabular freeboard according to ILLC as amended by at least one standard superstructure height as defined in Ch 1, Sec 4, [3.18.1], this tier may be defined as the 2nd tier and the tier above as the 3rd tier

c : Coefficient taken equal to:

$$c = 0.3 + 0.7\frac{b_1}{B_1}$$

For exposed parts of machinery casings, c is not to be taken less than 1.0

b_1 : Breadth of deckhouse at the position considered

B_1 : Actual maximum breadth of ship on the exposed weather deck at the position considered.

b_1/B_1 is not to be taken less than 0.25

b : Coefficient defined in Tab 8

x : X co-ordinate, in m, of the calculation point for the bulkhead considered. When determining sides of a deckhouse, the deckhouse is to be subdivided into parts of approximately equal length, not exceeding $0.15L$ each, and x is to be taken as the X co-ordinate of the centre of each part considered.

z : Z co-ordinate, in m, of the midpoint of stiffener span, or to the middle of the plate field

ℓ : Span, in m, to be taken as the superstructure height or deckhouse height respectively, and not less than 2.0 m

$p_{A\min}$: Minimum lateral pressure, in kN/m^2, defined in Tab 9.

Table 7 : Coefficient *n*

(Note: Change in title only, no change in Tab 7)

Table 8 : Coefficient *b*

(Note: Change in title only, no change in Tab 8)

Table 9 : Minimum lateral pressure $p_{A\min}$

L	$p_{A\min}$, in kN/m^2	
	Lowest tier of unprotected fronts	Elsewhere (1)
$90 < L \le 250$	$25 + \frac{L}{10}$	$12.5 + \frac{L}{20}$
$L > 250$	50	25
(1) For the 4th tier and above, $p_{A\min}$ is to be taken equal to ~~2.5~~ 12.5kN/m^2.		

Reason for the Rule Clarification:
Editorial correction (Refer to KC ID 478 and 479)

4. PRESSURE IN BOW AREA

4.1Bow flare area pressure

4.1.1

The bow pressure, in kN/m^2, to be considered for the reinforcement of the bow flare area is to be obtained from the following formula:

$$p_{FB} = K(p_S + p_W)$$

where:

p_S, p_W : Hydrostatic pressure and maximum hydrodynamic pressures among load cases H, F, R and P, calculated in normal ballast condition at T_B

K : Coefficient taken equal to:

$$K = \frac{c_{FL}\left(0.2V + 0.6\sqrt{L}\right)^2}{42C(C_B + 0.7)\left(1 + \frac{20}{C_B}\left(\frac{x}{L} - 0.7\right)^2\right)}(10 + z - T_B)$$ to be taken not less than 1.0

c_{FL} : Coefficient taken equal to:

$c_{FL} = 0.8$ in general

$c_{FL} = \dfrac{0.4}{1.2 - 1.09\sin\alpha}$ where the flare angle α is greater than 40°

Where, the flare angle α at the load calculation point is to be measured in plane of the frame between a vertical line and the tangent to the side shell plating. (see Fig 7)

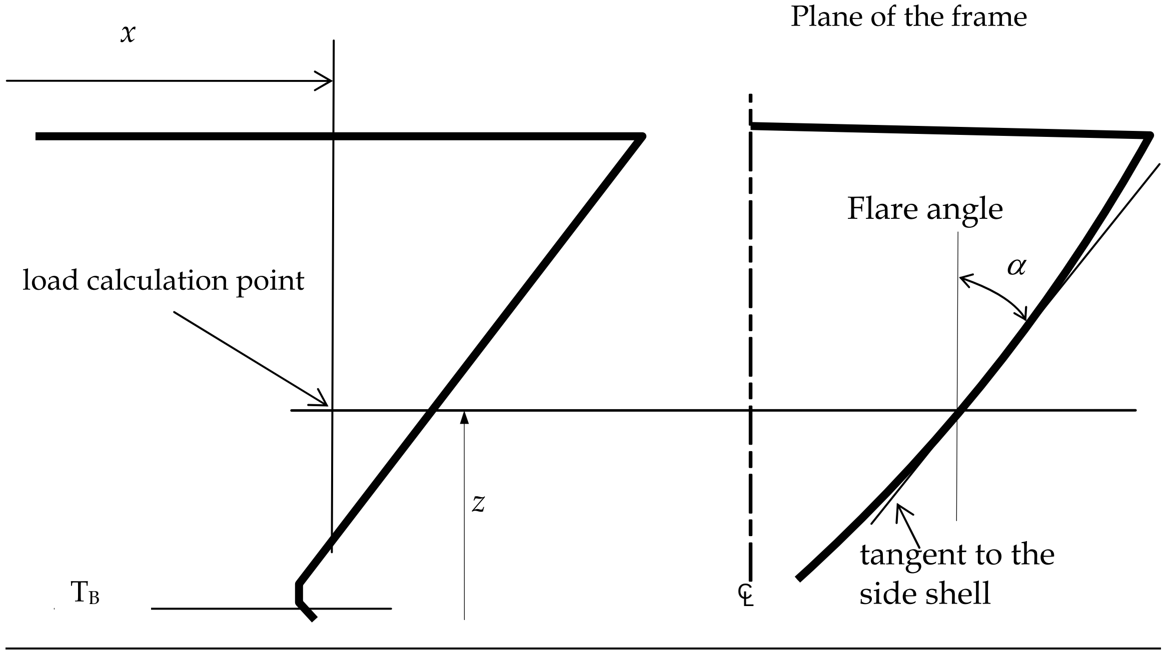


Figure 7: The definition of the flare angle

Reason for the Rule Clarification:
Clarification of the definition of flare angle (Refer to KC ID 533)

CHAPTER 5 – HULL GIRDER STRENGTH

SECTION 1 YIELDING CHECK

3. Checking criteria

3.1 Normal stresses

3.1.1

It is to be checked that the normal stresses σ_1 calculated according to [2.1.2] and, when applicable, [2.1.3] are in compliance with the following formula:

$\sigma_1 \le \sigma_{1,ALL}$

where:

$\sigma_{1,ALL}$: Allowable normal stress, in N/mm², obtained from the following formulae:

$$\sigma_{1,ALL} = \frac{130}{k} \quad \text{for} \quad \frac{x}{L} \le 0.1$$

$$\sigma_{1,ALL} = \frac{190}{k} - \frac{1500}{k}\left(\frac{x}{L} - 0.3\right)^2 \quad \text{for} \quad 0.1 < \frac{x}{L} < 0.3$$

$$\sigma_{1,ALL} = \frac{190}{k} \quad \text{for} \quad 0.3 \le \frac{x}{L} \le 0.7$$

~~$\sigma_{1,ALL} \frac{190}{k} - \frac{1500}{k}\left(\frac{x}{L} - 0.7\right)^2 \quad \text{for} \quad 0.7 < \frac{x}{L} < 0.9$~~

$$\sigma_{1,ALL} = \frac{130}{k} \quad \text{for} \quad \frac{x}{L} \ge 0.9$$

$$\sigma_{1,ALL} = \frac{130}{k} \quad \text{for} \quad \frac{x}{L} \le 0.1$$

$$\sigma_{1,ALL} = \frac{190}{k} - \frac{1500}{k}\left(\frac{x}{L} - 0.3\right)^2 \quad \text{for} \quad 0.1 < \frac{x}{L} < 0.3$$

$$\sigma_{1,ALL} = \frac{190}{k} \quad \text{for} \quad 0.3 \le \frac{x}{L} \le 0.7$$

$$\sigma_{1,ALL} = \frac{190}{k} - \frac{1500}{k}\left(\frac{x}{L} - 0.7\right)^2 \quad \text{for} \quad 0.7 < \frac{x}{L} < 0.9$$

$$\sigma_{1,ALL} = \frac{130}{k} \quad \text{for} \quad \frac{x}{L} \ge 0.9$$

Reason for the Rule Clarification:
Editorial correction

4. Section modulus and moment of inertia

4.5 Extent of higher strength steel

4.5.1

When a material factor for higher strength steel is used in calculating the required section modulus at bottom or deck according to [4.2] or [4.3], the relevant higher strength steel is to be adopted for all members contributing to the longitudinal strength (see [1]), at least up to a vertical distance, in m, obtained from the following formulae:

- above the baseline (for section modulus at bottom):

$$V_{HB} = \frac{\sigma_{1B} - k\sigma_{1,ALL}}{\sigma_{1B} + \sigma_{1D}} z_D$$

- below a horizontal line located at a distance V_D (see [1.4.2]) above the neutral axis of the hull transverse section (for section modulus at deck):

  $$V_{HD} = \frac{\sigma_{1D} - k\sigma_{1,ALL}}{\sigma_{1B} + \sigma_{1D}}\left(N + V_D\right)$$

where:

σ_{1B}, σ_{1D} : Normal stresses, in N/mm^2, at bottom and deck, respectively, calculated according to [2.1~~.2~~]

z_D : Z co-ordinate, in m, of the strength deck defined in [1.3], with respect to the reference co-ordinate system defined in Ch 1, Sec 4, [4]

Reason for the Rule Clarification:
Editorial correction

APPENDIX 1 - HULL GIRDER ULTIMATE STRENGTH

Symbols

For symbols not defined in this Appendix, refer to Ch 1, Sec 4.

I_Y : Moment of inertia, in m^4, of the hull transverse section around its horizontal neutral axis, to be calculated according to Ch 5, Sec 1, [1.5.1]

Z_{AB}, Z_{AD} : Section moduli, in ~~cm^3~~ m^3 at bottom and deck, respectively, defined in Ch 5, Sec 1, [1.4.2].

Reason for the Rule Clarification:
Editorial correction

2. CRITERIA FOR THE CALCULATION OF THE CURVE *M-X*

2.1 Simplified method based on incremental-iterative approach

2.1.2 Assumption

In applying the procedure described in [2.1.1], the following assumptions are generally to be made:

- the ultimate strength is calculated at hull transverse sections between two adjacent transverse webs.
- the hull girder transverse section remains plane during each curvature increment.
- the hull material has an elasto-plastic behaviour.
- the hull girder transverse section is divided into a set of elements, which are considered to act independently.

  These elements are:
  - transversely framed plating panels and/or ordinary stiffeners with attached plating, whose structural behaviour is described in [2.2.1]
  - hard corners, constituted by plating crossing, whose structural behaviour is described in [2.2.2].
- according to the iterative procedure, the bending moment M_i acting on the transverse section at each curvature value χ_i is obtained by summing the contribution given by the stress σ acting on each element. The stress σ, corresponding to the element strain ε, is to be obtained for each curvature increment from the non-linear load-end shortening curves σ- ε - of the element.

  These curves are to be calculated, for the failure mechanisms of the element, from the formulae specified in [2.2]. The stress σ is selected as the lowest among the values obtained from each of the considered load-end shortening curves σ- ε.
- The procedure is to be repeated until the value of the imposed curvature reaches the value χ_F, in m^{-1}, in hogging and sagging condition, obtained from the following formula:

$$\chi_F = \pm 0.003 \frac{M_Y}{EI_Y}$$

where:

M_Y : the lesser of the values M_{Y1} and M_{Y2}, in kN.m:

~~$M_{Y1} = 10^{-3} R_{eH} Z_{AB}$~~ $M_{Y1} = 10^{3} R_{eH} Z_{AB}$

~~$M_{Y2} = 10^{-3} R_{eH} Z_{AD}$~~ $M_{Y2} = 10^{3} R_{eH} Z_{AD}$

If the value χ_F is not sufficient to evaluate the peaks of the curve M-χ, the procedure is to be repeated until the value of the imposed curvature permits the calculation of the maximum bending moments of the curve.

Reason for the Rule Clarification:
Editorial correction

2.2 Load-end shortening curves σ-ε

2.2.6 Web local buckling of ordinary stiffeners made of flanged profiles

The equation describing the load-end shortening curve ~~σ_{CR1}-ε~~ σ_{CR3}-ε for the web local buckling of flanged ordinary stiffeners composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR3} = \Phi R_{eH} \frac{10^3 b_E t_p + h_{we} t_w + b_f t_f}{10^3 s t_p + h_w t_w + b_f t_f}$$

where

Φ : Edge function defined in [2.2.3]

b_E : Effective width, in m, of the attached shell plating, defined in [2.2.4]

h_{we} : Effective height, in mm, of the web, equal to:

$$h_{we} = \left(\frac{2.25}{\beta_w} - \frac{1.25}{\beta_w^2}\right) h_w \qquad \text{for } \beta_w > 1.25$$

$$h_{we} = h_w \qquad \text{for } \beta_w \le 1.25$$

$$\beta_w = \frac{h_w}{t_w}\sqrt{\frac{\varepsilon R_{eH}}{E}}$$

ε : Relative strain defined in [2.2.3]

Reason for the Rule Clarification:
Editorial correction

2.2.8 Plate buckling

The equation describing the load-end shortening curve σ_{CR5}-ε for the buckling of transversely stiffened panels composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR5} = \min\begin{cases} R_{eH}\,\Phi \\ R_{eH}\left[\frac{s}{\ell}\left(\frac{2.25}{\beta_E} - \frac{1.25}{\beta_E^2}\right) + 0.1\left(1 - \frac{s}{\ell}\right)\left(1 + \frac{1}{\beta_E^2}\right)^2\right] \end{cases}$$

where:

Φ : Edge function defined in [2.2.3].

~~β_E : Coefficient defined in [2.2.4]~~. $\beta_E = 10^3 \frac{s}{t_p}\sqrt{\frac{\varepsilon R_{eH}}{E}}$

s: plate breadth, in m, taken as the spacing between the ordinary stiffeners

ℓ: longer side of the plate, in m.

Reason for the Rule Clarification:
Clarification of the formula (Refer to KC ID 428)

Note: Users are reminded that the formula in Chapter 5, Appendix 1, 2.2.8, was corrected by Rule Change Notice No.1, November 2007.

CHAPTER 6 – HULL SCANTLINGS

SECTION 1 PLATING

2. Sheer strake

2.5 Welded sheer strake

2.5.3 Net thickness of the sheer strake in way of breaks of ~~long~~ effective superstructures

The net thickness of the sheer strake is to be increased in way of breaks of ~~long~~ effective superstructures occurring within 0.5L amidships, over a length of about one sixth of the ship's breadth on each side of the superstructure end.

This increase in net thickness is to be equal to 40% of the net thickness of sheer strake, but need not exceed 4.5 mm.

Where the breaks of superstructures occur outside 0.5L amidships, the increase in net thickness may be reduced to 30%, but need not exceed 2.5 mm.

2.5.4 Net thickness of the sheer strake in way of breaks of ~~short~~ non-effective superstructures

The net thickness of the sheer strake is to be increased in way of breaks of ~~short~~ non-effective superstructures occurring within 0.6L amidships, over a length of about one sixth of the ship's breadth on each side of the superstructure end.

This increase in net thickness is to be equal to 15% of the net thickness of sheer strake, but need not exceed 4.5 mm.

Reason for the Rule Clarification:

This correction is made to be in line with the definition specified in Ch 9 Sec 4 [1.1.5] (Refer to KC ID 518).

Similar correction is made for "short superstructure".

3. STRENGTH CHECK OF PLATING SUBJECTED TO LATERAL PRESSURE

3.1 Load model

3.1.3 Lateral pressure in flooded conditions

The lateral pressure in flooded conditions p_F is defined in Ch 4, Sec 6, [3.2.1].

Reason for the Rule Clarification:

This correction is made for the clarification of the lateral pressure in flooding condition to be considered. (Refer to KC ID 402)

SECTION 2 - ORDINARY STIFFENERS

3. YIELDING CHECK

3.1 Load model

3.1.3 Lateral pressure in flooded conditions

The lateral pressure in flooded conditions p_F is defined in Ch 4, Sec 6, [3.2.1].

Reason for the Rule Clarification:

This correction is made for the clarification of the lateral pressure in flooding condition to be considered. (Refer to KC ID 402)

3.4 Upper and lower connections of side frames of single side bulk carriers

3.4.1

The section moduli of the:

- side shell and hopper tank longitudinals that support the lower connecting brackets,
- side shell and topside tank longitudinals that support the upper connecting brackets

are to be such that the following relationship is separately satisfied for each lower and upper connecting bracket (see also Ch 3, Sec 6, Fig 22):

$$\sum_{n} w_i d_i \geq \alpha_T \frac{(p_S + p_W)\ell^2 \ell_1^2}{16 R_Y}$$

where:

n : Number of the longitudinal stiffeners of side shell and hopper / topside tank that support the lower / upper end connecting bracket of the side frame, as applicable

w_i : Net section modulus, in cm^3, of the i-th longitudinal stiffener of the side shell or hopper / topside tank that support the lower / upper end connecting bracket of the side frame, as applicable

d_i : Distance, in m, of the above i-th longitudinal stiffener from the intersection point of the side shell and hopper /topside tank

ℓ_1 : Spacing, in m, of transverse supporting webs in hopper / topside tank, as applicable

R_y : Lowest value of equivalent yield stress, in N/mm^2, among the materials of the longitudinal stiffeners of side shell and hopper / topside tanks that support the lower / upper end connecting bracket of the side frame

α_T : Coefficient taken equal to:

α_T = 150 for the longitudinal stiffeners supporting the lower connecting brackets

α_T = 75 for the longitudinal stiffeners supporting the upper connecting brackets

ℓ : Side frame span, in m, as defined in [3.3.1].

p_S , p_W : Still water and wave pressures as those for the side frame.

Reason for the Rule Clarification:

This correction is made for the clarification of the pressures for upper and lower connections if side frames. (Refer to KC ID 216)

4. WEB STIFFENERS OF PRIMARY SUPPORTING MEMBERS

4.1 Net scantlings

4.1.3 Connection ends of web stiffeners

Where the web stiffeners of primary supporting members are welded to ordinary stiffener face plates, the stress at ends of web stiffeners of primary supporting members in water ballast tanks, in N/mm^2, is to comply with the following formula when no bracket is fitted :

$\sigma \le 175$

where:

$$\sigma = 1.1 K_{con} K_{longi} K_{stiff} \frac{\Delta\sigma}{\cos\theta}$$

K_{con} : Coefficient considering stress concentration, taken equal to:

$K_{con} = 3.5$ for stiffeners in the double bottom or double side space (see Fig 8)

$K_{con} = 4.0$ for other cases (e.g. hopper tank, top side tank, etc.) (see Fig 8)

K_{longi} : Coefficient considering shape of cross section of the longitudinal, taken equal to:

$K_{longi} = 1.0$ for symmetrical profile of stiffener (e.g. T-section, flat bar)

$K_{longi} = 1.3$ for asymmetrical profile of stiffener (e.g. angle section, bulb profile)

K_{stiff} : Coefficient considering the shape of the end of the stiffener, taken equal to:

$K_{stiff} = 1.0$ for standard shape of the end of the stiffener (see Fig 9)

$K_{stiff} = 0.8$ for the improved shape of the end of the stiffener (see Fig 9)

θ : As given in Fig 10

$\Delta\sigma$: Stress range, in N/mm^2, transferred from longitudinals into the end of web stiffener, as obtained from the following formula:

$$\Delta\sigma = \frac{2W}{0.322h'\left[\left(A_{w1}/\ell_1\right) + \left(A_{w2}/\ell_2\right)\right] + A_{s0}}$$

W : Dynamic load, in N, as obtained from the following formula:

$W = 1000(\ell - 0.5s)sp$

p : Maximum inertial pressure due to liquid <u>in the considered compartment where the web stiffener is located</u> according to Ch 4 Sec 6 [2.2.1], in kN/m^2, of the probability level of 10^{-4}, calculated at mid-span of the ordinary stiffener

ℓ : Span of the longitudinal, in m

s : Spacing of the longitudinal, in m

A_{s0}, A_{w1}, A_{w2} : Geometric parameters as given in Fig 10, in mm^2

ℓ_1, ℓ_2 : Geometric parameters as given in Fig 10, in mm

h' : As obtained from following formula, in mm:

$$h' = h_s + h_0'$$

h_s : As given in Fig 10, in mm

h_0' : As obtained from the following formula, in mm

$h_0' = 0.636b'$ for $b' \le 150$

$h_0' = 0.216b' + 63$ for $150 < b'$

b' : Smallest breadth at the end of the web stiffener, in mm, as shown in Fig 10

Reason for the Rule Clarification:

This correction is made for the clarification of the pressure to be applied in the calculation of dynamic load transferred from the ordinary stiffeners to the ends of web stiffeners of the primary supporting members in water ballast tanks. (Refer to KC ID 327)

SECTION 3 BUCKLING & ULTIMATE STRENGTH OF ORDINARY STIFFENERS AND STIFFENED PANELS

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

In this section, compressive and shear stresses are to be taken positive, tension stresses are to be taken negative.

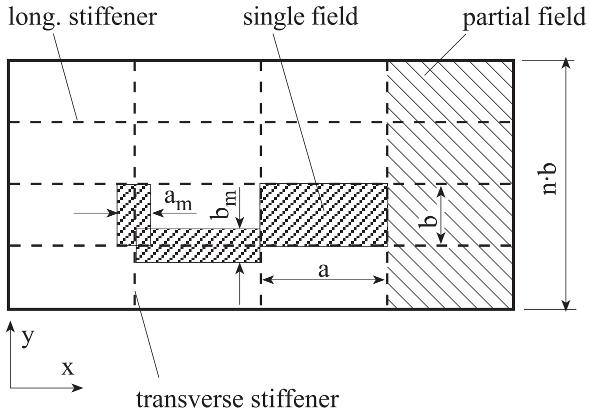
a : Length in mm of the longer side of the partial plate field in general or length in mm of the side of the partial plate field according Table 2, BLC 3 - 10

b : Length in mm of the shorter side of the partial plate field in general or length in mm of the side of the partial plate field according Table 2, BLC 3 - 10

α : Aspect ratio of elementary plate panel, taken equal to:

$$\alpha = \frac{a}{b}$$

n : Number of elementary plate panel breadths within the partial or total plate panel



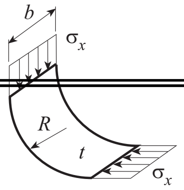
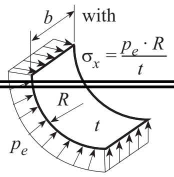
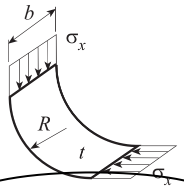
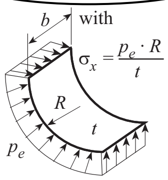
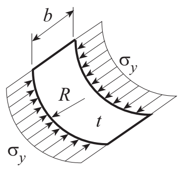
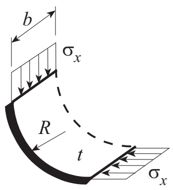
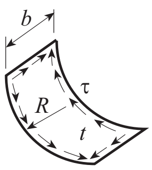
longitudinal : stiffener in the direction of the length a
transverse : stiffener in the direction of the breath b

Figure 1: General arrangement of panel

Reason for the Rule Clarification:

This correction is made for the clarification of the definition of the dimensions a and b.（Refer to KC ID 360）

Table 3: Buckling and reduction factor for curved plate panel with R/t ≤ 2500 [1]

Buckling-Load Case	Aspect ratio b/R	Buckling factor K	Reduction factor κ
1a 	$\frac{b}{R} \le 1.63\sqrt{\frac{R}{t}}$	$K = \frac{b}{\sqrt{R\,t}} + 3\frac{(R\,t)^{0.175}}{b^{0.35}}$	$\kappa_x = 1$ for $\lambda \le 0.4$ [2] $\kappa_x = 1.274 - 0.686 \cdot \lambda$ for $0.4 < \lambda \le 1.2$ $\kappa_x = \frac{0.65}{\lambda^2}$ for $\lambda > 1.2$
1b  with $\sigma_x = \frac{p_e \cdot R}{t}$; p_e = external pressure in [N/mm^2]	$\frac{b}{R} > 1.63\sqrt{\frac{R}{t}}$	$K = 0.3\frac{b^2}{R^2} + 2.25\left(\frac{R^2}{b\,t}\right)^2$	
1a 	$\frac{b}{R} \le 1.63\sqrt{\frac{R}{t}}$	$K = \frac{b}{\sqrt{R\,t}} + 3\frac{(R\,t)^{0.175}}{b^{0.35}}$	$\kappa_x = 1$ for $\lambda \le 0.4$ [2] $\kappa_x = 1.274 - 0.686 \cdot \lambda$ for $0.4 < \lambda \le 1.2$ $\kappa_x = \frac{0.65}{\lambda^2}$ for $\lambda > 1.2$
1b  with $\sigma_x = \frac{p_e \cdot R}{t}$; p_e = external pressure in [N/mm^2]	$\frac{b}{R} > 1.63\sqrt{\frac{R}{t}}$	$K = 0.3\frac{b^2}{R^2} + 2.25\left(\frac{R^2}{b\,t}\right)^2$	
2 	$\frac{b}{R} \le 0.5\sqrt{\frac{R}{t}}$	$K = 1 + \frac{2}{3}\frac{b^2}{R\,t}$	$\kappa_y = 1$ for $\lambda \le 0.25$ [2] $\kappa_y = 1.233 - 0.933 \cdot \lambda$ for $0.25 < \lambda \le 1$ $\kappa_y = 0.3/\lambda^3$ for $1 < \lambda \le 1.5$ $\kappa_y = 0.2/\lambda^2$ for $\lambda > 1.5$
	$\frac{b}{R} > 0.5\sqrt{\frac{R}{t}}$	$K = 0.267\frac{b^2}{R\,t}\left[3 - \frac{b}{R}\sqrt{\frac{t}{R}}\right] \ge 0.4\frac{b^2}{R\,t}$	
3 	$\frac{b}{R} \le \sqrt{\frac{R}{t}}$	$K = \frac{0.6 \cdot b}{\sqrt{R\,t}} + \frac{\sqrt{R\,t}}{b} - 0.3\frac{R\,t}{b^2}$	as in load case 1a
	$\frac{b}{R} > \sqrt{\frac{R}{t}}$	$K = 0.3\frac{b^2}{R^2} + 0.291\left(\frac{R^2}{b\,t}\right)^2$	
4 	$\frac{b}{R} \le 8.7\sqrt{\frac{R}{t}}$	$K = K_\tau \sqrt{3}$ $K_\tau = \left[28.3 + \frac{0.67\,b^3}{R^{1.5}\,t^{1.5}}\right]^{0.5}$	$\kappa_\tau = 1$ for $\lambda \le 0.4$ $\kappa_\tau = 1.274 - 0.686 \cdot \lambda$ for $0.4 < \lambda \le 1.2$ $\kappa_\tau = \frac{0.65}{\lambda^2}$ for $\lambda > 1.2$
	$\frac{b}{R} > 8.7\sqrt{\frac{R}{t}}$	$K_\tau = 0.28\frac{b^2}{R\sqrt{R\,t}}$	

Explanations for boundary conditions	- - - - - plate edge free ——— plate edge simply supported ━━━ plate edge clamped

[1] For curved plate fields with a very large radius the κ-value need not to be taken less than for the expanded plane field

[2] For curved single fields, e.g. bilge strake, which are located within plane partial or total fields, the reduction factor κ may taken as follow:

Load case 1b: $\kappa_x = \frac{0.8}{\lambda^2} \leq 1{,}0$ Load case 2: $\kappa_y = \frac{0.65}{\lambda^2} \leq 1.0$

Reason for the Rule Clarification:

This correction is made for the clarification of the buckling check for the curved plate. (Refer to KC ID 483)

SECTION 4 - PRIMARY SUPPORTING MEMBERS

1. GENERAL

1.1 Application

1.1.1

The requirements of this Section apply to the strength check of pillars and primary supporting members, subjected to lateral pressure and/or hull girder normal stresses for such members contributing to the hull girder longitudinal strength.

The yielding check is also to be carried out for such members subjected to specific loads.

Reason for the Rule Clarification:
Editorial correction is made for the clarification of application of the primary supporting members. (Refer to KC ID 525)

1.3 Primary supporting members for ships of 150 m or more in length L

1.3.1

For primary supporting members for ships having a length L of 150 m or more, the direct strength analysis is to be carried out according to the provisions specified in Ch 7, and the requirements in [4] are also to be complied with. In addition, the primary supporting members for **BC-A** and **BC-B** ships are to comply with the requirements in [3] ~~and [4].~~

Reason for the Rule Clarification:
Editorial correction is made for the clarification of application of the primary supporting members. (Refer to KC ID 373)

2. Scantling of primary supporting members for ships of less than 150m in length (L)

2.3 Floors

2.3.1 Net web thickness

The net thickness of floors in the double bottom structure, in mm, is not to be less than the greatest of ~~either of the~~ values t_1 to t_3 specified in the followings according to each location:

$$t_1 = C_2 \frac{pSB_{DB}}{(d_0 - d_1)\tau_a} \left(\frac{2|y|}{B'_{DB}} \right) \left\{ 1 - 2\left(\frac{x - x_c}{l_{DB}} \right)^2 \right\}$$

, where $|x - x_c|$ is less than $0.25\ell_{DB}$, $|x - x_c|$ is to be taken as $0.25\ell_{DB}$, and where $|y|$ is less than $B'_{DB}/4$, $|y|$ is to be taken as ~~$b'/4$~~ $B'_{DB}/4$,

$$t_2 = 1.75 \cdot \sqrt[3]{\frac{H^2 a^2 \tau_a}{C'_2} t_1}$$

$$t_3 = \frac{8.5 S_2}{\sqrt{k}}$$

where :

S : Spacing of solid floors, in m

d_0 : Depth of the solid floor at the point under consideration in m

d_1 : Depth of the opening, if any, at the point under consideration in m

B'_{DB} : Distance between toes of hopper tanks at the position of the solid floor under consideration, in m

C_2 : Coefficient obtained from Tab 5 depending on B_{DB}/ℓ_{DB}. For intermediate values of B_{DB}/ℓ_{DB}, C_2 is to be obtained by linear interpolation

p, B_{DB}, x_c, ℓ_{DB} : As defined in [2.2.1]

a : Depth of the solid floor at the point under consideration, in m. However, where horizontal stiffeners are fitted on the floor, a is the distance from the horizontal stiffener under consideration to the bottom shell plating or the inner bottom plating or the distance between the horizontal stiffeners under consideration

S_1 : Spacing, in m, of vertical ordinary stiffeners or girders

C'_2 : Coefficient given in Tab 6 depending on S_1/d_0. For intermediate values of S_1/d_0, C'_2 is to be determined by linear interpolation.

H : Value obtained from the following formulae:

a) where openings with reinforcement or no opening are provided on solid floors:

1) where slots without reinforcement are provided:

$$H = \sqrt{4.0\frac{d_2}{S_1} - 1.0}$$, without being taken less than 1.0

2) where slots with reinforcement are provided: $H = 1.0$

b) where openings without reinforcement are provided on solid floors:

1) where slots without reinforcement are provided:

$$H = \left(1 + 0.5\frac{\phi}{d_0}\right)\sqrt{4.0\frac{d_2}{S_1} - 1.0}$$, without being taken less than $1 + 0.5\frac{\phi}{d_0}$

2) where slots with reinforcement are provided:

$$H = 1 + 0.5\frac{\phi}{d_0}$$

d_2 : Depth of slots without reinforcement provided at the upper and lower parts of solid floors, in m, whichever is greater

ϕ : Major diameter of the openings, in m

S_2 : The smaller of S_1 or a, in m.

Reason for the Rule Clarification:

Editorial correction

CHAPTER 7 – DIRECT STRENGTH ANALYSIS

SECTION 4 HOT SPOT STRESS ANALYSIS FOR FATIGUE STRENGTH ASSESSMENT

3. Hot Spot Stress

3.3 Simplified method for the bilge hopper knuckle part

3.3.1

Table 1: Stress concentration factor K_0

Plate net thickness in FE model t (mm)	Angle of hopper slope plate to the horizontal θ (deg.)			
	40	45	50	90
16	3.0	3.2	3.4	4.2
18	2.9	3.1	3.3	4.0
20	2.8	3.0	3.2	3.8
22	2.7	2.9	3.1	3.6
24	2.6	2.8	3.0	3.5
26	2.6	2.7	2.9	3.4
28	2.5	2.7	2.8	3.3
30	2.4	2.6	2.7	3.2

Note: Alternatively, K_0 can be determined by the following formula.

$$K_0 = \frac{0.14\theta \cdot (1.15 - 0.0033\theta)}{(0.5t)^{(0.2+0.0028\theta)}}$$

Reason for the Rule Clarification:

Editorial correction is made for the clarification of the plate thickness. (Refer to KC ID 287)

CHAPTER 8 – FATIGUE CHECK OF STRUCTURAL DETAILS

SECTION 5 STRESS ASSESSMENT OF HATCH CORNERS

2. Nominal stress range

2.1 Nominal stress range due to wave torsional moment

2.1.1

The nominal stress range, in N/mm^2, due to cross deck bending induced by wave torsion moments is to be obtained from the following formula:

$$\Delta\sigma_{WT} = \frac{2}{1000} F_S F_L \frac{Q \cdot B_H}{W_Q}$$

where:

$$Q = \frac{1000\,u}{\dfrac{(B_H + b_s)^3}{12 E I_Q} + \dfrac{2.6 B_H}{E A_Q}}$$

u : Displacement of hatch corner in longitudinal direction, in m, taken equal to:

$$u = \frac{31.2}{1000} \frac{M_{WT}\, \omega}{I_T E\ DOC}$$

DOC : Deck opening coefficient, taken equal to:

$$DOC = \frac{L_C B}{\sum_{i=1}^{n} L_{H,i} B_{H,i}}$$

M_{WT} : Maximum wave torsional moment, in kN.m, defined in Ch 4, Sec 3, [3.4.1], with $f_p = 0.5$

F_S : Stress correction factor, taken equal to:

$$F_S = 5$$

F_L : Correction factor for longitudinal position of hatch corner, taken equal to:

$$F_L = 1.75 \frac{x}{L} \quad \text{for } 0.57 \le x/L \le 0.85$$

$$F_L = 1.0 \quad \text{for } x/L < 0.57 \text{ and } x/L > 0.85$$

B_H : Breadth of hatch opening, in m

W_Q : Section modulus of the cross deck about z-axis, in m^3, including upper stool, near hatch corner (see Fig 2)

I_Q : Moment of inertia of the cross deck about z-axis, in m^4, including upper stool, near the hatch corner (see Fig 2)

A_Q : Effective shear area of the whole section of the cross deck, in m^2, including upper stool, near the hatch corner (see Fig 2). For the determination of the effective shear area the consideration of only the plate elements is sufficient, and the stiffeners can be neglected.

b_S : Breadth of remaining deck strip, in m, beside the hatch opening

I_T : Torsion moment of inertia of ships cross section, in m^4, calculated within cross deck area by neglecting upper and lower stool of the bulkhead (see Fig 1). It may be calculated according to App 1

ω : Sector coordinate, in m^2, calculated at the same cross section as I_T and at the Y and Z location of the hatch corner (see Fig 1) It may be calculated according to App 1

L_C : Length of cargo area, in m , being the distance between engine room bulkhead and collision bulkhead

$B_{H,i}$: Breadth of hatch opening of hatch i, in m

$L_{H,i}$: Length of hatch opening of hatch i, in m

n : Number of hatches.

Reason for the Rule Clarification:
Editorial correction is made for the clarification of the shear area of the cross-deck. (Refer to KC ID 355)

3. Hot spot stress

3.1 Hot spot stress range

3.1.1

The hot spot stress range, in *N/mm²*, is to be obtained from the following formula:

$$\Delta\sigma_W = K_{gh} \cdot \Delta\sigma_{WT}$$

where,

K_{gh} : Stress concentration factor for the hatch corner, taken equal to:

~~$K_{gh} = \frac{r_a + 2r_b}{3r_a} \cdot \left\{ 1 + \left(\frac{b}{1.23 l_{CD} + 0.8b} \frac{0.22 l_{CD}}{r_a} \right)^{0.65} \right\}$, to be taken not less than 1.0~~

$$K_{gh} = \frac{r_a + 2r_b}{3r_a} \cdot \left\{ 1 + \left(\frac{2b}{1.23 l_{CD} + 1.6b} \frac{0.22 l_{CD}}{r_a} \right)^{0.65} \right\}$$, to be taken not less than 1.0

where:

r_a : Radius, in m, in major axis

r_b : Radius, in m, in minor axis (if the shape of corner is a circular arc, r_b is to be equal to r_a)

l_{CD} : Length of cross deck, in m, in longitudinal direction

b : Distance, in m, from the edge of hatch opening to the ship's side

Reason for the Rule Clarification:
Editorial Correction of a typo in the formula of K_{gh}. (Refer to KC ID 386.)

CHAPTER 9 – OTHER STRUCTURES

SECTION 1 FORE PART

3. Load model

3.2 Pressure in bow area

3.2.1 Lateral pressure in intact condition

The pressure in bow area, in kN/m^2, is to be taken equal to (p_S+ p_W).

where:

p_S, p_W : Hydrostatic ~~pressure~~ and ~~maximum~~ hydrodynamic pressures ~~among load cases H, F, R and P,~~ according to Ch 4, Sec 5, or internal still water and inertial pressures according to Ch 4, Sec 6, [2], to be considered among load cases H, F, R and P.

Reason for the Rule Clarification:

Editorial correction is made for the clarification of the lateral pressure in bow area. (Refer to KC ID 495)

5. Strengthening of flat bottom forward area

5.4 Primary supporting members

5.4.1 Girders

The net thickness of girders in double bottom forward area, in mm, is not to be less than the greatest of either of the value t_1 to t_3 specified in the followings according to each location:

$$t_1 = \frac{c_A p_{SL} S \ell}{2(d_0 - d_1)\tau_a}$$

$$t_2 = 1.75 \sqrt[3]{\frac{H^2 a^2 \tau_a}{C_1'} t_1}$$

$$t_3 = \frac{C_1'' a}{\sqrt{k}}$$

where:

c_A : Coefficient taken equal to:

$c_A = 3/A$, with $0.3 \le c_A \le 1.0$

A : Loaded area, in m^2, between the supports of the structure considered, obtained from the following formula:

$A = S\ell$

p_{SL} : As defined in [3.4]

S : Spacing of centre or side girders under consideration, in m

ℓ : ~~Spacing~~ Span of ~~floors~~ centre or side girders between floors under consideration, in m

d_0 : Depth of the centre or side girder under consideration, in m

d_1 : Depth of the opening, if any, at the point under consideration, in m

H : Value obtained from the following formulae:

(a) Where the girder is provided with an unreinforced opening: $H = 1 + 0.5\dfrac{\phi}{\alpha}$

(b) In other cases: $H = 1.0$

ϕ : Major diameter of the openings, in m

α : The greater of a or S_1, in m.

a : Depth of girders at the point under consideration, in m, Where, however, if horizontal stiffeners are fitted on the girder, "a" is the distance from the horizontal stiffener under consideration to the bottom shell plating or inner bottom plating, or the distance between the horizontal stiffeners under consideration

S_1 : Spacing, in m, of vertical ordinary stiffeners or floors

C_1' : Coefficient obtained from Tab 5 depending on S_1/a. For intermediate values of S_1/a, C_1' is to be determined by linear interpolation.

C_1'' : Coefficient obtained from Tab 6 depending on S_1/a. For intermediate values of S_1/a, C_1'' is to be obtained by linear interpolation.

5.4.2 Floors

The net thickness of floors in double bottom forward area, in mm, is not to be less than the greatest of either of the value t_1 to t_3 specified in the followings according to each location:

$$t_1 = \frac{c_A p_{SL} S \ell}{2(d_0 - d_1)\tau_a}$$

$$t_2 = 1.75 \cdot \sqrt[3]{\frac{H^2 a^2 \tau_a}{C_2'} t_1}$$

$$t_3 = \frac{8.5 S_2}{\sqrt{k}}$$

where :

~~c_A : As defined in [5.4.1]~~

c_A : Coefficient taken equal to:

$c_A = 3/A$, with $0.3 \le c_A \le 1.0$

A : Loaded area, in m^2, between the supports of the structure considered, obtained from the following formula:

A=Sℓ

p_{SL} : As defined in [3.4]

S : Spacing of ~~solid~~ floors under consideration, in m

ℓ : ~~Spacing of girders~~ Span of floors between centre girder and side girder or side girders under consideration, in m

d_0 : Depth of the solid floor at the point under consideration in m

d_1 : Depth of the opening, if any, at the point under consideration in m

H : Value obtained from the following formulae:

c) Where openings with reinforcement or no opening are provided on solid floors:

3) Where slots without reinforcement are provided:

$H = \sqrt{4.0\frac{d_2}{S_1} - 1.0}$, without being taken less than 1.0

4) Where slots with reinforcement are provided: $H = 1.0$

d) Where openings without reinforcement are provided on solid floors:

3) Where slots without reinforcement are provided:

$H = \left(1 + 0.5\frac{\phi}{d_0}\right)\sqrt{4.0\frac{d_2}{S_1} - 1.0}$, without being taken less than $1 + 0.5\frac{\phi}{d_0}$

4) Where slots with reinforcement are provided:

$H = 1 + 0.5\frac{\phi}{d_0}$

d_2 : Depth of slots without reinforcement provided at the upper and lower parts of solid floors, in m, whichever is greater

S_1 : Spacing, in m, of vertical ordinary stiffeners or girders

ϕ : Major diameter of the openings, in m.

a : Depth of the solid floor at the point under consideration, in m, Where, however, if horizontal stiffeners are fitted on the floor, "a" is the distance from the horizontal stiffener under consideration to the bottom shell plating or the inner bottom plating or the distance between the horizontal stiffeners under consideration

S_2 : The smaller of S_1 or a , in m

C_2' : Coefficient given in Tab 7 depending on S_1/d_0 . For intermediate values of S_1/d_0 , C_2' is to be determined by linear interpolation.

Reason for the Rule Clarification:

Editorial correction is made for the clarification of spacing and span of primary supporting members. (Refer to KC ID 500)

SECTION 2 AFT PART

2. Load model

2.2 Lateral pressures

2.2.1 Lateral pressure in intact condition

The aft part lateral pressure in intact conditions, in kN/m^2, is to be taken equal to ($p_S + p_W$).

where:

p_S, p_W : Hydrostatic ~~pressure~~ and ~~maximum~~ hydrodynamic pressures ~~among load cases H, F, R and P,~~ according to Ch 4, Sec 5, or internal still water and inertial pressures according to Ch 4, Sec 6, [2], to be considered among load cases H, F, R and P.

Reason for the Rule Clarification:

Editorial correction is made for the clarification of the lateral pressure in the aft part, similar to the same clarification made in the bow area in Ch. 9, Sec.1 [3.2.1]. (Refer to KC ID 495)

4. SCANTLINGS

4.1 ~~Side plating~~ Plating

Reason for the Rule Clarification:
Editorial correction.

SECTION 3 MACHINERY SPACE

1. GENERAL

1. GENERAL

1.2 Scantlings

1.2.1 Net scantlings

As specified in Ch 3, Sec 2 all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 3,~~ Sec 3 ~~<u>Sec 2, </u>~~3.1~~<u>[3.1]</u>.

<u>Reason for the Rule Clarification:</u>

Editorial correction

SECTION 4 SUPERSTRUCTURES AND DECKHOUSES

1. GENERAL

1.1 Definitions

1.1.3 Long deckhouse

A long deckhouse is a deckhouse the length of which within 0.4*L* amidships exceeds 0.2*L* ~~or 12 m, whichever is the greater~~. The strength of a long deckhouse is to be specially considered.

1.1.5 Non-effective superstructure

For the purpose of this section, all superstructures being located beyond 0.4*L* amidships or having a length of less than 0.15*L* ~~or less than 12 m~~ are considered as non-effective superstructures.

1.1.7 Effective superstructure

Effective superstructure is a superstructure not covered by the definition given in [1.1.5].

Reason for the Rule Clarification:

The definition for "Effective superstructure" is added for clarification.

In addition, considering the ship's length of CSR application, unnecessary wording "12m" which is always less than 0.15L or 0.2L is deleted.

CHAPTER 10 – HULL OUTFITTING

SECTION 1 – RUDDER AND MANOEUVRING ARRANGEMENT

3. Scantlings of the rudder stock

3.1 Rudder stock diameter

3.1.1

The diameter of the rudder stock, in ~~m~~ mm, for transmitting the rudder torque is not to be less than:

$$D_t = 4.2\sqrt[3]{Q_R\, k_r}$$

where:

Q_R : As defined in [2.1.2], [2.2.2] and [2.2.3]

The related torsional stress, in N/mm^2, is:

$$\tau_t = \frac{68}{k_r}$$

where:

k_r : As defined in [1.4.2] and[1.4.3].

Reason for the Rule Clarification:

Editorial correction

3.3 Analysis

3.3.2 Data for the analysis

ℓ_{10} ,.., ℓ_{50} : Lengths, in m, of the individual girders of the system

I_{10} ,.., I_{50} : Moments of inertia of these girders, in cm^4

For rudders supported by a sole piece the length ℓ_{20} is the distance between lower edge of rudder body and centre of sole piece, and I_{20} is the moment of inertia of the pintle in the sole piece.

Load on rudder body, in kN/m, (general):

$$p_R = \frac{C_R}{\ell_{10}\cdot 10^3}$$

Load on semi-spade rudders, in kN/m:

$$p_{R10} = \frac{C_{R2}}{\ell_{10}\cdot 10^3}$$

$$p_{R20} = \frac{C_{R1}}{\ell_{20}\cdot 10^3}$$

C_R, C_{R1}, C_{R2} : As defined in [2.1] and [2.2]

Z : Spring constant, in kN/m, of support in the sole piece or rudder horn respectively:

for the support in the sole piece (see Fig 3):

$$Z = \frac{6.18\, I_{50}}{\ell_{50}^3}$$

for the support in the rudder horn (see Fig 4):

$$Z = \frac{1}{f_b + f_t}$$

f_b : Unit displacement of rudder horn, in m/kN, due to a unit force of 1 kN acting in the centre of support

$$f_b = \frac{1.3\, d^3\, 10^8}{3\, E\, I_n}$$

$$f_b = 0.21 \frac{d^3}{I_n} \quad \text{(guidance value for steel)}$$

I_n : Moment of inertia of rudder horn, in cm^4, around the x-axis at $d/2$ (see Fig 4)

f_t : Unit displacement due to a torsional moment of the amount 1, in m/kN

$$f_t = \frac{d\, e^2}{G\, J_t}$$

~~$$f_t = \frac{d\, e^2 \sum u_i / t_i}{3.17 \cdot 10^8\, F_T^2}$$~~ $$f_t = \frac{d\, e^2 \sum u_i / t_i}{3.14 \cdot 10^8\, F_T^2} \text{ for steel}$$

G : Modulus of rigity, kN/m^2:

$$G = 7.92 \cdot 10^7 \quad \text{for steel}$$

J_t : Torsional moment of inertia, in m^4

F_T : Mean sectional area of rudder horn, in m^2

u_i : Breadth, in mm, of the individual plates forming the mean horn sectional area

t_i : Plate thickness of individual plate having breadth u_i, in mm

e, d : Distances, in m, according to Fig 4

K_{11}, K_{22}, K_{12} : Rudder horn compliance constants calculated for rudder horn with 2-conjugate elastic supports (Fig 5).The 2-conjugate elastic supports are defined in terms of horizontal displacements, y_i, by the following equations:

at the lower rudder horn bearing:

~~$y_1 = - K_{12} F_{A2} - K_{22} F_{A1}$~~ $y_1 = - K_{12} B_2 - K_{22} B_1$

at the upper rudder horn bearing:

~~$y_2 = - K_{11} F_{A2} - K_{12} F_{A1}$~~ $y_2 = - K_{11} B_2 - K_{12} B_1$

where

y_1, y_2 : Horizontal displacements, in m, at the lower and upper rudder horn bearings, respectively

~~F_{A1}, F_{A2}~~ B_1, B_2 : Horizontal support forces, in kN, at the lower and upper rudder horn bearings, respectively

K_{11}, K_{22}, K_{12} : Obtained, in m/kN, from the following formulae:

$$K_{11} = 1.3 \frac{\lambda^3}{3EJ_{1h}} + \frac{e^2 \lambda}{GJ_{th}}$$

$$K_{12} = 1.3\left[\frac{\lambda^3}{3EJ_{1h}} + \frac{\lambda^2(d-\lambda)}{2EJ_{1h}}\right] + \frac{e^2\lambda}{GJ_{th}}$$

$$K_{22} = 1.3\left[\frac{\lambda^3}{3EJ_{1h}} + \frac{\lambda^2(d-\lambda)}{EJ_{1h}} + \frac{\lambda(d-\lambda)^2}{EJ_{1h}} + \frac{(d-\lambda)^3}{3EJ_{2h}}\right] + \frac{e^2 d}{GJ_{th}}$$

d : Height of the rudder horn, in m, defined in Fig 5. This value is measured downwards from the upper rudder horn end, at the point of curvature transition, till the mid-line of the lower rudder horn pintle

λ : Length, in m, as defined in Fig 5. This length is measured downwards from the upper rudder horn end, at the point of curvature transition, till the mid-line of the upper rudder horn bearing. For $\lambda = 0$, the above formulae converge to those of spring constant Z for a rudder horn with 1-elastic support, and assuming a hollow cross section for this part

e : Rudder-horn torsion lever, in m, as defined in Fig 5 (value taken at $z = d/2$)

J_{1h} : Moment of inertia of rudder horn about the x axis, in m^4, for the region above the upper rudder horn bearing. Note that J_{1h} is an average value over the length λ (see Fig 5)

J_{2h} : Moment of inertia of rudder horn about the x axis, in m^4, for the region between the upper and lower rudder horn bearings. Note that J_{2h} is an average value over the length $d - \lambda$ (see Fig 5)

J_{th} : Torsional stiffness factor of the rudder horn, in m^4

For any thin wall closed section

$$J_{th} = \frac{4F_T^2}{\sum_i \frac{u_i}{t_i}}$$

F_T : Mean of areas enclosed by outer and inner boundaries of the thin walled section of rudder horn, in m^2

u_i : Length, in mm, of the individual plates forming the mean horn sectional area

t_i : Thickness, in mm, of the individual plates mentioned above.

Note that the J_{th} value is taken as an average value, valid over the rudder horn height.

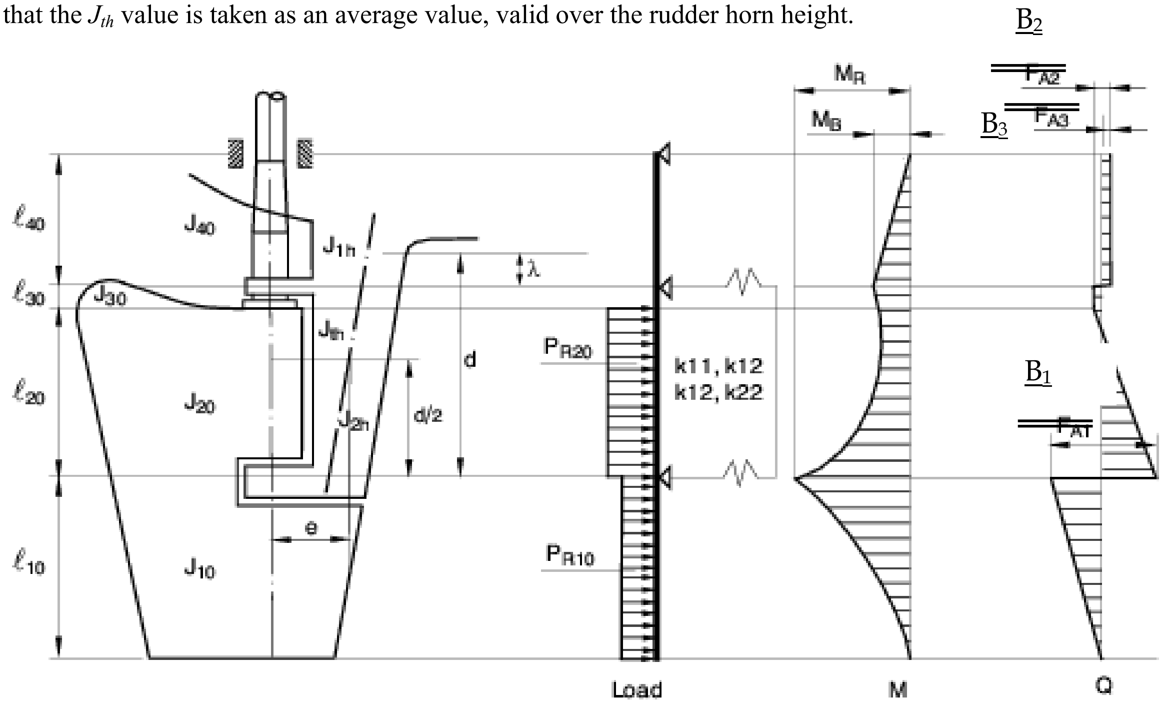


Figure 5 Semi-spade rudder (with 2-conjugate elastic supports)

Reason for the Rule Clarification:

Editorial correction is made to be in line with IACS UR S10. (Refer to KC ID 558)

3.4 Rudder trunk

3.4.4

The weld at the connection between the rudder trunk and the shell or the bottom of the skeg is to be full penetration.

The fillet shoulder radius r, in mm, is to be as large as practicable and to comply with the following formulae:

$r = 60$ when $\sigma \geq 40 / k$ N/mm^2

$r = 0.1D_1$, without being less than 30, when $\sigma < 40 / k$ N/mm^2

~~without being less than 30,~~

where D_1 is defined in [3.2.1].

The radius may be obtained by grinding. If disk grinding is carried out, score marks are to be avoided in the direction of the weld.

The radius is to be checked with a template for accuracy. Four profiles at least are to be checked. A report is to be submitted to the Surveyor.

Reason for the Rule Clarification:

Editorial correction

5. Rudder body, rudder bearings

5.1 Strength of rudder body

5.1.3

For rudder bodies without cut-outs the permissible stress are limited to:

- bending stress, in N/mm^2, due to M_R defined in [3.3.3]:

  $\sigma_b = 110$

- shear stress, in N/mm^2, due to Q_1 defined in [3.3.3]:

  $\tau_t = 50$

- equivalent stress, in N/mm^2, due to bending and shear:

  ~~$\sigma_v = \sqrt{\sigma \frac{2}{b} + 3\tau^2} = 120$~~ $\sigma_v = \sqrt{\sigma_b{}^2 + 3\tau^2} = 120$

In case of openings in the rudder plating for access to cone coupling or pintle nut the permissible stresses according to [5.1.4] apply. Smaller permissible stress values may be required if the corner radii are less than $0.15h_o$, where h_o is the height of opening.

Reason for the Rule Clarification:

Editorial correction

5.2 Rudder plating

5.2.1

The thickness of the rudder plating, in mm, is to be determined according to the following formula:

~~$t_P = 1.74a\sqrt{p_R k} + 2.5$~~ $t_P = 1.74a\beta\sqrt{p_R k} + 2.5$

where:

$p_R = 10T + \frac{C_R}{10^3 A}$, in kN/m^2

a : Smaller unsupported width of a plate panel, in m.

~~The influence of the aspect ratio of the plate panels may be taken into account according to Ch 3.~~

$\beta = \sqrt{1.1 - 0.5\left(\frac{a}{b}\right)^2}$ max, 1.00, if $\frac{b}{a} \geq 2.5$

b greatest unsupported width of a plate panel, in m.

However, the thickness is to be not less than the thickness of the shell plating at aft part according to Ch 9, Sec 2.

Regarding dimensions and welding, [10.1.1] is to be comply with.

Reason for the Rule Clarification:

Editorial correction is made to be in line with IACS UR S10 (Refer to KC 569)

10. Rudder coupling flanges

10.1.3

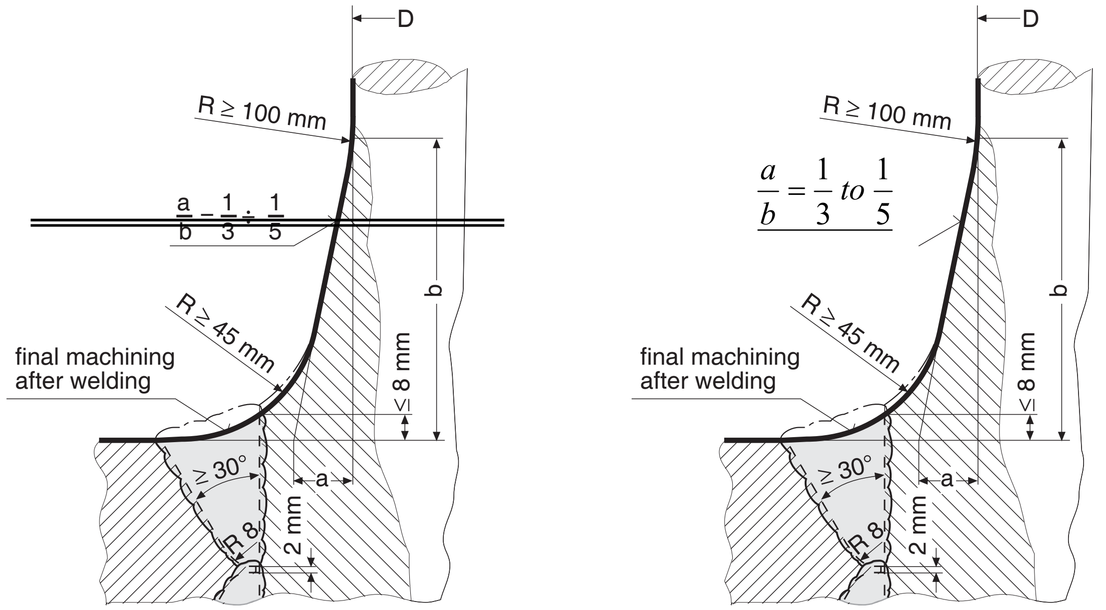


Figure 21 Welded joint between rudder stock and coupling flange

Reason for the Rule Clarification:

Editorial correction

CHAPTER 11 –CONSTRUCTION AND TESTING

SECTION 2 WELDING

2. Types of welded connection

2.6 Fillet welds

Table 1 Categories of fillet welds

Category	Kinds of fillet welds	As-built thickness of abutting plate, t, in mm (1)	Leg length of fillet weld, in mm (2)	Length of fillet welds, in mm	Pitch, in mm
F0	Double continuous weld	t	$0.7t$	-	-
F1	Double continuous weld	$t \leq 10$	$0.5t + 1.0$	-	-
		$10 \leq t < 20$	$0.4t + 2.0$	-	-
		$20 \leq t$	$0.3t + 4.0$	-	-
F2	Double continuous weld	$t \leq 10$	$0.4t + 1.0$	-	-
		$10 \leq t < 20$	$0.3t + 2.0$	-	-
		$20 \leq t$	$0.2t + 4.0$	-	-
F3	Double continuous weld	$t \leq 10$	$0.3t + 1.0$	-	-
		$10 \leq t < 20$	$0.2t + 2.0$		
		$20 \leq t$	$0.1t + 4.0$		
F4	Intermittent weld	$t \leq 10$	$0.5t + 1.0$	75	300
		$10 \leq t < 20$	$0.4t + 2.0$		
		$20 \leq t$	$0.3t + 4.0$		

(1) t is as-built thickness of the thinner of two connected members

(2) Leg length of fillet welds is made fine adjustments corresponding to the corrosion addition t_C specified in Ch 3, Sec 3, Tab 1 as follows:
+ 1.0 mm for $t_C > 5$
+ 0.5 mm for $5 \geq t_C > 4$
+ 0.0 mm for $4 \geq t_C > 3$
- 0.5 mm for $t_C \leq 3$

(3) The weld sizes are to be rounded to the nearest half millimeter.

Reason for the Rule Clarification:
Editorial correction is made for clarification of the weld size in order to harmonize the CSR for double hull oil tanker. (Refer to KC ID 507)

2.6.2 Intermittent welds

Where double continuous fillet welds in lieu of intermittent welds are applied, leg length of fillet welds is to be of category ~~F2~~ F3.

Reason for the Rule Clarification:

It is a typo. As its application is limited to weld connection of the secondary member not importance structural members, the lowest double continuous category, e.g., F3, was originally intended in lieu of the intermittent weld. (Refer to KC ID 508)