# Common Structural Rules for Bulk Carriers, July 2008

# Rule Change Notice No. 1
# January 2009

Notes: (1) These Rule Changes enter into force on 1 July 2009.

# Table of Contents

# Common Structural Rules for Bulk Carriers, July 2008

# Rule Change Notice No.1-1 (Hull Girder Strength)

Notes: (1) These Rule Changes enter into force on 1 July 2009.

For technical background for Rule Changes in this present document, reference is made to separate document Technical Background for Rule Change Notice No.1-1.

# CHAPTER 5 HULL GIRDER STRENGTH

## Section 1 YIELDING CHECK

## 2. Hull girder stresses

### 2.2 Shear stresses

#### 2.2.2 Simplified calculation of shear stresses induced by vertical shear forces

The shear stresses induced by the vertical shear forces in the calculation point are obtained, in N/mm$^2$, from the following formula:

$$\tau_1 = \left(Q_{SW} + Q_{WV} - \varepsilon \Delta Q_C\right) \frac{S}{I_Y t} \delta$$

where:

$t$ : Minimum net thickness, in mm, of side and inner side plating, as applicable according to Tab 1

$\delta$ : Shear distribution coefficient defined in Tab 1

$\varepsilon = \text{sgn}\left(Q_{SW}\right)$

$\Delta Q_C$ : Shear force correction (see Fig 2) at the section considered. The shear force correction is to be considered independently forward and aft of the transverse bulkhead for the hold considered. ~~, which~~ The shear force correction takes into account, when applicable, the portion of loads transmitted by the double bottom girders to the transverse bulkheads:

- for ships with any non-homogeneous loading conditions, such as alternate hold loading conditions and heavy ballast conditions carrying ballast in hold(s):

~~$\Delta Q_C = \alpha \left| \frac{M}{B_H \ell_H} - \rho T_{LC} \right|$~~ $\Delta Q_C = \alpha \left| \frac{M}{B_H \ell_H} - \rho T_{LC,mh} \right|$ for each non-homogeneous loading condition

- for other ships and homogeneous loading conditions:

$\Delta Q_C = 0$

$\varphi = 1.38 + 1.55 \frac{\ell_0}{b_0}$, to be taken not greater than 3.7

$$\alpha = g \frac{\ell_0 b_0}{2 + \varphi \frac{\ell_0}{b_0}}$$

$\ell_0$ , $b_0$ : Length and breadth, respectively, in m, of the flat portion of the double bottom in way of the hold considered; $b_0$ is to be measured on the hull transverse section at the middle of the hold

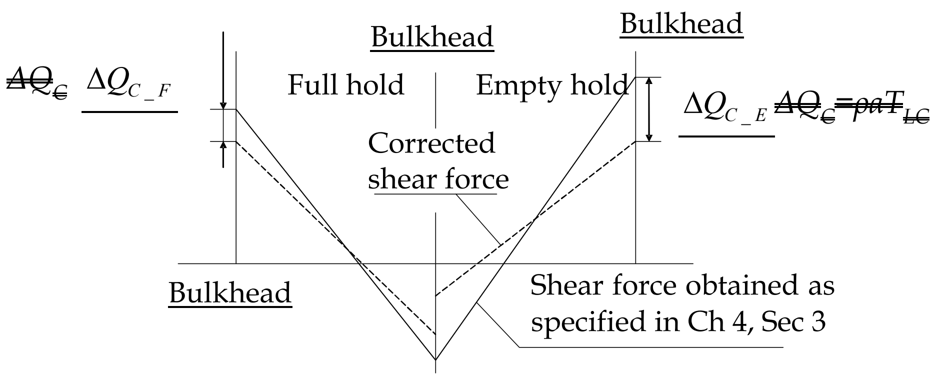
$\ell_H$ : Length, in m, of the hold considered, measured between the middle of the transverse corrugated bulkheads depth

$B_H$ : Ship's breadth, in m, measured at the level of inner bottom on the hull transverse section at the middle of the hold considered

$M$ : ~~Total mass of cargo, in t, in the hold of the section considered~~ Mass, in t, in the considered section.

- Adjacent cargo hold is loaded in a non homogeneous loading condition for the condition under consideration
  M is to include the total mass in the hold and the mass of water ballast in double bottom tank, bounded by side girders in way of hopper tank plating or longitudinal bulkhead.
- Other cases
  M is the total mass in the hold.

~~$T_{LC}$~~ $T_{LC,mh}$ : Draught, in m, measured vertically on the hull transverse section at the middle of the hold considered, from the moulded baseline to the waterline in the loading condition considered.




$\Delta Q_{C\_F}$ : shear force correction for the full hold

$\Delta Q_{C\_E}$ : shear force correction for the empty hold

**Figure 2: Shear force correction $\Delta Q_C$**

**Table 1: Shear stresses induced by vertical shear forces**

| Ship typology | Location | *t*, in mm | $\delta$ |
|---|---|---|---|
| Single side ship | Sides | $t_S$ | 0,5 |
| Double side ship | Sides | $t_S$ | $0.5(1-\phi)$ |
| | Inner sides | $t_{IS}$ | $0.5\phi$ |

where:

$t_S$, $t_{IS}$ : Minimum net thicknesses, in mm, of side and inner side, respectively

$t_{SM}$, $t_{ISM}$ : Mean net thicknesses, in mm, over all the strakes of side and inner side , respectively. They are calculated as $\Sigma(\ell_i\, t_i) / \Sigma\ell_i$, where $\ell_i$ and $t_i$ are the length, in m, and the net thickness, in mm, of the i$^{th}$ strake of side and inner side.

$\phi$ : Coefficient taken equal to: $\phi = 0.275 + 0.25\dfrac{t_{ISM}}{t_{SM}}$

#### 2.2.3 Shear stresses in flooded conditions of BC-A or BC-B ships

This requirement applies to BC-A or BC-B ships, in addition to [2.2.1] and [2.2.2].

The shear stresses, in the flooded conditions specified in Ch 4, Sec 3, are to be obtained at the calculation ~~any~~ point, in N/mm$^2$, from the following formula:

$$\tau_1 = \left(Q_{SW,F} + Q_{WV,F} - \varepsilon\Delta Q_C\right)\frac{S}{I_Y t}\delta$$

$$\varepsilon = \mathrm{sgn}\,(Q_{SW,F})$$

$\Delta Q_C$ : Shear force correction, to be calculated according to [2.2.2],where the mass ~~*M* is to include the mass~~ of the ingressed water ~~in the hold considered~~ is to be added to *M* and where the draught ~~$T_{LC}$~~ $T_{LC,mh}$ is to be measured up to the equilibrium waterline.

*t* : Net thickness, in mm, of the side plating.

# 5. Permissible still water bending moment and shear force

## 5.1 Permissible still water bending moment and shear force stresses

### 5.1.3 Permissible still water shear force - Simplified calculation

Where the shear stresses are obtained through the simplified procedure in [2.2.2], the permissible positive or negative still water shear force in intact condition at any hull transverse section is obtained, in *kN*, from the following formula:

$$Q_P = \varepsilon\left(\frac{120}{k\delta}\frac{I_Y t}{S} + \Delta Q_C\right) - Q_{WV}$$

where:

$$\varepsilon = \mathrm{sgn}(Q_{SW})$$

$\delta$ : Shear distribution coefficient defined in Tab 1

$t$ : Minimum net thickness, in mm, of side and inner side plating, as applicable according to Tab 1

$\Delta Q_C$ : Shear force corrections defined in [2.2.2], to be considered independently forward and aft of the transverse bulkhead.

A lower value of the permissible still water shear force may be considered, if requested by the Shipbuilder.

# 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 $m^3$, at bottom and deck, respectively, defined in Ch 5, Sec 1, [1.4.2].

$R_{eHs}$ : Minimum yield stress, in $N/mm^2$, of the material of the considered stiffener.

$R_{eHp}$ : Minimum yield stress, in $N/mm^2$, of the material of the considered plate.

As : Net sectional area, in $cm^2$, of stiffener, without attached plating

$A_p$ : Net sectional area, in $cm^2$, of attached plating

## 2. Criteria for the calculation of the curve M-$\chi$

### 2.1 Simplified method based on a incremental-iterative approach

#### 2.1.1 Procedure

The curve $M$-$\chi$ is to be obtained by means of an incremental-iterative approach, summarised in the flow chart in Fig 1.

In this approach, the ultimate hull girder bending moment capacity $M_U$ is defined as the peak value of the curve with vertical bending moment $M$ versus the curvature $\chi$ of the ship cross section as shown in Fig 1**.** The curve is to be obtained through an incremental-iterative approach.

Each step of the incremental procedure is represented by the calculation of the bending moment $M_i$ which acts on the hull transverse section as the effect of an imposed curvature $\chi_i$.

For each step, the value $\chi_i$ is to be obtained by summing an increment of curvature $\Delta\chi$ to the value relevant to the previous step $\chi_{i-1}$.This increment of curvature corresponds to an increment of the rotation angle of the hull girder transverse section around its horizontal neutral axis.

This rotation increment induces axial strains $\varepsilon$ in each hull structural element, whose value depends on the position of the element. In hogging condition, the structural elements above the neutral axis are lengthened, while the elements below the neutral axis are shortened. Vice-versa in sagging condition.

The stress $\sigma$ induced in each structural element by the strain $\varepsilon$ is to be obtained from the load-end shortening curve $\sigma$-$\varepsilon$ of the element, which takes into account the behaviour of the element in the non-linear elasto-plastic domain.

The distribution of the stresses induced in all the elements composing the hull transverse section determines, for each step, a variation of the neutral axis position, since the relationship $\sigma$-$\varepsilon$ is non-linear. The new position of the neutral axis relevant to the step considered is to be obtained by means of an iterative process, imposing the equilibrium among the stresses acting in all the hull elements.

Once the position of the neutral axis is known and the relevant stress distribution in the section structural elements is obtained, the bending moment of the section $M_i$ around the new position of the neutral axis, which corresponds to the curvature $\chi_i$ imposed in the step considered, is to be obtained by summing the contribution given by each element stress.

The main steps of the incremental-iterative approach described above are summarised as follows (see also Fig 1):

**Step 1** Divide the transverse section of hull into stiffened plate elements.

**Step 2** Define stress-strain relationships for all elements as shown in Tab 1

**Step 3** Initialize curvature $\chi_1$ and neutral axis for the first incremental step with the value of incremental curvature (curvature that induces a stress equal to 1% of yield strength in strength deck) as:

$$\chi_1 = \Delta\chi = \frac{0.01\frac{R_{eH}}{E}}{z_D - N}$$

where:

$z_D$ : Z co-ordinate, in m, of strength deck at side, with respect to reference co-ordinate defined in Ch 1, Sec 4, [4]

**Step 4** Calculate for each element the corresponding strain ~~$\varepsilon_i = \chi z_i$~~ $\varepsilon_i = \chi\ (z_i - z_{NA})$ and the corresponding stress $\sigma_i$

**Step 5** Determine the neutral axis $z_{NA\_cur}$ at each incremental step by establishing force equilibrium over the whole transverse section as:

$\Sigma A_i\ \sigma_i = \Sigma A_j\ \sigma_j$ (i-th element is under compression, j-th element under tension)

**Step 6** Calculate the corresponding moment by summing the contributions of all elements as:

$$M_U = \sum \sigma_{Ui} A_i \left|(z_i - z_{NA\_cur})\right|$$

**Step 7** Compare the moment in the current incremental step with the moment in the previous incremental step. If the slope in $M$-$\chi$ relationship is less than a negative fixed value, terminate the process and define the peak value of $M_U$. Otherwise, increase the curvature by the amount of $\Delta\chi$ and go to **Step 4**.

### 2.1.3 Modeling of the hull girder cross section

Hull girder transverse sections are to be considered as being constituted by the members contributing to the hull girder ultimate strength.

Sniped stiffeners are also to be modeled imaginarily, taking account that they doesn't contribute to the hull girder strength.

The structural members are categorized into an ordinary stiffener element, a stiffened plate element or a hard corner element.

The plate panel including web plate of girder or side stringer is idealized into either a stiffened plate element, an attached plate of an ordinary stiffener element or a hard corner element.

The plate panel is categorized into the following two kinds:

- longitudinally stiffened panel of which the longer side is in the longitudinal direction, and
- transversely stiffened panel of which the longer side is in the perpendicular direction to the longitudinal direction.

- Hard corner element

Hard corner elements are sturdier elements composing the hull girder transverse section, which collapse mainly according to an elasto-plastic mode of failure (material yielding); they are generally constituted by two plates not lying in the same plane.

The extent of a hard corner element from the point of intersection of the plates is taken equal to $20t_p$ on transversely stiffened panel and to 0.5*s* on a longitudinally stiffened panel. (See Fig 6)

where:

$t_p$ : Gross offered thickness of the plate, in mm

$s$ : Spacing of the adjacent longitudinal stiffener, in m

Bilge, sheer strake-deck stringer elements, girder-deck connections and face plate-web connections on large girders are typical hard corners.

- Ordinary stiffener element

The ordinary stiffener constitutes an ordinary stiffener element together with the attached plate.

The attached plate width is in principle:

- equal to the mean spacing of the ordinary stiffener when the panels on both sides of the stiffener are longitudinally stiffened, or
- equal to the width of the longitudinally stiffened panel when the panel on one side of the stiffener is longitudinally stiffened and the other panel is of the transversely stiffened. (See Fig 6)

- Stiffened plate element

The plate between ordinary stiffener elements, between an ordinary stiffener element and a hard corner element or between hard corner elements is to be treated as a stiffened plate element. (See Fig 6)

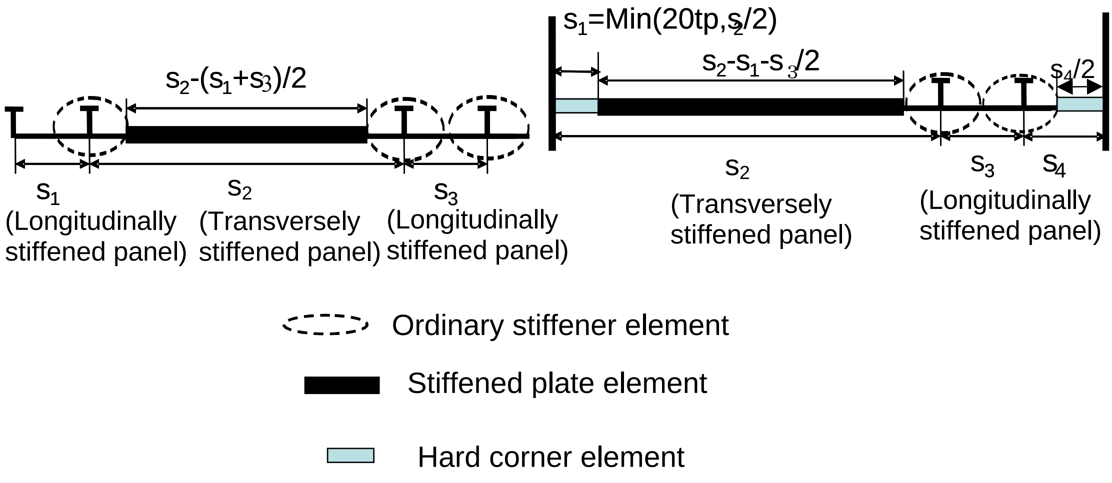



**Figure 6: Extension of the breadth of the attached plating and hard corner element**

The typical examples of modeling of hull girder section are illustrated in Figs 7 and 8.

Notwithstanding the foregoing principle these figures are to be applied to the modeling in the vicinity of upper deck, sheer strake and hatch side girder.

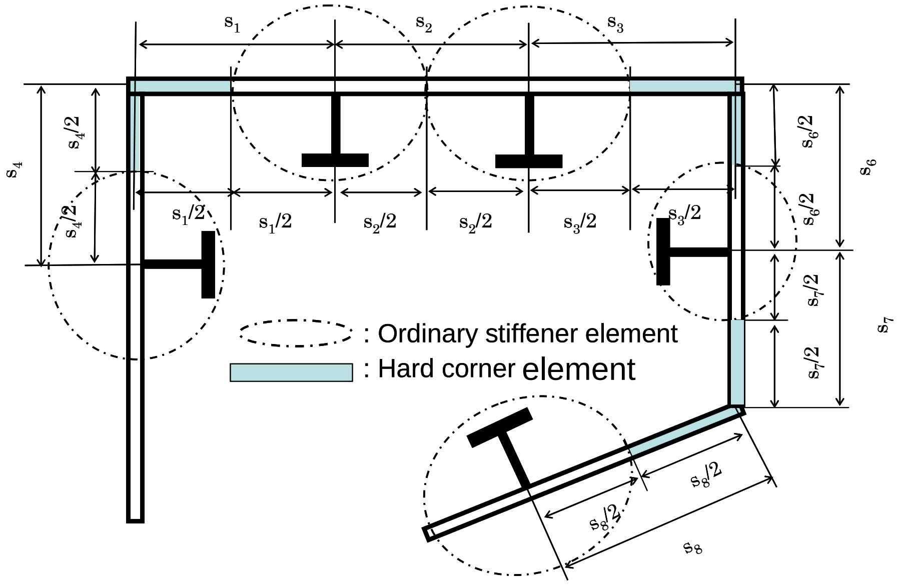



**Figure 7: Extension of the breadth of the attached plating and hard corner element**

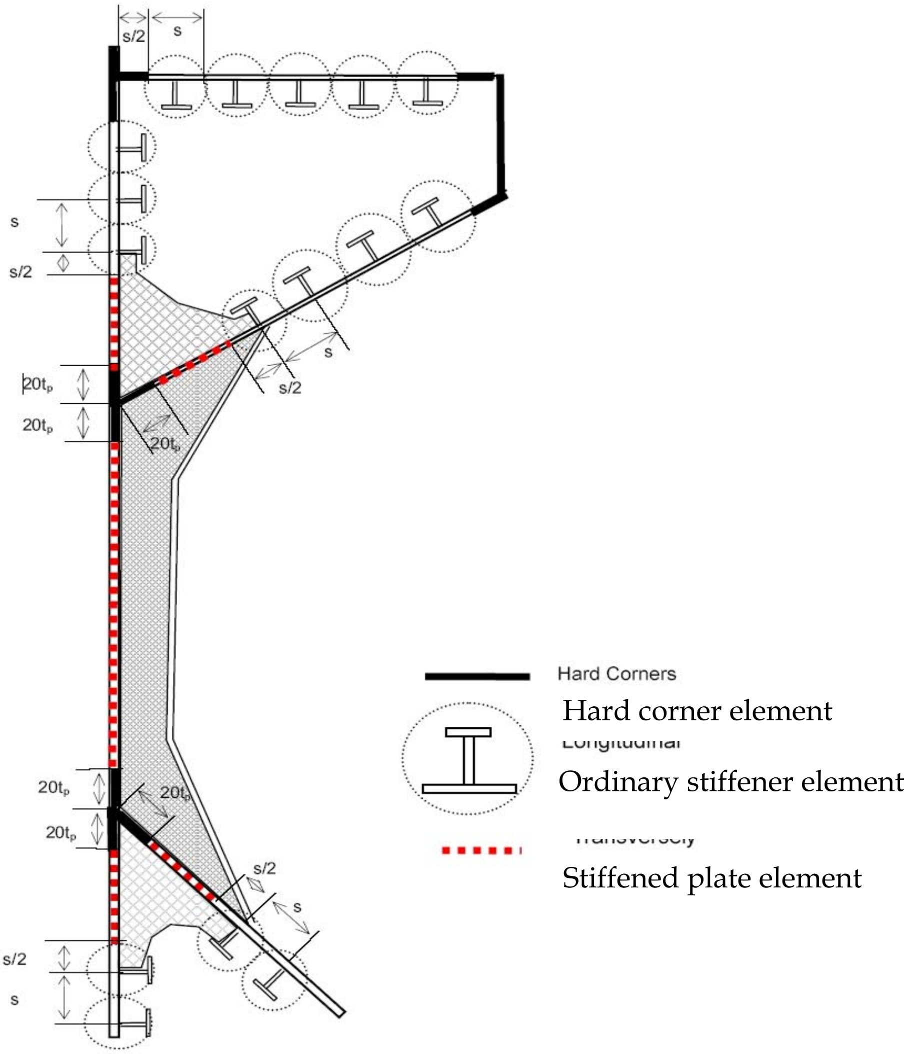



**Figure 8: Examples of the configuration of stiffened plate elements, ordinary stiffener elements and hard corner elements on a hull section**

(Note)

(1) In case of the knuckle point as shown in Fig 9, the plating area adjacent to knuckles in the plating with an angle greater than 30 degrees is defined as a hard corner. The extent of one side of the corner is taken equal to $20t_p$ on transversely framed panels and to $0.5s$ on longitudinally framed panels from the knuckle point.

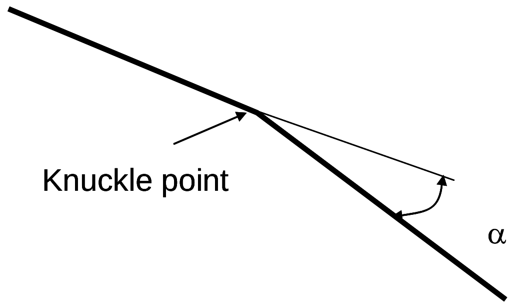



**Figure 9: The case of plating with knuckle point**

(2) Where the plate members are stiffened by non-continuous longitudinal stiffeners, the non-continuous stiffeners are considered only as dividing a plate into various elementary plate panels.

(3) Where the opening is provided in the stiffened plate element, the openings are to be considered in accordance with Ch 5 Sec 1, [1.2.7], [1.2.8] and [1.2.9].

(4) Where attached plating is made of steels having different thicknesses and/or yield stresses, an average thickness and/or average yield stress obtained by the following formula are to be used for the calculation.

$$t = \frac{t_1 s_1 + t_2 s_2}{s}, \qquad R_{eHp} = \frac{R_{eHp1} t_1 s_1 + R_{eHp2} t_2 s_2}{ts}$$

Where,

$R_{eH1}$, $R_{eH2}$, $t_1$, $t_2$, $s_1$, $s_2$ and s are shown in Fig 10.

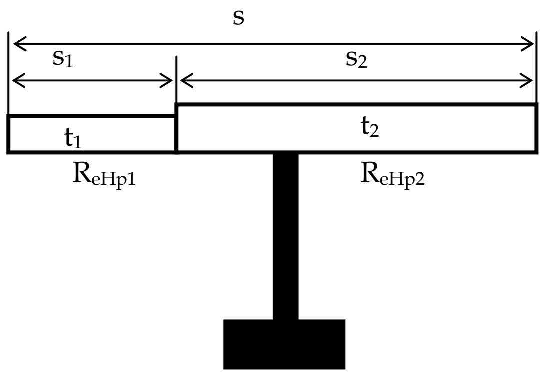



**Figure 10: Element with different thickness and yield strength**

## 2.2 Load-end shortening curves σ-ε

### 2.2.1 Stiffened plate element ~~Plating panels~~ and ordinary stiffener~~s~~ element

Stiffened plate element ~~Plating panels~~ and ordinary stiffener~~,~~ element composing the hull girder transverse sections may collapse following one of the modes of failure specified in Tab 1.

- Where the plate members are stiffened by non-continuous longitudinal stiffeners, the stress of the element is to be obtained in accordance with [2.2.3] to [2.2.7], taking into account the non-continuous longitudinal stiffener.

  In calculating the total forces for checking the hull girder ultimate strength, the area of non-continuous longitudinal stiffener is to be assumed as zero.

- Where the opening is provided in the stiffened plate element, the considered area of the stiffened plate element is to be obtained by deducting the opening area from the plating in calculating the total forces for checking the hull girder ultimate strength. The consideration of the opening is in accordance with the requirement in Ch 5 Sec 1, [1.2.7] to [1.2.9].
- For stiffened plate element, the effective breadth of plate for the load shortening portion of the stress-strain curve is to be taken as full plate breadth, i.e. to the intersection of other plate or longitudinal stiffener – not from the end of the hard corner element nor from the attached plating of ordinary stiffener element, if any. In calculating the total forces for checking the hull girder ultimate strength, the area of the stiffened plate element is to be taken between the hard corner element and the ordinary stiffener element or between the hard corner elements, as applicable.

**Table 1: Modes of failure of stiffened plate element ~~plating panel~~ and ordinary stiffener~~s~~ element**

| Element | Mode of failure | Curve $\sigma$–$\varepsilon$ defined in |
|---|---|---|
| Lengthened stiffened plate element ~~transversely framed plating panel~~ or ordinary stiffener~~s~~ element | Elasto-plastic collapse | [2.2.3] |
| Shortened ordinary stiffener~~s~~ element | Beam column buckling<br>Torsional buckling<br>Web local buckling of flanged profiles<br>Web local buckling of flat bars | [2.2.4]<br>[2.2.5]<br>[2.2.6]<br>[2.2.7] |
| Shortened stiffened plate element ~~transversely framed plating panel~~ | Plate buckling | [2.2.8] |

### 2.2.2 Hard corner~~s~~ element

~~Hard corners are sturdier elements composing the hull girder transverse section, which collapse mainly according to an elasto-plastic mode of failure (material yielding). These elements are generally constituted of two plates not lying in the same plane. Bilge, sheer strake-deck stringer elements, girder-deck connections and face plate-web connections on large girders are typical hard corners.~~

The relevant load-end shortening curve σ-ε is to be obtained for lengthened and shortened hard corners according to [2.2.3].

### 2.2.3 Elasto-plastic collapse of structural elements

The equation describing the load-end shortening curve $\sigma$-$\varepsilon$ for the elasto-plastic collapse of structural elements composing the hull girder transverse section is to be obtained from the following formula, valid for both positive (shortening) and negative (lengthening) strains (see Fig 2):

~~$\sigma = \Phi R_{eH}$~~ $\sigma = \Phi R_{eHA}$

where:

$R_{eHA}$ : Equivalent minimum yield stress, in N/mm$^2$, of the considered element, obtained by the following formula

$$R_{eHA} = \frac{R_{eHp} A_p + R_{eHs} A_s}{A_p + A_s}$$

$\Phi$ : Edge function, equal to:

$\Phi = -1$ for $\varepsilon < -1$

$\Phi = \varepsilon$ for $-1 \le \varepsilon \le 1$

$\Phi = 1$ for $\varepsilon > 1$

$\varepsilon$ : Relative strain, equal to:

$$\varepsilon = \frac{\varepsilon_E}{\varepsilon_Y}$$

$\varepsilon_E$ : Element strain

$\varepsilon_Y$ : Strain at yield stress in the element, equal to:

~~$\varepsilon_Y = \frac{R_{eH}}{E}$~~ $\varepsilon_Y = \frac{R_{eHA}}{E}$

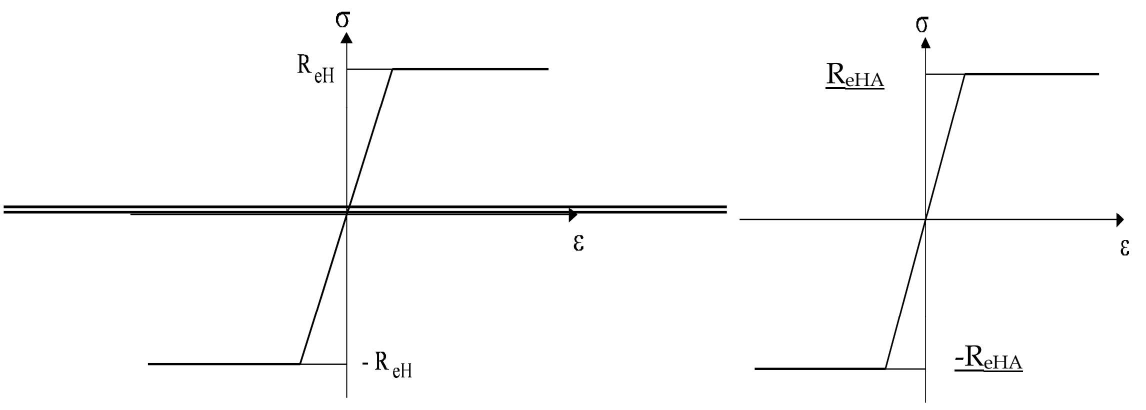



**Figure 2: Load-end curve $\sigma$-$\varepsilon$ for elasto plastic collapse**

### 2.2.4 Beam column buckling

The equation describing the load-end shortening curve $\sigma_{CR1}$-$\varepsilon$ for the beam column buckling of ordinary stiffeners composing the hull girder transverse section is to be obtained from the following formula (see Fig 3):

~~$\sigma_{CR1} = \Phi \sigma_{C1} \frac{A_{Stif} + 10 b_E t_p}{A_{Stif} + 10 s t_p}$~~ $\sigma_{CR1} = \Phi \sigma_{C1} \frac{A_S + A_{pE}}{A_S + A_p}$

where:

$\Phi$ : Edge function defined in [2.2.3]

~~$A_{Stif}$ : Net sectional area of the stiffener, in cm², without attached plating~~

$\sigma_{C1}$ : Critical stress, in N/mm², equal to:

$$\sigma_{C1} = \frac{\sigma_{E1}}{\varepsilon} \quad \text{for } \sout{\sigma_{E1} \le \frac{R_{eH}}{2}\varepsilon} \quad \sigma_{E1} \le \frac{R_{eHB}}{2}\varepsilon$$

~~$$\sigma_{C1} = R_{eH}\left(1 - \frac{R_{eH}\,\varepsilon}{4\sigma_{E1}}\right) \quad \text{for } \sigma_{E1} > \frac{R_{eH}}{2}\varepsilon$$~~

$$\sigma_{C1} = R_{eHB}\left(1 - \frac{R_{eHB}\,\varepsilon}{4\sigma_{E1}}\right) \quad \text{for } \sigma_{E1} > \frac{R_{eHB}}{2}\varepsilon$$

$R_{eHB}$ : Equivalent minimum yield stress, in N/mm², of the considered element, obtained by the following formula

$$R_{eHB} = \frac{R_{eHp} A_{pE1} l_{pE} + R_{eHs} A_s l_{sE}}{A_{pE1} l_{pE} + A_s l_{sE}}$$

$A_{pE1}$ : Effective area, in cm², equal to

$$A_{pE1} = 10 b_{E1} t_p$$

$l_{pE}$ : Distance, in mm, measured from the neutral axis of the stiffener with attached plate of width $b_{E1}$ to the bottom of the attached plate

$l_{sE}$ : Distance, in mm, measured from the neutral axis of the stiffener with attached plate of width $b_{E1}$ to the top of the stiffener

$\varepsilon$ : Relative strain defined in [2.2.3]

$\sigma_{E1}$ : Euler column buckling stress, in N/mm², equal to:

$$\sigma_{E1} = \pi^2 E \frac{I_E}{A_E l^2} 10^{-4}$$

$I_E$ : Net moment of inertia of ordinary stiffeners, in cm⁴, with attached shell plating of width $b_{E1}$

$b_{E1}$ : Effective width, in m, of the attached shell plating, equal to:

$$b_{E1} = \frac{s}{\beta_E} \quad \text{for } \beta_E > 1.0$$

$$b_{E1} = s \quad \text{for } \beta_E \le 1.0$$

~~$$\beta_E = 10^3 \frac{s}{t_p}\sqrt{\frac{\varepsilon R_{eH}}{E}}$$~~

$$\beta_E = 10^3 \frac{s}{t_p}\sqrt{\frac{\varepsilon R_{eHp}}{E}}$$

~~$A_E$~~ $A_{pE}$ : Net sectional area, in cm², of ~~ordinary stiffeners with~~ attached shell plating of width $b_E$, equal to:

$$A_{pE} = 10 b_E t_p$$

$b_E$ : Effective width, in m, of the attached shell plating, equal to:

$$b_E = \left( \frac{2.25}{\beta_E} - \frac{1.25}{\beta_E^2} \right) s \quad \text{for } \beta_E > 1.25$$

$$b_E = s \quad \text{for } \beta_E \le 1.25$$

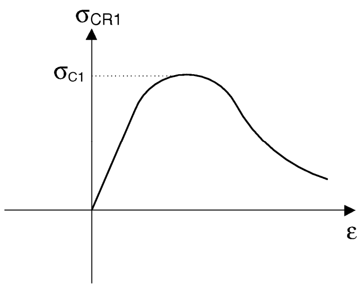



**Figure 3: Load-end shortening curve $\sigma_{CR1}$-$\varepsilon$ for beam column buckling**

### 2.2.5 Torsional buckling

The equation describing the load-end shortening curve $\sigma_{CR2}$-$\varepsilon$ for the flexural-torsional buckling of ordinary stiffeners composing the hull girder transverse section is to be obtained according to the following formula (see Fig 4).

$$~~\sigma_{CR2} = \Phi \frac{A_{Stiff}\sigma_{C2} + 10st_p\sigma_{CP}}{A_{Stiff} + 10st_p}~~ \qquad \sigma_{CR2} = \Phi \frac{A_s\sigma_{C2} + A_p\sigma_{CP}}{A_s + A_p}$$

where:

$\Phi$ : Edge function defined in [2.2.3]

~~$A_{Stiff}$ : Net sectional area of stiffener, in cm$^2$, without attached plate~~

$\sigma_{C2}$ : Critical stress, in N/mm$^2$, equal to:

$$\sigma_{C2} = \frac{\sigma_{E2}}{\varepsilon} \quad \text{for } ~~\sigma_{E2} \le \frac{R_{eH}}{2}\varepsilon~~ \quad \sigma_{E2} \le \frac{R_{eHs}}{2}\varepsilon$$

$$~~\sigma_{C2} = R_{eH}\left(1 - \frac{R_{eH}\,\varepsilon}{4\sigma_{E2}}\right) \quad \text{for } \sigma_{E2} > \frac{R_{eH}}{2}\varepsilon~~$$

$$\sigma_{C2} = R_{eHs}\left(1 - \frac{R_{eHs}\,\varepsilon}{4\sigma_{E2}}\right) \quad \text{for } \sigma_{E2} > \frac{R_{eHs}}{2}\varepsilon$$

$\sigma_{E2}$ : Euler torsional buckling stress, in N/mm$^2$, defined in Ch 6, Sec 3, [4.3]

$\varepsilon$ : Relative strain defined in [2.2.3]

$\sigma_{CP}$ : Buckling stress of the attached plating, in N/mm$^2$, equal to:

$$~~\sigma_{CP} = \left( \frac{2.25}{\beta_E} - \frac{1.25}{\beta_E^2} \right) R_{eH}~~ \qquad \sigma_{CP} = \left( \frac{2.25}{\beta_E} - \frac{1.25}{\beta_E^2} \right) R_{eHp} \quad \text{for } \beta_E > 1.25$$

$$~~\sigma_{CP} = R_{eH}~~ \qquad \sigma_{CP} = R_{eHp} \quad \text{for } \beta_E \le 1.25$$

$\beta_E$ : Coefficient defined in [2.2.4]

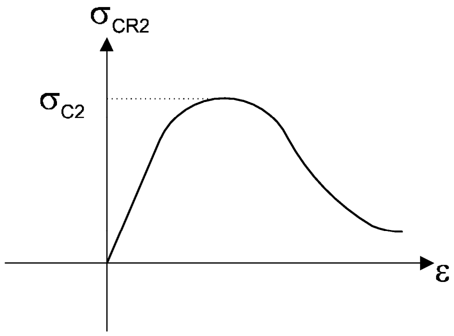



**Figure 4: Load-end shortening curve $\sigma_{CR2}$-$\varepsilon$ for flexural-torsional buckling**

### 2.2.6 Web local buckling of ordinary stiffeners made of flanged profiles

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

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

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

where

$\Phi$ : 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:

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

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

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

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

$\varepsilon$ : Relative strain defined in [2.2.3]

### 2.2.7 Web local buckling of ordinary stiffeners made of flat bars

The equation describing the load-end shortening curve $\sigma_{CR4}$-$\varepsilon$ for the web local buckling of flat bar ordinary stiffeners composing the hull girder transverse section is to be obtained from the following formula (see Fig 5):

~~$\sigma_{CR4} = \Phi \dfrac{10 s t_P \sigma_{CP} + A_{Stiff} \sigma_{C4}}{A_{Stiff} + 10 s t_P}$~~

$$\sigma_{CR4} = \Phi \frac{A_p \sigma_{CP} + A_s \sigma_{C4}}{A_p + A_s}$$

where:

$\Phi$ : Edge function defined in [2.2.3]

~~$A_{Stiff}$ : Net sectional area of stiffener, in cm$^2$, without attached plate~~

$\sigma_{CP}$ : Buckling stress of the attached plating, in N/mm$^2$, defined in [2.2.5]

$\sigma_{C4}$ : Critical stress, in N/mm$^2$, equal to:

$$\sigma_{C4} = \frac{\sigma_{E4}}{\varepsilon} \qquad \text{for } ~~\sigma_{E4} \le \frac{R_{eH}}{2}\varepsilon~~ \quad \sigma_{E4} \le \frac{R_{eHs}}{2}\varepsilon$$

~~$$\sigma_{C4} = R_{eH}\left(1 - \frac{R_{eH}\,\varepsilon}{4\sigma_{E4}}\right) \qquad \text{for } \sigma_{E4} > \frac{R_{eH}}{2}\varepsilon$$~~

$$\sigma_{C4} = R_{eHs}\left(1 - \frac{R_{eHs}\,\varepsilon}{4\sigma_{E4}}\right) \qquad \text{for } \sigma_{E4} > \frac{R_{eHs}}{2}\varepsilon$$

$\sigma_{E4}$ : Local Euler buckling stress, in N/mm$^2$, equal to:

$$\sigma_{E4} = 160000\left(\frac{t_w}{h_w}\right)^2$$

$\varepsilon$ : Relative strain defined in [2.2.3].

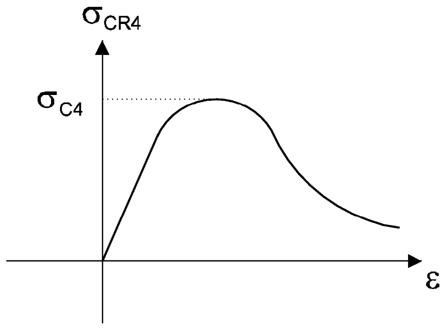



**Figure 5: Load-end shortening curve $\sigma_{CR4}$-$\varepsilon$ for web local buckling**

### 2.2.8 Plate buckling

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

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

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

where:

$\Phi$ : Edge function defined in [2.2.3].

~~$$\beta_E = 10^3\frac{s}{t_p}\sqrt{\frac{\varepsilon R_{eH}}{E}}$$~~ $$\beta_E = 10^3\frac{s}{t_p}\sqrt{\frac{\varepsilon R_{eHp}}{E}}$$

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

$\ell$ : longer side of the plate, in m.

# Common Structural Rules for Bulk Carriers, July 2008

# Technical Background for Rule Change Notice No.1-1 (Hull Girder Strength)

# Technical Background for the Changes Regarding Hull Girder Strength

## 1. Reason for the Rule Change in:

### 1.1 Chapter 5, Section 1, [2.2.2], [2.2.3] and [5.1.3]

These changes are made to clarify the requirements (Refer to KC ID 353, 453 and 459).
The way to consider any shear force corrections forward and aft of transverse bulkheads is specified in [2.2.2] and [5.1.3].
It is specified that the total mass M in those holds loaded in non-homogeneous loading conditions deadweight such as water ballast and fuel oil tank in double bottom, bounded by side girders in way of hopper tank plating or longitudinal bulkhead.
In addition, the symbol "$T_{LC}$" defined in Chapter 1 Section 4, [2.1.1] is defined differently in Chapter 5 Section 1.

### 1.2 Chapter 5, Appendix 1, Symbols, [2.1.1], [2.1.3], [2.2.1] to [2.2.8]

These changes are made to clarify the requirements (Refer to KC ID 499, 519 and 520).
The position and extent of the hard corners is specified in order to provide the equivalent definition of hard corners used in the CSR for Bulk Carriers regarding hull girder ultimate strength calculations to the one used in the CSR for Oil Tankers.
The calculation method is specified for those cases where any attached plating and stiffeners are made of steels having different yield stresses and/or thicknesses.
The way to consider non-continuous stiffeners for the hull girder ultimate strength calculation is specified.
In cases where attached plating and stiffeners are made of steel having different yield stresses, load end shortening curves are to be separately calculated for the stiffeners and the attached plates, i.e. the method is similar to the "weighted average method on area" in consideration of the net area of stiffeners and attached plates because this approach is very simple and easy to understand.
However, as described in Annex 1, this approach sometimes give a smaller ultimate strength in comparison to the results attained from a 3D non-linear FEA in cases where the yield stress of stiffeners is smaller than that of any attached plates. This is because the area of such attached plates is greater than that of the stiffeners. Normally, such a case is scarcely found in actual designs.
From the results of 3D non-linear FEA, it has been found that any underestimation of the load end shortening curves for beam column buckling of such stiffened panels can be resolved by considering the first moment of such stiffened panels. In addition, load end shortening curves for modes of failure other than beam column buckling can be evaluated by using the yield stress of stiffeners and attached plates, respectively.

## 2. Summary of Rule Changes

### 2.1 Chapter 5, Section 1, [2.2.2], [2.2.3] and [5.1.3]

The shear force correction is to be considered independently forward and aft of transverse bulkheads for any hold considered.
In addition, the total mass *M* may include masses of water ballast in double bottoms tanks, bounded by side girders in way of hopper tank plating or longitudinal bulkheads, if such spaces are loaded for the non-homogeneous loading condition considered.
Finally, the symbol "$T_{LC}$" is changed to "$T_{LC\_mh}$"

**2.2 Chapter 5, Appendix 1, [2.1.1], [2.1.3], [2.2.1] to [2.2.8]**

**2.2.1 Chapter 5, Appendix 1, Symbols and [2.1.1]**

(1) Definitions of necessary symbols are added in order to evaluate stiffened panels in cases where any attached plating and stiffeners are made of steel having different stresses.
(2) Editorial correction in [2.1.1] is made.

**2.2.2 Ch 5 Appendix 5 [2.1.3]**

The new paragraph [2.1.3] is added for the modelling of hull girder cross sections.
The extent of hard corner elements from corners is taken equal to $20t_p$ on transversely framed panels and to $0.5s$ on longitudinally framed panels.
In cases where attached plating is made of steels having different thicknesses and/or yield stresses, average thickness and/or average yield stress are to be used in calculations.

**2.2.3 Ch 5 Appendix 5, [2.2.1] to [2.2.8]**

The provisions regarding the definition of hard corners specified in [2.2.2] are shifted to a new paragraph [2.1.3].
In addition, the ways to calculate the load-end shortening curves of the following cases are explained: in cases where attached plating and stiffener are made of steels having different yield stresses; in cases where plate members are stiffened by non-continuous longitudinal stiffeners; in cases where openings are provided in stiffened plate elements; and, in cases where stiffened plate elements are provided.

## 3. Impact on Scantling

**3.1 Chapter 5, Section 1, [2.2.2], [2.2.3] and [5.1.3]**

There is no change in terms of steel weight by comparing that before and after the proposed rule change.

**3.2 Chapter 5, Appendix 1, [2.1.1], [2.1.3], [2.2.1] to [2.2.8]**

There is no change in terms of steel weight by comparing that before and after the proposed rule change.

# Annex 1: Evaluation method of the load end shortening curve for stiffened panel where the attached plate and stiffener are made of steel having different yield stresses

## 1. Introduction

The evaluation methodology of hull girder ultimate strength in CSR-BC is based on Smith's method.

In cases where any attached plates and stiffeners are made of steel having different yield stresses, the procedures and formulae for load end shortening curves are not described in the current Rules.

The following two methods to deal with such elements were considered.

(1) Using lower yield stresses.

(2) Considering plate elements and stiffener elements to be separate elements, and calculating the load-end shortening curves for the stiffener and the attached plating separately as follows:

For stiffeners: by adding attached plating having the same yield stress as the stiffener and then determining the shortening curve and the stress to be applied to the stiffener only.

For attached plating: by adding a stiffener having the same yield stress as the attached plating and then determining the shortening curve and the stress to be applied to the attached plating only.

Finally, load end shortening curves for stiffened panels can be obtained by adding the load end shortening curve for the stiffener to the load end shortening curve for the attached plating and dividing the sum by the total area of the stiffened panel.

This method is called "Method A". It has been confirmed that any load end shortening curve obtained by this method is nearly equal to that obtained by using the average yield stress considering areas of any stiffeners and attached plates.

It is obvious that the method specified in (1) above gives a conservative load end shortening curve because the higher yield strengths of stiffeners or panels is not taking into account. On the other hand, because Method A is simple and easy to understand, this method has been indicated in the IACS KC DB 520 as a practicable approach to evaluate the load end shortening curves of stiffened panels with different yield stresses between attached plates and stiffeners

However, there are some cases where Method A may give inadequate values of the load end shortening curves of stiffened panels of different materials used for the attached plate and the stiffener. Specifically, in cases where stiffened panel elements consist of attached plates of HT36 and stiffeners of HT 32, the load end shortening curves of such elements are sometimes overestimated in comparison to the results of 3D non-linear FEAs (FEA). On the contrary, in cases where elements consist of attached plates of HT32 and stiffeners of HT36, the load end shortening curves of such stiffened panel elements are sometimes underestimated in comparison to the results of FEA.

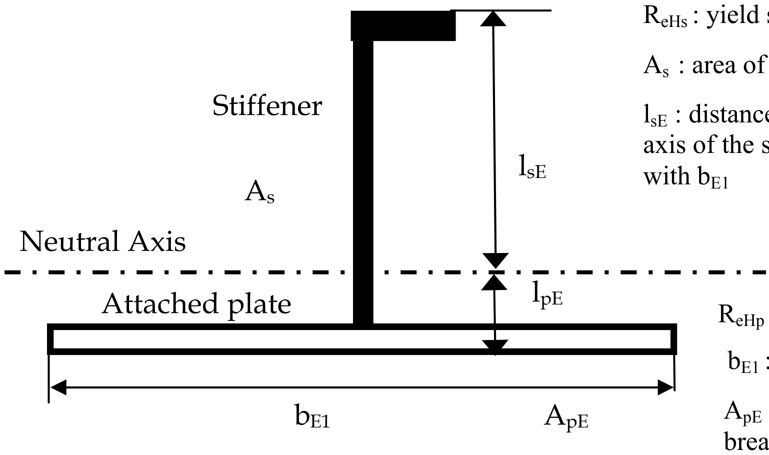
Although stiffeners with yield stresses lower than that of attached plates are rarely used in actual ship design, any underestimated result obtained by Method A should be resolved.

Since the areas of attached plates are larger than that of stiffeners in most cases, the load end shortening curve of the stiffened panel obtained by method A is affected by the yield strength of the attached plating. However, in reality, the yield stress of the stiffener has great impact on its load end shortening curve if beam-column buckling takes place, the parameters other than the areas of stiffeners and attached plates should be considered to accurately estimate the load end shortening curves of stiffened panels of attached plates and stiffeners having different yield stresses

In order to reduce the dependency on the areas of attached panels, the first moment of stiffened panels instead of the areas of attached plates and stiffeners are considered.

This method is called "Method B".

For example, using Method B, load end shortening curves of beam column buckling are calculated in the following manner:




$R_{eHs}$ : yield stress of the stiffener

$A_s$ : area of the stiffener

$l_{sE}$ : distance to the top of the stiffener from the neutral axis of the stiffened panel having the attached plate with $b_{E1}$

$R_{eHp}$ : yield stress of the attached plate

$b_{E1}$ : effective width of the attached plate

$A_{pE}$ : area of the attached plate with effective breadth $b_{E1}$.

$l_{pE}$ : distance to the bottom of the attached plate from the neutral axis of the stiffened panel having the attached plate with $b_{E1}$

Equivalent yield stress $R_{eHB}$ of the stiffened panel can be expressed by the following formula:

$$R_{eHB} = \frac{R_{eHp} A_{pE1} l_{pE} + R_{eHs} A_s l_{sE}}{A_{pE1} l_{pE} + A_s l_{sE}}$$

The load end shortening curve for the beam column buckling is obtained from the following formula:

$$\sigma_{CR1} = \Phi \sigma_{C1} \frac{A_S + A_{pE}}{A_S + A_p}$$

where:

$\Phi$ and $\varepsilon$: defined in [2.2.3], Ch 5 Appendix 1 of the Rules.

$\sigma_{C1}$ : Critical stress, in N/mm$^2$, equal to:

$$\sigma_{C1} = \frac{\sigma_{E1}}{\varepsilon} \quad \text{for} \quad \sigma_{E1} \le \frac{R_{eHB}}{2}\varepsilon$$

$$\sigma_{C1} = R_{eHB}\left(1 - \frac{R_{eHB}\,\varepsilon}{4\sigma_{E1}}\right) \quad \text{for} \quad \sigma_{E1} > \frac{R_{eHB}}{2}\varepsilon$$

$A_{pE1}$ : Effective area, in cm$^2$, equal to $10 b_{E1} t_p$

$\sigma_{E1}$ : Euler column buckling stress, in N/mm$^2$, equal to:

$$\sigma_{E1} = \pi^2 E \frac{I_E}{A_E l^2} 10^{-4}$$

$I_E$ : Net moment of inertia of ordinary stiffeners, in cm$^4$, with attached shell plating of width $b_{E1}$

$b_{E1}$ : Effective width, in m, of the attached shell plating, equal to:

$$b_{E1} = \frac{s}{\beta_E} \quad \text{for} \quad \beta_E > 1.0$$

$$b_{E1} = s \quad \text{for} \quad \beta_E \le 1.0$$

$$\beta_E = 10^3 \frac{s}{t_p}\sqrt{\frac{\varepsilon R_{eHp}}{E}}$$

$A_{pE}$ : Net sectional area, in cm$^2$, of attached shell plating of width $b_E$, equal to:

$$A_{pE} = 10 b_E t_p$$

$b_E$ : Effective width, in m, of the attached shell plating, equal to:

$$b_E = \left( \frac{2.25}{\beta_E} - \frac{1.25}{\beta_E^2} \right) s \quad \text{for } \beta_E > 1.25$$

$$b_E = s \quad \text{for } \beta_E \le 1.25$$

3D non-linear FEAs are carried out for the purpose of verifying the accuracy of the ultimate strength of stiffened panels obtained by Method B as well as Method A.

## 2. FEA

96 cases of the collapse analyses of the stiffened panels with non-linear FEM have been performed. The scantlings of stiffened plates analysed are listed in Table 1. As seen in Fig.1, the stiffened panels are modelled in the range of double span – double bay. Periodical continuous conditions are imposed along the edges of the model in the longitudinal and transverse directions. The material properties used in the analyses are as follows:

Young's Modulus : E = 206000 N/mm2
Poisson's Ratio: n = 0.3
Strain Hardening Rate: H'=0

Case 1 : 315 N/mm$^2$ for attached plate and 315 N/mm$^2$ for stiffener
Case 2 : 315 N/mm$^2$ for attached plate and HT 355 N/mm$^2$for stiffener (Different material case)
Case 3 : 355 N/mm$^2$ for attached plate and HT 315 N/mm$^2$ for stiffener (Different material case)
Case 4 : 355 N/mm$^2$ for attached plate and 355 N/mm$^2$ for stiffener

Table 1 Scantling and yield strength of each analysis case

| Stiffener | | Attached plate | | | |
|---|---|---|---|---|---|
| Type | Size (mm) | Length a (mm) | Breadth b (mm) | Aspect ratio (a/b) | Thickness tp (mm) |
| Angle | 250x90x12/16 | 2400 | 800 | 3.0 | 10 |
| | | | | | 15 |
| | | | | | 20 |
| | | | | | 25 |
| | | 4000 | 800 | 5.0 | 10 |
| | | | | | 15 |
| | | | | | 20 |
| | | | | | 25 |
| T-bar | 400x120x13/18 | 3600 | 900 | 4.0 | 10 |
| | | | | | 15 |
| | | | | | 20 |
| | | | | | 25 |
| | | 5400 | 900 | 6.0 | 10 |
| | | | | | 15 |
| | | | | | 20 |
| | | | | | 25 |
| Flat-bar | 300x15 | 2400 | 800 | 3.0 | 10 |
| | | | | | 15 |
| | | | | | 20 |
| | | | | | 25 |
| | | 4000 | 800 | 5.0 | 10 |
| | | | | | 15 |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | 20 |
| | | | | | 25 |

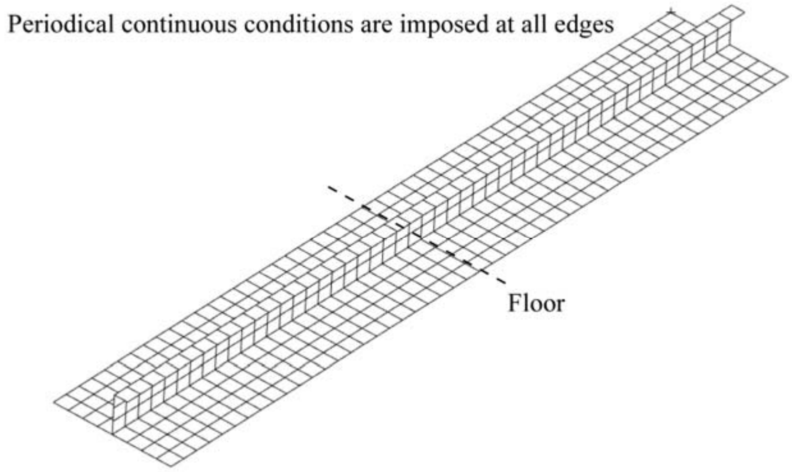



Fig.1 Model of stiffened panel

## 3. Verification results of the two methods

The results of the FEA, method A and Method B analyses are shown in Fig. 2 to Fig. 7. In these figures, FEA results are indicated by a line, the results of Method A and Method B are indicated by symbols.

Generally, it was found that there is good agreement between the results obtained by both methods and those by FEA from these figures except those cases where the plate thickness is 10mm.

However, considering the actual thickness of hull transverse members, both methods can be used for the evaluation of ultimate strength.

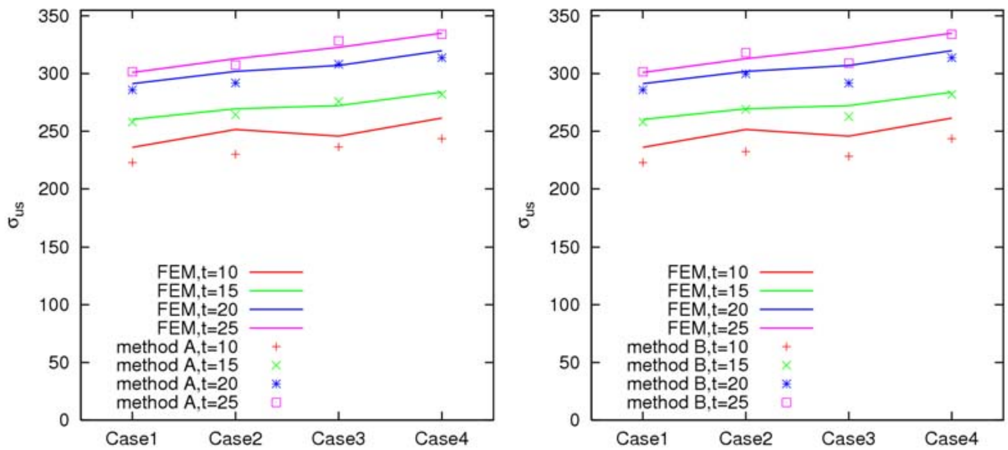



Fig. 2 Comparison on ultimate strength (Angle a/b=3.0)

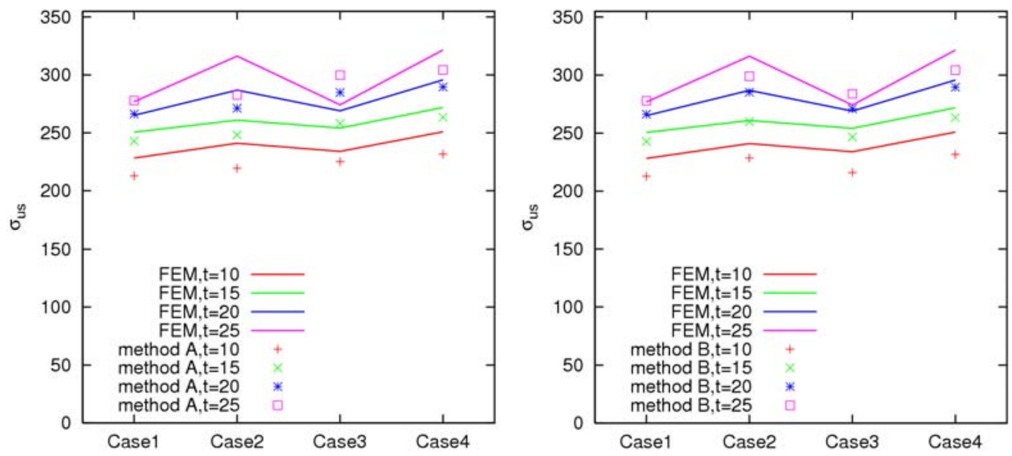


Fig. 3 Comparison on ultimate strength (Angle a/b=5.0)

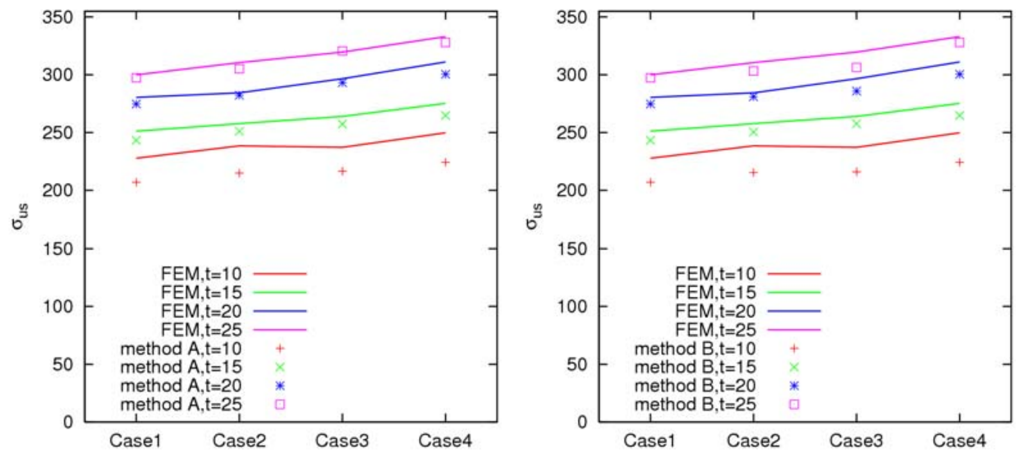


Fig. 4 Comparison on ultimate strength (T-bar a/b=4.0)

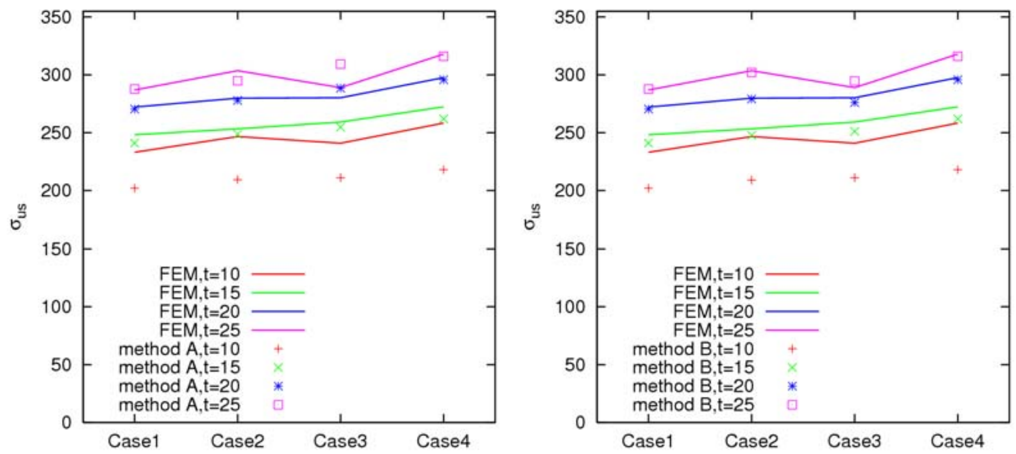


Fig. 5 Comparison on ultimate strength (T-bar a/b=6.0)

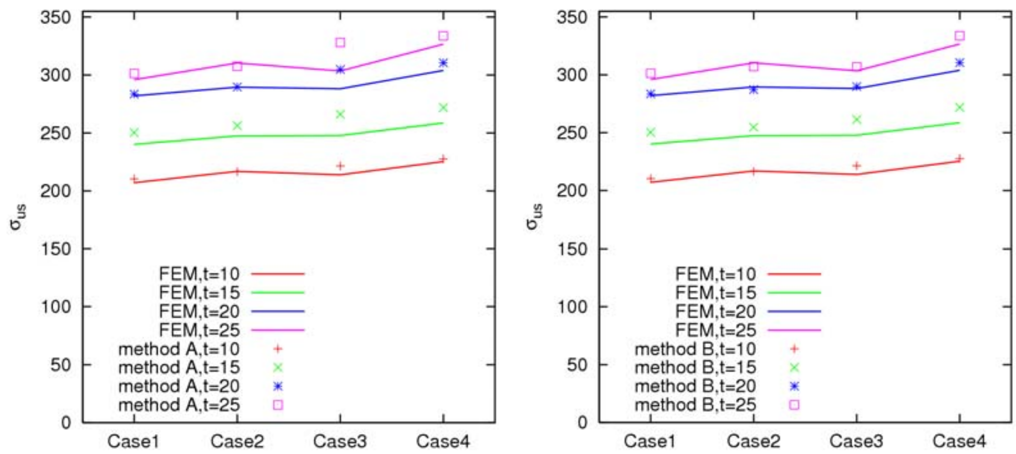



Fig. 6 Comparison on ultimate strength (Flat-bar a/b=3.0)

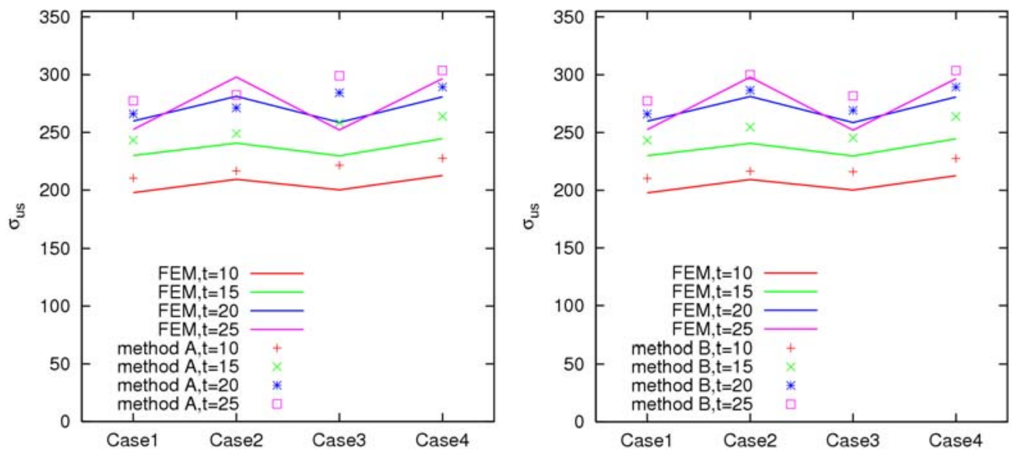



Fig. 7 Comparison on ultimate strength (Flat-bar a/b=5.0)

In order to discuss the accuracy of the results of Method A and Method B, a ratio obtained by dividing the results of both methods into that of FEA is given in Fig. 8 to Fig. 13.

Here, we call attention to the results of Case 2 and Case 3 in cases where any attached plates and stiffeners are made of steels having different yield stresses.

The ultimate strengths of all of the calculation conditions in Case 3 evaluated by Method A always are greater than those in Case 3.

In addition, the error (difference) becomes greater in those cases where the thickness of the attached plate with large aspect ratio becomes greater. This is because the ultimate strength of the stiffened panels is strongly affected by the yield strengths of attached plates.

On the other hand, the error of any results obtained by Method B seems to be smaller than those obtained by Method A, and any tendencies obtained by Method A cannot be observed in the results obtained by Method C.

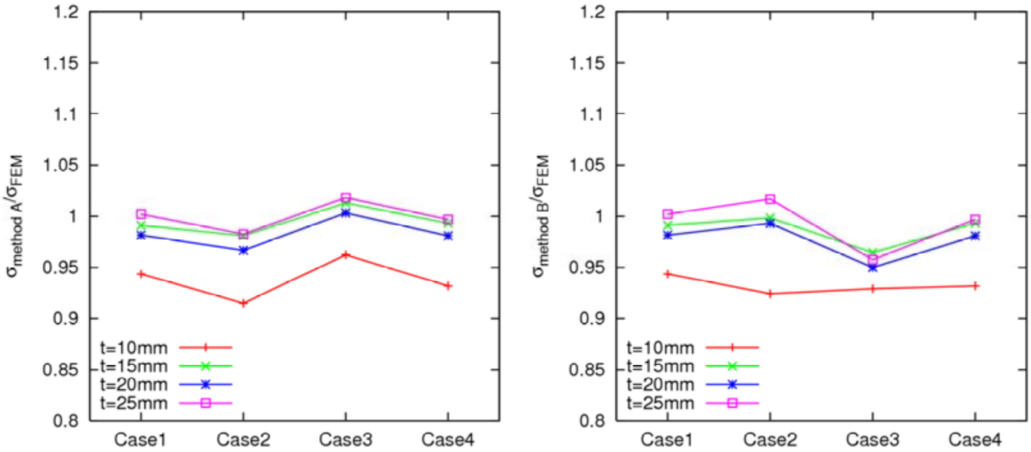



Fig. 8 Comparison on accuracy of estimation method (Angle a/b=3.0)

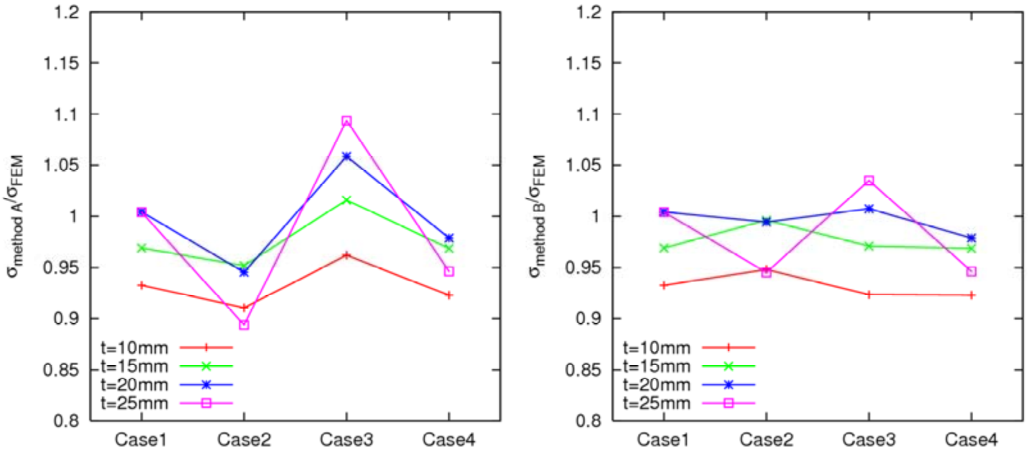



Fig. 9 Comparison on accuracy of estimation method (Angle a/b=5.0)

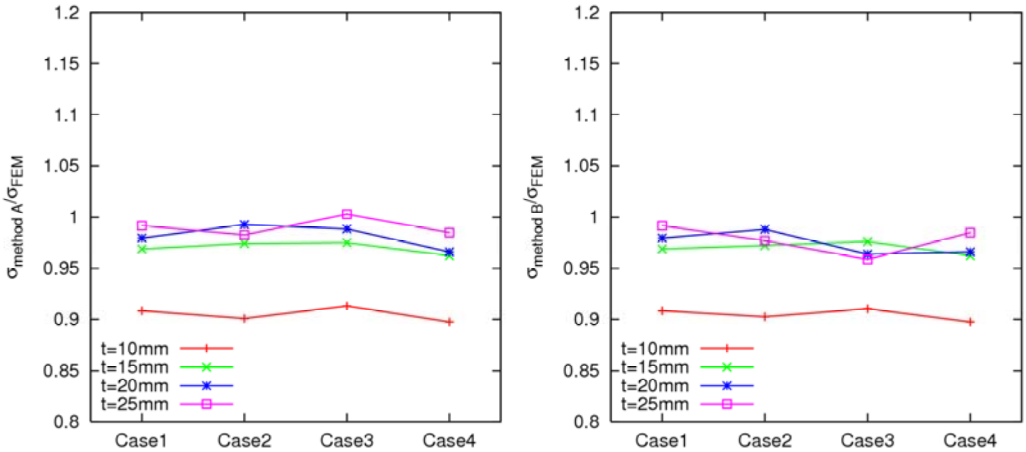



Fig. 10 Comparison on accuracy of estimation method (T-bar a/b=4.0)

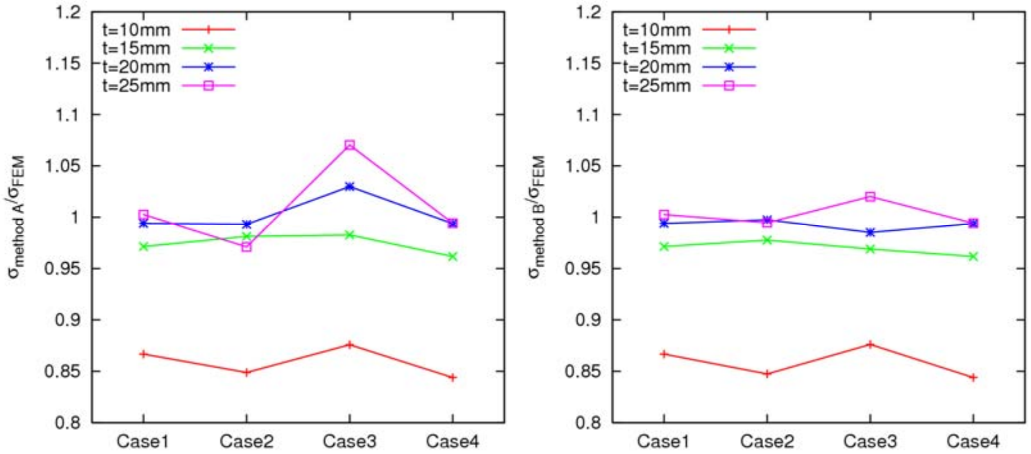



Fig. 11 Comparison on accuracy of estimation method (T-bar a/b=6.0)

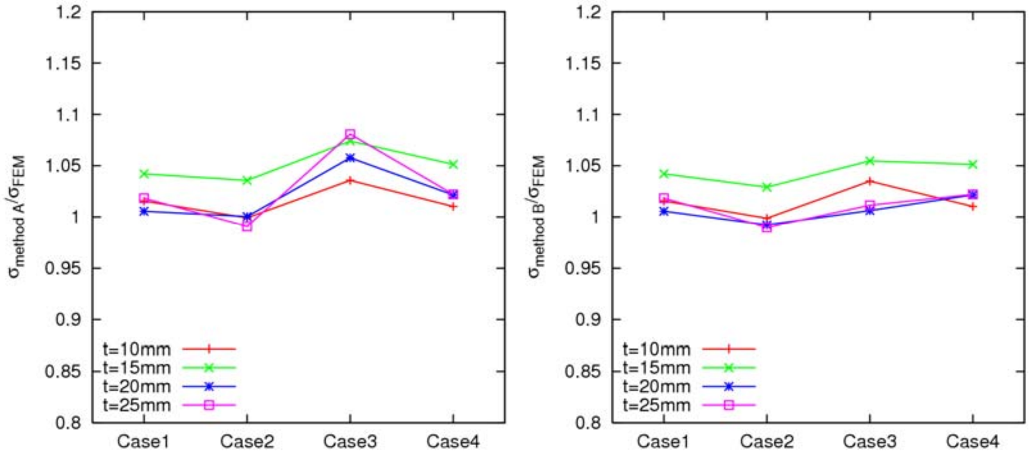



Fig. 12 Comparison on accuracy of estimation method (Flat-bar a/b=3.0)

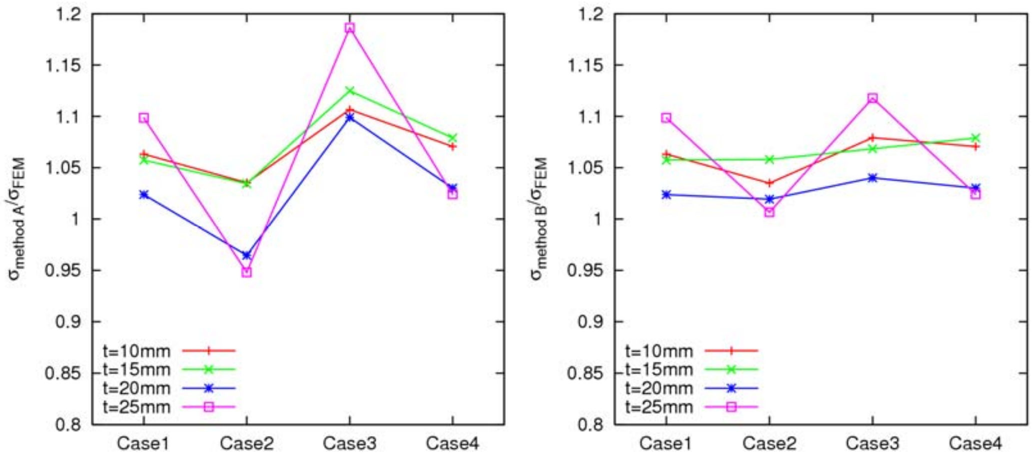



Fig. 13 Comparison on accuracy of estimation method (Flat-bar a/b=5.0)

For the purpose of confirming the accuracy of any results obtained by Method A and Method B, average values and coefficients of variation (COV) are calculated and those results are given in Figure 14 and 15.

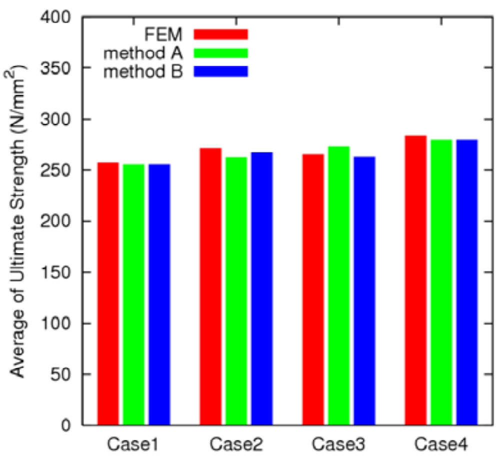



Fig. 14 Averages of Ultimate Strength in Each Case

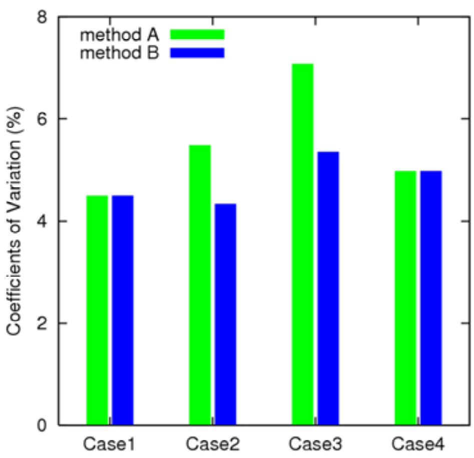



Fig. 15 Coefficients of Variation in Each Case

From Figure 15, it is obvious that the variance of any results obtained by method B is small. This means the accuracy of any results obtained by Method B is higher than those results obtained by Method A.

## 4. Conclusion

Two methods to estimate the ultimate strength of stiffened panels in cases where attached plates and stiffeners are made of steel having different yield stresses are considered.

One is Method A, where the yield stress used in the estimation of beam-column buckling is calculated so as to be the weighted average value of the yield stresses of the stiffener and the attached plating according to their area.

The other is method B, where the yield stress in the estimation of beam-column buckling is set to the weighted average value of the yield stresses of the stiffener and the attached plating according to the product of their areas and their distances from the neutral axis.

In order to evaluate the accuracy of the ultimate strength of the stiffened panel obtained by both methods, the results obtained by both methods are compared to those obtained by 3D non-linear FEAs.

From these comparison works, the following findings are obtained.

(1) The method A is very simple and practicable, but it may overestimated the ultimate strength in the case that the yield strength of the stiffener is lower than that of the attach plating

(2) Method B is not as simple and practicable as Method A, but it gives more accurate ultimate strength values for stiffened panels in comparison to those obtained by Method A.

Therefore, in cases where attached panels and stiffeners are made of steel having different yield stresses, Method B should be used for the evaluation of the load end shortening curve thereof.

The text in the RCP is based on this.

# Common Structural Rules for Bulk Carriers, July 2008

# Rule Change Notice No.1-2 (Hatch Covers)

Notes: (1) These Rule Changes enter into force on 1 July 2009.

For technical background for Rule Changes in this present document, reference is made to separate document Technical Background for Rule Change Notice No.1-2.

# CHAPTER 9 OTHER STRUCTURES

## Section 5 HATCH COVERS

**Symbols**

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

$p_S$ : Still water pressure, in kN/m$^2$, defined in [4.1]

$p_W$ : Wave pressure, in kN/m$^2$, defined in [4.1]

$p_C$ : Pressure acting on the hatch coaming, in kN/m$^2$, defined in [6.2]

$F_S$, $F_W$ : Coefficients taken equal to:

$F_S = 0$ and $F_W = 0.9$ for ballast water loads on hatch covers of the ~~cargo~~ ballast hold

$F_S = 1.0$ and $F_W = 1.0$ in other cases

$s$ : Length, in m, of the shorter side of the elementary plate panel

$\ell$ : Length, in m, of the longer side of the elementary plate panel

$b_p$ : Effective width, in m, of the plating attached to the ordinary stiffener or primary supporting member, defined in [3]

$w$ : Net section modulus, in cm$^3$, of the ordinary stiffener or primary supporting member, with an attached plating of width $b_p$

$A_{sh}$ : Net shear sectional area, in cm$^2$, of the ordinary stiffener or primary supporting member

$m$ : Boundary coefficient for ordinary stiffeners and primary supporting members, taken equal to:

$m = 8$ , in the case of ordinary stiffeners and primary supporting members simply supported at both ends or supported at one end and clamped at the other end

$m = 12$ , in the case of ordinary stiffeners and primary supporting members clamped at both ends

$t_C$ : Total corrosion addition, in mm, defined in [1.4]

$\sigma_a$ , $\tau_a$ : Allowable stresses, in N/mm$^2$, defined in [1.5]

# 1. General

## 1.5 Allowable stresses

### 1.5.1

*Ref. ILLC, as amended (Resolution MSC.143(77) Reg. 15(6) and 16(5))*

The allowable stresses $\sigma_a$ and $\tau_a$, in N/mm$^2$, are to be obtained from Tab 2.

**Table 2 Allowable stresses, in N/mm²**

| Members of | Subjected to | $\sigma_a$, in N/mm² | $\tau_a$, in N/mm² |
|---|---|---|---|
| Weathertight hatch cover | External pressure, as defined in Ch 4, Sec 5, ~~[2]~~[5.2.1] | 0.80 $R_{eH}$ | 0.46 $R_{eH}$ |
| Pontoon hatch cover | | 0.68 $R_{eH}$ | 0.39 $R_{eH}$ |
| Weathertight hatch cover and pontoon hatch cover | Other loads, as defined in Ch 4 ,Sec 5, [5.1.1] and Ch 4, Sec 6, [2] | 0.90 $R_{eH}$ | 0.51 $R_{eH}$ |

# 5. Strength check

## 5.2 Plating

### 5.2.3 Critical buckling stress check

The compressive stress $\sigma$ in the hatch cover plating, induced by the bending of primary supporting members, parallel to the direction of ordinary stiffeners is to comply with the following formula:

$$\sigma \leq \frac{0.88}{S}\sigma_{C1}$$

where:

S : Safety factor defined in Ch 6, Sec 3

$\sigma_{C1}$ : Critical buckling stress, in N/mm², taken equal to:

$$\sigma_{C1} = \sigma_{E1} \quad \text{for} \quad \sigma_{E1} \leq \frac{R_{eH}}{2}$$

$$\sigma_{C1} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E1}}\right) \quad \text{for} \quad \sigma_{E1} > \frac{R_{eH}}{2}$$

$$\sigma_{E1} = 3.6\, E\left(\frac{t}{1000s}\right)^2$$

$t$ : Net thickness, in mm, of plate panel

The compressive stress $\sigma$ in the hatch cover plating, induced by the bending of primary supporting members, perpendicular to the direction of ordinary stiffeners is to comply with the following formula:

$$\sigma \leq \frac{0.88}{S}\sigma_{C2}$$

where:

S : Safety factor defined in Ch 6, Sec 3

$\sigma_{C2}$ : Critical buckling stress, in N/mm², taken equal to:

$$\sigma_{C2} = \sigma_{E2} \quad \text{for} \quad \sigma_{E2} \leq \frac{R_{eH}}{2}$$

$$\sigma_{C2} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E2}}\right) \quad \text{for} \quad \sigma_{E2} > \frac{R_{eH}}{2}$$

$$\sigma_{E2} = 0.9\, m\, E\left(\frac{t}{1000s_s}\right)^2$$

$m$ : Coefficient taken equal to:

$$m = c\left[1+\left(\frac{s_s}{\ell_s}\right)^2\right]^2 \frac{2.1}{\psi+1.1}$$

$t$ : Net thickness, in mm, of plate panel

$s_s$ : Length, in m, of the shorter side of the plate panel

$\ell_s$ : Length, in m, of the longer side of the plate panel

$\psi$ : Ratio between smallest and largest compressive stress

$c$ : Coefficient taken equal to:

$c$ = 1.3 when plating is stiffened by primary supporting members

$c$ = 1.21 when plating is stiffened by ordinary stiffeners of angle or T type

$c$ = 1.1 when plating is stiffened by ordinary stiffeners of bulb type

$c$ = 1.05 when plating is stiffened by flat bar

$c$ = 1.30 when plating is stiffened by ordinary stiffeners of U type. The higher c value but not greater than 2.0 may be taken if it is verified by buckling strength check of panel using non-linear FEA and deemed appropriate by the Society.

An averaged value of c is to be used for plate panels having different edge stiffeners.

~~In addition, t~~The bi-axial compression stress in the hatch cover plating, when calculated by means of finite element analysis, is to comply with the requirements in Ch 6, Sec 3.

## 5.3 Ordinary stiffeners

### 5.3.2 Minimum net thickness of web

The web net thickness of the ordinary stiffener, in mm, is to be not less than ~~the minimum values given in [5.2.2]~~ 4mm.

## 5.4 Primary supporting members

### 5.4.2 Minimum net thickness of web

The web net thickness of primary supporting members, in mm, is to be not less than ~~the minimum values given in [5.2.2]~~ 6mm.

# Common Structural Rules for Bulk Carriers, July 2008

# Technical Background for Rule Change Notice No.1-2 (Hatch Covers)

# Technical Background for the Change Regarding Hatch Covers

## 1. Reason for the Rule Changes

### 1.1 Symbols

To consider the internal pressure due to ballast water in ballast hold, the load combination coefficients are introduced in Symbols. The rule change is made to clarify the application of the symbols Fs and Fw.

### 1.2 Table 2 Allowable stresses

According to ILLC and IACS UR S21, the external pressure is only external wave pressure acting on the hatch cover. However, as the pressure is referred to Ch 4 Sec 5 [2] which are mentioned not only the wave pressure on exposed deck but also other distributed load and concentrated loads.

This rule change is made according to the answer in KC ID 537 in order to be in line with ILLC and IACS UR S21.

### 1.3 "5.2.3 Critical buckling stress"

#### 1.3.1 Application of buckling check

When the bi-axial compression stress in the hatch cover plating calculated by means of finite element analysis, buckling check is to be carried out in accordance with the requirement in Ch 6 Sec 3. This check is alternative check to the buckling check using the compression stress obtained by a grillage analysis as specified in IACS UR S21.

This rule change is made according to the answer in KC ID 477 in order to be in line with IACS UR S21.

#### 1.3.2 "c" or "F1" factor for ordinary stiffener of U type

There are many hatch covers stiffened by ordinary stiffener of U type. As the ordinary stiffener of U-type has the merit of being more resistant to rotational effect than other ordinary stiffener of flat bar, angle type or T type. However, the coefficient "c" is taken equal to 1.05 to 1.2 corresponding to the type of stiffener. Regarding this issue, the interpretation is made according to the results as shown in Annex 1.

### 1.4 5.3.2 Minimum thickness of ordinary stiffener and 5.4.2 Minimum thickness of Primary supporting member

The definition of the web minimum thickness of ordinary stiffeners and primary supporting members was linked to the minimum requirements for the hatch cover plating, as defined in URS 21 and ILLC Reg. 16 (5.b). These rules contain no requirement for minimum web thickness for ordinary stiffeners and primary supporting members. But the rules for hatch covers of CSR-BC should have such a minimum requirement, comparable to the approach for the ship structure.

The reason is the change to the net thickness concept, which has not taken into account for the stiffeners. Hatch cover manufactures demand that the minimum net thickness of ordinary stiffeners plus the corrosion margin of 2mm has not to be greater than the well proven gross thickness of 6mm.

In addition, the relation to the distance between ordinary stiffeners ($t_{min}$ = 10s) is only valid for the hatch cover plating.

The rule change is made in accordance with the answer in KC ID 535.

## 2. Summary of the Rule Change

### 2.1 Symbols

The use of the coefficients Fs=0 and Fw=0.9 are limited for hatch covers of the ballast hold in case scantling check is done against the ballast water pressure.

**2.2 Table 2**

The reference is changed to Ch 4 Sec 5 [5.2.1] from Ch 4 Sec 5 [2] and clarification of "other load" is made.

**2.3 "5.2.3 Critical buckling stress"**

**2.3.1 Application of buckling check**

The used stress for buckling check is clarified as follows.

For uni-axial compression stress, the stress is obtained by a grillage analysis.

For bi-axial compression stress, the stresses are obtained by a FEA

**2.3.2 "c" or "F1" factor for ordinary stiffener of U type**

According to the results specified in Annex 1, the coefficient "c" for ordinary stiffener of U-type can be taken to higher value than 1.3. However, "c" value depends on the aspect ratio as shown in Annex 1. Therefore, the coefficient "c" is taken equal to 1.3 as a minimum, but the higher value may be used if it is verified by buckling strength check of panel using non-linear FEA and deemed appropriate by the Society.

In addition, the treatment of the different edge stiffeners is added according to Table 1 in Ch 6 Sec 3.

**2.4 "5.3.2 Minimum thickness of web of ordinary stiffener" and "5.4.2 Minimum thickness of Primary supporting member"**

(1) The relation to the distance between ordinary stiffeners ($t_{min}$ = 10s) is only valid for the hatch cover plating. Therefore this requirement is deleted the reference to the minimum thickness of hatch cover plate for ordinary stiffeners and primary supporting.

(2) In addition to the change, described in (1) above, the minimum net web thickness of ordinary stiffener of 6mm has been changed to 4mm.

(3) In addition to the change, described in (2) above, the minimum net thickness of 6mm is specified in the requirement for web of primary supporting member, but the value is the same as the current Rule.

## 3. Effects and impact on scantling due to this definition

**3.1 Items in 2.1, 2.2 and 2.3.1 mentioned above**

As the rule change is only made for the clarification, there is no scantling impact due to these changes.

**3.2 Items in 2.3.2 mentioned above**

Regarding the U-type stiffeners, the coefficient "c" is to be an appropriate value deemed by the Society because the factor of such stiffeners are not defined in CSR and IACS UR S21. The minimum value is newly defined by this rule change although the used value still depends on the discretion of the Society. Therefore, the scantling impact due to this change can not be estimated.

**3.3 Item in 2.4**

The minimum web thickness for ordinary stiffeners and primary supporting members is decreased.

The impact on scantling can not be estimated in general. Depending on the hatch cover type, the hatch cover size and loads, different design criteria determine the dimensions of the structure. One manufacturer estimates the weight increase when using the current CSR approach with 40% for ordinary stiffeners (KC-ID. 535).

# Annex 1: Technical Background for the Changes regarding F1 factor for transverse compressed plate fields in buckling check of hatch cover plating

## 1. Reason for the Rule Change in Ch 9 Sec 5 [5.2.3]

It was requested to make an interpretation for the factor "c" in case of U-type stiffener in buckling assessment of hatch covers. The factor "c" considers the torsion stiffness of the longitudinal stiffener of an elementary plate panel under transverse compression loads. The following values are given in the URS 11:

$c$ = 1.3 when plating is stiffened by primary supporting members

$c$ = 1.21 when plating is stiffened by ordinary stiffeners of angle or T type

$c$ = 1.1 when plating is stiffened by ordinary stiffeners of bulb type

$c$ = 1.05 when plating is stiffened by flat bar

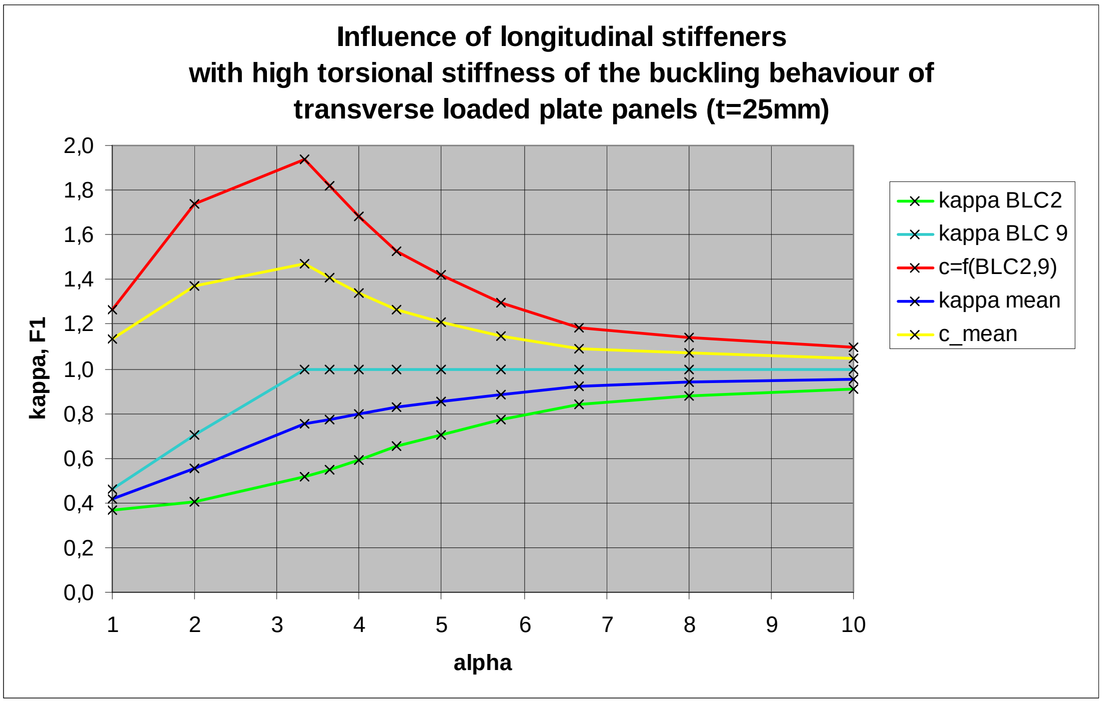
The intention of this RC is to make a proposal for the "c" factor for U-type stiffener

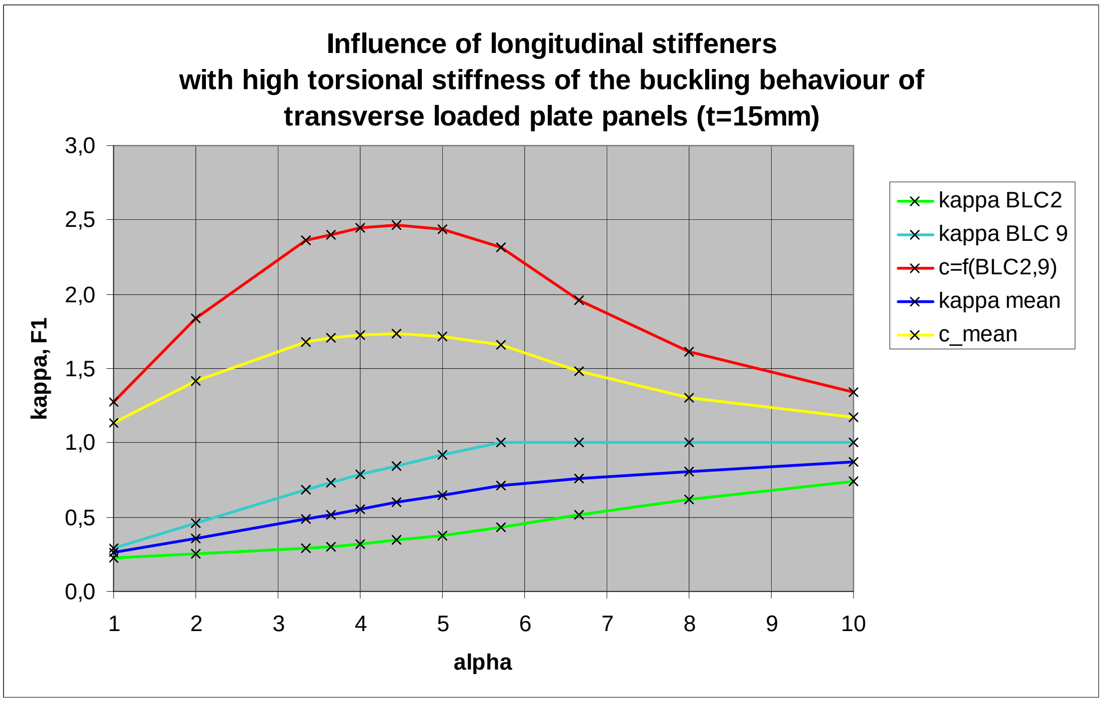
## 2. Summary of the Rule Change

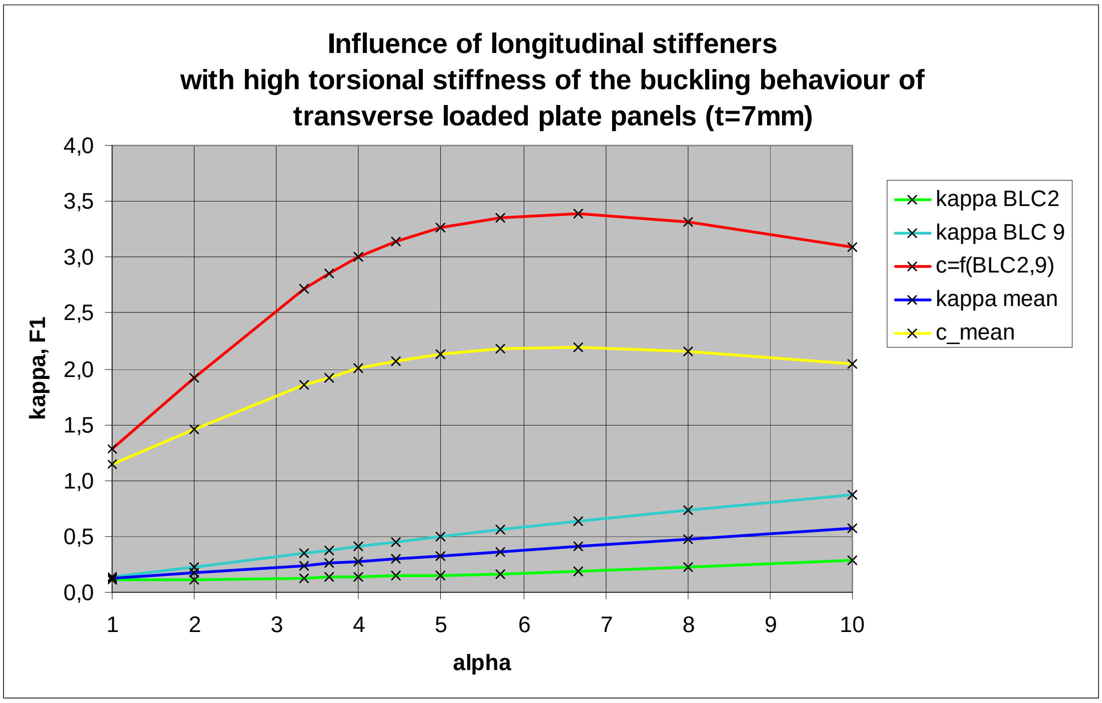
The derivation of the "c"-factor for U-type stiffeners based on nonlinear FE-analyses should be treated as a future development, because this work is beyond the capability of CSR PT1. CSR PT1 proposes to make a comparison study to estimate a F1 value by comparing the buckling load case (BLC) 9 (clamped edges) with the reference BLC 2 (simply supported).

Both buckling load cases BLC 2 and BLC 9 are theoretical cases and the real boundary condition of the U-Profile is in between these extreme cases. As a short term solution we propose to use the mean buckling reduction factor $\kappa_y$ value of both BLC's to estimate the "c"-factor for U-type stiffeners.

The following diagrams show the buckling reduction factors of BLC 1 and 9 together with the mean value and the "c"-factors as a function of $c = \kappa_y(9) / \kappa_y(1)$ and $c = \kappa_y(mean) / \kappa_y(1)$ for different plate thicknesses and aspect ratios.


Influence of longitudinal stiffeners
with high torsional stiffness of the buckling behaviour of
transverse loaded plate panels (t=25mm)
kappa, F1
2,0
1,8
1,6
1,4
1,2
1,0
0,8
0,6
0,4
0,2
0,0
1
2
3
4
5
6
7
8
9
10
alpha
kappa BLC2
kappa BLC 9
c=f(BLC2,9)
kappa mean
c_mean


Influence of longitudinal stiffeners
with high torsional stiffness of the buckling behaviour of
transverse loaded plate panels (t=15mm)
kappa, F1
3,0
2,5
2,0
1,5
1,0
0,5
0,0
1
2
3
4
5
6
7
8
9
10
alpha
kappa BLC2
kappa BLC 9
c=f(BLC2,9)
kappa mean
c_mean




The diagrams show the following dependencies

- With decreasing thickness the "c" factor increases
- With decreasing thickness the range of a constant "c" factor increases

Different hatch cover designs show aspect ratios between 3 and 8 with a majority of ratios between 3 and 6. The plate thickness is typically below 10mm. For these parameter ranges a "c" factor of 2.0 may be assumed.

To be in line with the simple definitions of "c" in URS 11 a constant "c" value of 1.3 can be used regardless of the thickness and aspect ratio. The diagrams leads to the assumption, that a higher value might be possible, taking the aspect ratio and plate thickness into account. But this has to be verified as a future development for CSR-BC.

## 3. Effects and impact on scantling due to this definition

The highest value for "c", given in the URS 11 is 1.3 for primary supporting members. Higher values are not allowed by IACS up to now. Defining a constant value of 1.3 for U-type stiffeners regardless of plate field aspect ratios or thicknesses, we do not change the result of the plate buckling check for hatch covers and this definition has no impact on scantling.

With the selection of a higher "c" value for such kind of stiffeners, the buckling strength of hatch cover plating, stiffened with U-type stiffeners increases with respect to transverse loaded plate fields.

# Common Structural Rules for Bulk Carriers, July 2008

# Rule Change Notice No.1-3 (Steel Coil)

Notes: (1) These Rule Changes enter into force on 1 July 2009.

For technical background for Rule Changes in this present document, reference is made to separate document Technical Background for Rule Change Notice No.1-3.

# CHAPTER 4 DESIGN LOADS

## Section 2 SHIP MOTION AND ACCELERATIONS

### 2. Ship absolute motions and accelerations

#### 2.1 Roll

**2.1.1**

The roll period $T_R$, in s, and the single roll amplitude $\theta$, in deg, are given by:

$$T_R = \frac{2.3k_r}{\sqrt{GM}}$$

$$\theta = \frac{9000(1.25 - 0.025T_R)f_p k_b}{(B+75)\pi}$$

where:

$k_b$ : Coefficient taken equal to:

$k_b$ = 1.2 for ships without bilge keel

$k_b$ = 1.0 for ships with bilge keel

$k_r$ : Roll radius of gyration, in m, in the considered loading condition. When $k_r$ is not known, the values indicated in Tab 1 may be assumed.

$GM$ : Metacentric height, in m, in the considered loading condition. When $GM$ is not known, the values indicated in Tab 1 may be assumed.

**Table 1: Values of $k_r$ and $GM$**

| Loading condition | | $k_r$ | $GM$ |
|---|---|---|---|
| Full load condition | ~~(~~Alternate or homogeneous loading~~)~~ | 0.35$B$ | 0.12$B$ |
| | <u>Steel coil loading</u> | <u>0.42B</u> | <u>0.24B</u> |
| Normal ballast condition | | 0.45$B$ | 0.33$B$ |
| Heavy ballast condition | | 0.40$B$ | 0.25$B$ |

# CHAPTER 6 HULL SCANTLING

## Section 1 PLATING

## 2. General requirements

### 2.7 Inner bottom loaded by steel coils on a wooden support

#### 2.7.1 General

The net thickness of inner bottom, bilge hopper sloping plate and inner hull for ships intended to carry steel coils is to comply with [2.7.2] to [2.7.4].

The provision is determined by assuming Fig 2 as the standard means of securing steel coils. ~~In case where steel coils are lined up two or more tier, formulae in [2.7.2] and [2.7.3] can be applied to the case that only lowest tier of steel coils is in contact with hopper sloping plate or inner hull plate.~~ ~~In other cases, scantlings of plate thickness are calculated by direct strength analysis or other procedures.~~

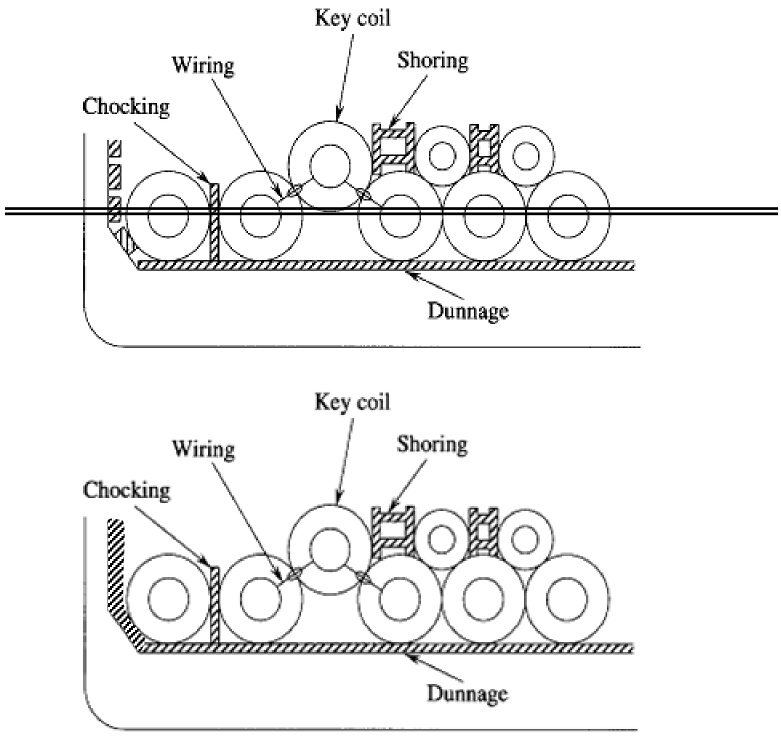



**Figure 2: Inner bottom loaded by steel coils**

#### 2.7.1 bis1 Accelerations

In order to calculate the accelerations, the following coordinates are to be used for the centre of gravity.

$x_{G-sc}$ = 0.75 $\ell_H$ forward of aft bulkhead, where the hold of which the mid position is located forward from 0,45L from A.E.

$x_{G-sc}$ = 0.75 $\ell_H$ afterward of fore bulkhead, where the hold of which the mid position is located afterward from 0,45L from A.E.

$$y_{G-sc} = \varepsilon \frac{B_h}{4}$$

$$z_{G-sc} = h_{DB} + \left\{ 1 + (n_1 - 1)\frac{\sqrt{3}}{2} \right\} \frac{d_{sc}}{2}$$

where:

$\varepsilon$ : 1.0 when a port side structural member is considered , or -1.0 when a starboard side structural member is considered.

$B_h$ : breadth in m, at the mid of the hold, of the cargo hold at the level of connection of bilge hopper plate with side shell or inner hull

$d_{sc}$ : diameter of steel coils, in m

$h_{DB}$ : height of inner bottom, in m

$\ell_H$ : Cargo hold length, in m

Vertical acceleration $a_Z$, in m/s$^2$,.are to be calculated by the formulae defined in Ch 4, Sec 2, [3.2] and tangential acceleration $a_R$ due to roll, in m/s$^2$ .is to be calculated by the following formula.

$$a_R = \theta \frac{\pi}{180} \left( \frac{2\pi}{T_R} \right)^2 \sqrt{{y_{G\_SC}}^2 + R^2}$$

where:

$\theta$, $T_R$ and $R$: as defined in Ch 4 Sec 2, [3.2].

### 2.7.2 Inner bottom plating

The net thickness of plating of longitudinally framed inner bottom is to be not less than the value obtained, in mm, from the following formula:

~~$t = K_1 \sqrt{\frac{(g + a_Z)F}{\lambda_P R_Y}}$~~

$$t = K_1 \sqrt{\frac{\{g(\cos(C_{ZP}\Phi)\cos(C_{ZR}\theta)) + a_z\}F}{\lambda_P R_Y}}$$

where:

$K_1$ : Coefficient taken equal to:

$$K_1 = \sqrt{\frac{1.7 s\ell K_2 - 0.73 s^2 K_2^2 - (\ell - \ell')^2}{2\ell'(2s + 2\ell K_2)}}$$

$a_Z$ : Vertical acceleration, in m/s2, defined in ~~Ch 4, Sec 2, [3.2]~~ [2.7.1 bis1]

$\Phi$ : Single pitch amplitude, in deg, defined in Ch 4, Sec 2, [2.2]

$\theta$ : Single roll amplitude, in deg, defined in Ch 4, Sec 2, [2.1]

$C_{ZP}$,$C_{ZR}$ : Load combination factor defined in Ch 4, Sec 4, [2.2]

$F$ : Force, in kg, taken equal to:

$$F = K_S \frac{W n_1 n_2}{n_3} \quad \text{for } n_2 \le 10 \text{ and } n_3 \le 5$$

$$F = K_S n_1 W \frac{l}{l_S} \quad \text{for } n_2 > 10 \text{ or } n_3 > 5$$

$\lambda_P$ : Coefficient defined in Tab 6

$K_S$ : Coefficient taken equal to:

$K_S = 1.4$ when steel coils are lined up in one tier with a key coil

$K_S = 1.0$ in other cases

$W$ : Mass of one steel coil, in kg

$n_1$ : Number of tiers of steel coils

$n_2$ : Number of load points per elementary plate panel of inner bottom (See Figs 3 and 4), taken equal to:

When $n_3 \le 5$, $n_2$ can be obtained from Tab 3 according to the values of $n_3$ and $\ell / \ell_S$

- in case of steel coils loaded as shown in Fig 3, $n_2$ is obtained from Tab 3 according to the values of $n_3$ and $\ell/\ell_S$
- in case of steel coils loaded as shown in Fig 4, $n_2 = n_3$

$n_3$ : Number of dunnages supporting one steel coil

$\ell_S$ : Length of a steel coil, in m

$K_2$ : Coefficient taken equal to:

$$K_2 = -\frac{s}{\ell} + \sqrt{\left(\frac{s}{\ell}\right)^2 + 1.37\left(\frac{\ell}{s}\right)^2\left(1 - \frac{\ell'}{\ell}\right)^2 + 2.33}$$

$\ell'$ : Distance, in m, between outermost load points per elementary plate panel of inner bottom plate in ship length, taken equal to: (See Figs 3 and 4). When $n_2 \le 10$ and $n_3 \le 5$, $\ell'$ can be obtained from Tab 4 according to the values of $\ell$, $\ell_S$, $n_2$ and $n_3$. When $n_2 > 10$ or $n_3 > 5$, $\ell'$ is to be taken equal to $\ell$.

- in case of steel coils loaded as shown in Fig 3, $\ell'$ is obtained from Tab 4 according to the values of $\ell$, $\ell_S$, $n_2$ and $n_3$
- in case of steel coils loaded as shown in Fig 4, $\ell'$ is the actual value.

### 2.7.3 Bilge hHopper sloping plate and inner hull plateing

The net thickness of plating of longitudinally framed bilge hopper sloping plate and inner hull is to be not less than the value obtained, in mm, from the following formula:

$$t = K_1 \sqrt{\frac{[g \cos(\theta_1 - \theta_2) + a_Y \sin\theta_1] F'}{\lambda_P R_Y}}$$

$$t = K_1 \sqrt{\frac{a_{hopper} F'}{\lambda_p Ry}}$$

where:

$K_1$ : Coefficient defined in [2.7.2]

~~$\theta_1$~~ $\theta_h$ : Angle, in deg, between inner bottom plate and bilge hopper sloping plate or inner hull platec~~ing~~

~~$\theta_2$ : Single roll amplitude, in deg, defined in Ch 4, Sec 2, [2.1]~~

~~$a_Y$ : Transverse acceleration, in m/s², defined in Ch 4, Sec2, [3.2]~~

$$a_{hopper} = -C_{YR} a_R \sin\left(\tan^{-1}\left|\frac{y_{G\_sc}}{R}\right| - \theta_h\right) + g\cos(\theta_h - C_{YG}\theta)\cos(C_{XG}\Phi) + C_{YS} a_{sway} \sin\theta_h$$

$a_R$ : tangential acceleration defined in [2.7.1 bis1].

$a_{sway}$ : Transverse acceleration due to sway, in m/s$^2$, defined in Ch 4, Sec 2, [2.4]

$C_{XG}$, $C_{YS}$, $C_{YR}$, $C_{YG}$: Load combination factors defined in Ch 4, Sec 4, [2.2]

$y_{G\_sc}$ : Centre of gravity in transverse direction, in m, defined in [2.7.1 bis1]

$R$ : Coefficient defined in Ch 4 Sec 2, [3.2.1]

$F'$ : Force, in kg, taken equal to:

$$F' = \frac{W n_2 C_k}{n_3} \quad \text{for } n_2 \le 10 \text{ and } n_3 \le 5$$

$$F' = C_k W \frac{l}{l_S} \quad \text{for } n_2 > 10 \text{ or } n_3 > 5 .$$

$\lambda_P$ : Coefficient defined in Tab 6

$W$, $n_2$, $n_3$, $\Phi$ and $\theta$ : As defined in [2.7.2]

$C_k$ : Coefficient taken equal to:

$C_k$ = ~~4.0~~3.2 when steel coils are lined up two or more tier, or when steel coils are lined up one tier and key coil is located second or third from bilge hopper sloping plate or inner hull plate

$C_k$ = ~~2.5~~2.0 for other cases

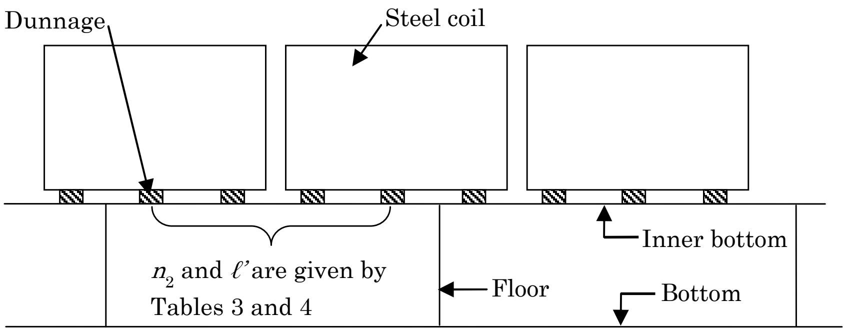



**Figure 3: Loading condition of steel coils (Example of $n_2 = 4$, $n_3 = 3$)**

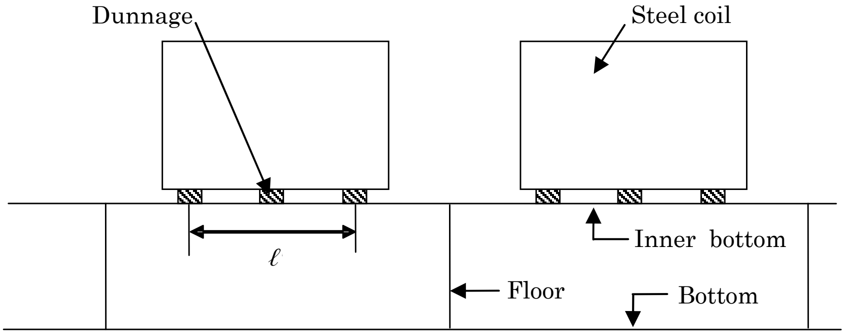



**Figure 4: Loading condition of steel coils (Example of $n_2 = 3$, $n_3 = 3$)**

### 2.7.4

~~Where the number of load points per elementary plate panel $n_2$ is greater than 10 and/or the number of dunnages $n_3$ is greater than 5, the inner bottom may be considered as loaded by a uniform distributed load. In such a case, the thickness of the inner bottom plating is to be obtained according to [3.2.1]~~. (void)

**Table 3: Number $n_2$ of load points per elementary plate panel**

| $n_2$ | $n_3 = 2$ | $n_3 = 3$ | $n_3 = 4$ | $n_3 = 5$ |
|---|---|---|---|---|
| **1** | $0 < \frac{\ell}{\ell_S} \le 0.5$ | $0 < \frac{\ell}{\ell_S} \le 0.33$ | $0 < \frac{\ell}{\ell_S} \le 0.25$ | $0 < \frac{\ell}{\ell_S} \le 0.2$ |
| **2** | $0.5 < \frac{\ell}{\ell_S} \le 1.2$ | $0.33 < \frac{\ell}{\ell_S} \le 0.67$ | $0.25 < \frac{\ell}{\ell_S} \le 0.5$ | $0.2 < \frac{\ell}{\ell_S} \le 0.4$ |
| **3** | $1.2 < \frac{\ell}{\ell_S} \le 1.7$ | $0.67 < \frac{\ell}{\ell_S} \le 1.2$ | $0.5 < \frac{\ell}{\ell_S} \le 0.75$ | $0.4 < \frac{\ell}{\ell_S} \le 0.6$ |
| **4** | $1.7 < \frac{\ell}{\ell_S} \le 2.4$ | $1.2 < \frac{\ell}{\ell_S} \le 1.53$ | $0.75 < \frac{\ell}{\ell_S} \le 1.2$ | $0.6 < \frac{\ell}{\ell_S} \le 0.8$ |
| **5** | $2.4 < \frac{\ell}{\ell_S} \le 2.9$ | $1.53 < \frac{\ell}{\ell_S} \le 1.87$ | $1.2 < \frac{\ell}{\ell_S} \le 1.45$ | $0.8 < \frac{\ell}{\ell_S} \le 1.2$ |
| **6** | $2.9 < \frac{\ell}{\ell_S} \le 3.6$ | $1.87 < \frac{\ell}{\ell_S} \le 2.4$ | $1.45 < \frac{\ell}{\ell_S} \le 1.7$ | $1.2 < \frac{\ell}{\ell_S} \le 1.4$ |
| **7** | $3.6 < \frac{\ell}{\ell_S} \le 4.1$ | $2.4 < \frac{\ell}{\ell_S} \le 2.73$ | $1.7 < \frac{\ell}{\ell_S} \le 1.95$ | $1.4 < \frac{\ell}{\ell_S} \le 1.6$ |
| **8** | $4.1 < \frac{\ell}{\ell_S} \le 4.8$ | $2.73 < \frac{\ell}{\ell_S} \le 3.07$ | $1.95 < \frac{\ell}{\ell_S} \le 2.4$ | $1.6 < \frac{\ell}{\ell_S} \le 1.8$ |
| **9** | $4.8 < \frac{\ell}{\ell_S} \le 5.3$ | $3.07 < \frac{\ell}{\ell_S} \le 3.6$ | $2.4 < \frac{\ell}{\ell_S} \le 2.65$ | $1.8 < \frac{\ell}{\ell_S} \le 2.0$ |
| **10** | $5.3 < \frac{\ell}{\ell_S} \le 6.0$ | $3.6 < \frac{\ell}{\ell_S} \le 3.93$ | $2.65 < \frac{\ell}{\ell_S} \le 2.9$ | $2.0 < \frac{\ell}{\ell_S} \le 2.4$ |

**Table 4: Distance between load points in ship length direction per elementary plate panel of inner bottom**

| $n_2$ | $n_3$ | | | |
|---|---|---|---|---|
| | **2** | **3** | **4** | **5** |
| **1** | Actual breadth of dunnage | | | |
| **2** | $0.5\ell_S$ | $0.33\ell_S$ | $0.25\ell_S$ | $0.2\ell_S$ |
| **3** | $1.2\ell_S$ | $0.67\ell_S$ | $0.50\ell_S$ | $0.4\ell_S$ |
| **4** | $1.7\ell_S$ | $1.20\ell_S$ | $0.75\ell_S$ | $0.6\ell_S$ |
| **5** | $2.4\ell_S$ | $1.53\ell_S$ | $1.20\ell_S$ | $0.8\ell_S$ |
| **6** | $2.9\ell_S$ | $1.87\ell_S$ | $1.45\ell_S$ | $1.2\ell_S$ |
| **7** | $3.6\ell_S$ | $2.40\ell_S$ | $1.70\ell_S$ | $1.4\ell_S$ |
| **8** | $4.1\ell_S$ | $2.73\ell_S$ | $1.95\ell_S$ | $1.6\ell_S$ |
| **9** | $4.8\ell_S$ | $3.07\ell_S$ | $2.40\ell_S$ | $1.8\ell_S$ |
| **10** | $5.3\ell_S$ | $3.60\ell_S$ | $2.65\ell_S$ | $2.0\ell_S$ |

# Section 2 ORDINARY STIFFENERS

## 2. General requirements

### 2.5 Ordinary stiffeners of inner bottom loaded by steel coils on a wooden support

#### 2.5.1 General

The requirements of this sub-article apply to the ordinary stiffeners located on inner bottom plate, bilge hopper sloping plate and inner hull plate when loaded by steel coils on a wooden support (dunnage), as indicated in Fig 2 of Ch 6, Sec 1.

~~In case where steel coils are lined up two or more tier, formulae in [2.5.2] and [2.5.3] can be applied to the case that only lowest tier of steel coils is in contact with hopper sloping plate or inner hull plate. In other cases, scantlings of net section modulus and net shear section area are calculated by direct strength analysis or other procedures.~~

#### 2.5.2 Ordinary stiffeners located on inner bottom plating

The net section modulus $w$, in cm$^3$, and the net shear sectional area $A_{sh}$, in cm$^2$, of single span ordinary stiffeners located on inner bottom plating are to be not less than the values obtained from the following formulae:

~~$$w = K_3 \frac{(g + a_Z)F}{8\lambda_S R_Y}$$~~

~~$$A_{sh} = \frac{5(g + a_Z)F}{\tau_a \sin\phi} 10^{-3}$$~~

$$w = K_3 \frac{[g \cdot \cos(C_{ZP}\Phi) \cdot \cos(C_{ZR}\theta) + a_Z] \cdot F}{8 \cdot \lambda_S R_Y}$$

$$A_{sh} = \frac{5[g \cdot \cos(C_{ZP}\Phi) \cdot \cos(C_{ZR}\theta)) + a_Z] \cdot F}{\tau_a \sin\phi} 10^{-3}$$

where:

$K_3$ : Coefficient defined in Tab 1. When $n_2$ is greater than 10, $K_3$ is to be taken equal to $2\ell/3$

$a_Z$ : Vertical acceleration, in m/s$^2$, defined in ~~Ch 4, Sec2, [3.2]~~ Ch 6, Sec 1, [2.7.1 bis1]

$\Phi$ : Single pitch amplitude, in deg, defined in Ch 4, Sec 2, [2.2]

$\theta$ : Single roll amplitude, in deg, defined in Ch 4, Sec 2, [2.1]

$C_{ZP}$, $C_{ZR}$ : Load combination factor defined in Ch 4, Sec 4, [2.2]

$F$ : Force, in kg, defined in Ch 6, Sec 1, [2.7.2]

$\lambda_S$ : Coefficient defined in Tab 3

$\phi$ : Angle, in deg, defined in [3.2.3].

### 2.5.3 Ordinary stiffeners located on bilge hopper sloping plate or inner hull plateing

The net section modulus $w$, in cm$^3$, and the net shear sectional area $A_{sh}$, in cm$^2$, of single span ordinary stiffeners located on bilge hopper sloping plate and inner hull plate are to be not less than the values obtained from the following formulae:

~~$$w = K_3 \frac{[g\cos(\theta_1 - \theta_2) + a_Y \sin\theta_1]F'}{8\lambda_S R_Y}$$~~

~~$$A_{sh} = \frac{5 a_Y F'}{\tau_a \sin\varphi \sin\phi} 10^{-3}$$~~

$$w = K_3 \frac{a_{hopper} F'}{8\lambda_S R_Y}$$

$$A_{sh} = \frac{5 a_{hopper} F'}{\tau_a \sin\phi} 10^{-3}$$

where:

$K_3$ : Coefficient defined in Tab 1. When $n_2 > 10$, $K_3$ is taken equal to $2\ell/3$.

~~$\theta_1$, $\theta_2$ : Angles, in deg, defined in Ch 6, Sec 1, [2.7.3]~~

$\theta_h$ : Angle, in deg, between inner bottom plate and bilge hopper sloping plate or inner hull plate

~~$a_Y$ : Transverse acceleration, in m/s$^2$, defined in Ch 4, Sec 2, [3.2]~~

$a_{hopper}$ : Acceleration, in m/s$^2$, defined in Ch 6 Sec 1, [2.7.3]

$F'$ : Force, in kg, defined in Ch 6, Sec 1, [2.7.3]

$\lambda_S$ : Coefficient defined in Tab 3

$\phi$ : Angle, in deg, defined in [3.2.3]

~~$\varphi$ : Angle, in deg, between inner bottom plating and hopper sloping plate or inner hull plating.~~

~~$\ell'$ : Distance, in m, between load points per elementary plate panel of inner bottom plate in ship length, sloping plate or inner hull plating, as defined in Ch 6, Sec 1, [2.7.2].~~

$\ell'$ : Distance, in m, between outermost load points per elementary plate panel in ship length

**Table 1 : Coefficient $K_3$**

| $n_2$ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| $K_3$ | $\ell$ | $\ell - \frac{\ell'^2}{\ell}$ | $\ell - \frac{2\ell'^2}{3\ell}$ | $\ell - \frac{5\ell'^2}{9\ell}$ | $\ell - \frac{\ell'^2}{2\ell}$ | $\ell - \frac{7\ell'^2}{15\ell}$ | $\ell - \frac{4\ell'^2}{9\ell}$ | $\ell - \frac{3\ell'^2}{7\ell}$ | $\ell - \frac{5\ell'^2}{12\ell}$ | $\ell - \frac{11\ell'^2}{27\ell}$ |

### 2.5.4

~~Where the number of load points per elementary plate panel $n_2$ is greater than 10 and/or the number of dunnages $n_3$ is greater than 5, the inner bottom may be considered as loaded by a uniform distributed load. In such a case, the scantling of the inner bottom ordinary stiffeners is to be obtained according to [3.2.3].~~ (void)

# Common Structural Rules for Bulk Carriers, July 2008

# **Technical Background for Rule Change Notice No.1-3 (Steel Coil)**

# Technical Background for the Change Regarding Scantling Formula for Steel Coil Loading

## 1. Background of Rule change regarding steel coil loading

### 1.1 Addition of GM and $k_r$ value for steel coil loading to the note of Table 1 in Ch 4, Sec 2, [2.1.1]

Roll radius of gyration ($k_r$) and metacentric height ($GM$) in the considered loading condition is used for the calculation of the parameters regarding the ship's absolute motion and accelerations. When these values are not known, the default values specified in Table 1 in Ch 4, Sec 2, [2.1.1] may be assumed in the current CSR.

However, these default values specified in the Table do not correspond to the steel coil loading condition because the steel coil load is normally concentrated near the inner bottom.
The rule change is made to set the $GM$ value based on the actual design values given in Table 1 and the averaged values of GM and $k_r$ is about 0.24B and 0.42B, respectively.

**Table 1 Actual $GM$ Value**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| B | 32.26 | 32.26 | 31.00 | 29.40 | 23.00 | 19.60 | 23.50 | 23.70 |
| Actual $GM$ | 8.05 | 7.76 | 8.34 | 7.99 | 4.39 | 4.12. | 4.95 | 5.10 |
| $GM$ = X*B | 0.245 | 0.241 | 0.269 | 0.272 | 0.191 | 0.210 | 0.211 | 0.215 |
| B | 27.00 | 26.00 | 23.50 | 24.50 | 24.40 | 23.70 | 27.0 | 23.700 |
| Actual $GM$ | 6.88 | 6.38 | 4.95 | 5.78 | 4.93 | 5.06 | 6.89 | 5.10 |
| $GM$ = X*B | 0.255 | 0.245 | 0.211 | 0.236 | 0.202 | 0.214 | 0.255 | 0.215 |
| B | 23.50 | 22.30 | 27.00 | 27.00 | 32.26 | 32.26 | 27.20 | 32.26 |
| Actual $GM$ | 4.95 | 4.65 | 6.89 | 6.93 | 9.30 | 9.11 | 6.12 | 9.14 |
| $GM$ = X*B | 0.211 | 0.209 | 0.255 | 0.257 | 0.288 | 0.282 | 0.225 | 0.283 |

The $GM$ and $k_r$ value for steel coil loading are newly added to Table 1 in Ch 4, Sec 2, [2.1.1] as a default value.

### 1.2 Modification of the requirements in Ch 6, Sec 1, [2.7.1] and Ch 6, Sec 2, [2.5.1]

The 3rd sentence and the 4th sentence in Ch 6, Sec 1, [2.7.1] and the 2nd sentence and the 3rd sentence in Ch 6, Sec 2, [2.5.1] are deleted due to the following reasons.

(a) As the term of the acceleration in the scantling formula is revised in order to accommodate any loading pattern of steel coil as mentioned in Annex 1, the limitation of the rule application regarding the loading pattern is not necessary.

(b) In addition, CSR does not permit overruling the scantling determined by the prescriptive requirement by FEA.

### 1.3 Clarification of the treatment of centre of gravity for steel coil loading

If the actual centre of gravity in steel coil loaded condition is known, it is better to use the actual one in calculating the acceleration. Therefore, this treatment has been added to the text.
If the actual centre of gravity is not known, the standard value of the centre of gravity is needed. Then the centre of gravity $(x, y, z)$ is set up $\left(mid-hold, \varepsilon B_h/4, h_{DB}+\left(1+(n_1-1)\sqrt{3}/2\right)d_{SC}/2\right)$ as a conservative manner, where $B_h$ is defined as a breadth of the cargo hold and ε is 1.0 when a port side structural member is considered, or -1.0 when a starboard side structural member is considered.

### 1.4 Amendment of the formulae for plating and ordinary stiffeners of inner bottom, bilge hopper and inner hull

In the current formulae for inner bottom plating and ordinary stiffeners (inner bottom longitudinals), load cases H and F are only considered but the load cases R and P is not considered. The rule change is made to consider the all load cases.

The current formulae for plating and ordinary stiffeners of bilge hopper and inner hull give the excessive scantling due to the account of gravity acceleration in duplicate and conservative coefficient $C_k$ . In addition, formula for shear area of the ordinary stiffeners is modified.

### 1.5 Amendment of the treatment which the number of load points per elementary plate panel is greater than 10 and/or the number of dunnages is greater than 5.

In the current requirements, the number of load points per elementary plate panel $n_2$ is greater than 10 and/or the number of dunnages $n_3$ is greater than 5, the scantling of plating and ordinary stiffeners may be checked by the formulae based on uniform distributed loads. However, this assumption is inappropriate because the scantling formula for steel coil is based on the line load which is transformed from the concentrated loads due to steel coil acting on the most severe locations of an elementary plate panel. Even if the number of load points becomes larger than 10, this assumption for the load model should be kept.

Therefore, the texts of Ch 6, Sec 1, [2.7.4] and Ch 6, Sec 2, [2.5.4] are deleted.

Furthermore, in order to clarify the treatment where the number of load points per elementary plate panel is greater than 10 and/or the number of dunnages is greater than 5, the relevant text is revised.

The technical backgrounds of these modifications are described in Annex 1.

## 2. Summary of Rule Changes

### 2.1 Ch 4, Sec 2, Table 1

The GM and $k_r$ values are added to Table 1 as averaged values based on the investigation results of actual ships' data.

### 2.2 Ch 6, Sec 1, [2.7.1]

The 3rd and the 4th sentences are deleted.

### 2.3 Ch 6, Sec 1, [2.7.2], [2.7.3], [2.7.4]

The new paragraph [2.7.1 bis1] is added for calculating the acceleration and the paragraph [2.7.4] is deleted. The tangential acceleration due to roll is added.

$$a_R = \theta \frac{\pi}{180}\left(\frac{2\pi}{T_R}\right)^2 \sqrt{{y_{SC}}^2 + R^2}$$

Where,

$y_{G\_SC}$: Centre of gravity in transverse direction, in m, is taken equal to $y_{G-sc} = \varepsilon \frac{B_h}{4}$

$R$: Coefficient defined in Ch 4 Sec 2, [3.2.1] of the Rules

$T_R$: Roll period, in s, defined in Ch 4, Sec 2, [2.1.1] of the Rules

$B_h$: breadth in m, at the mid of the hold.

In order to consider the acceleration of pitch, although the effect is very small because the hold length is relative short, the definition of $x_{G\_SC}$ is added as follows.

$x_{G-sc} = 0.75\ \ell_H$ forward of aft bulkhead, where the hold of which the mid position is located forward from 0,45L from A.E.

$x_{G-sc} = 0.75\ell_H$ afterward of fore bulkhead, where the hold of which the mid position is located afterward from 0,45L from A.E

The backgrounds of these modifications are described in Annex 1

**2.4 Ch 6, Sec 1, [2.7.2]**

The scantling formula for load cases H and F is revised in order to consider all load cases. In addition, the interpretation of the case where $n_2>10$ or $n_3>5$ is added.

$$t = K_1\sqrt{\frac{\{g(\cos(C_{ZP}\Phi)\cdot\cos(C_{ZR}\theta)) + a_z\}F}{\lambda_P R_Y}}$$

Where,

For $n_2<=10$ and $n_3<=5$, $F = K_S \dfrac{Wn_1n_2}{n_3}$

For $n_2>10$ or $n_3>5$ $F = K_S n_1 W \dfrac{l}{l_S}$

Definitions of all symbols are specified in the Rule text.

**2.5 Ch 6, Sec 1, [2.7.3]**

In the current formula, the gravity component is accounted in duplicate because the acceleration "$a_y$" contains the component of gravity acceleration. The formula is corrected to consider the gravity acceleration component correctly and to correspond to the all load case. In addition, the coefficient ck is changed based on the experimental data.

$$t = K_1\sqrt{\frac{a_{hopper}F'}{\lambda_p Ry}}$$

Where,

For $n_2<=10$ and $n_3<=5$, $F' = \dfrac{Wn_2C_k}{n_3}$

For $n_2>10$ or $n_3>5$ $F' = C_k W \dfrac{l}{l_S}$

$$a_{hopper} = -C_{YR}a_R \sin\left(\tan^{-1}\left|\frac{y_{G\_SC}}{R}\right| - \theta_h\right) + g\cos(\vartheta_h - C_{YG}\theta)\cos(C_{XG}\Phi) + C_{YS}a_{sway}\sin\theta_h$$

Definitions of all symbols are specified in the Rule text.

**2.6 Ch 6, Sec 1, [2.7.4]**

As the interpretation of the cases where $n_2>10$ and/or $n_3>5$ are added to the renumbered paragraph [2.7.3], the paragraph [2.7.4] is deleted.

**2.7 Ch 6, Sec 2, [2.5.1]**

The 2nd and the 3rd sentences are deleted.

**2.8 Ch 6, Sec 2, [2.5.2] and [2.5.3]**

The formulae for all load cases are provided as similar to the revision of the scantling formula for plating in Ch 6 Sec 1.

**2.9 Ch 6, Sec 2, [2.5.4]**

As the interpretation of the cases where $n_2>10$ and/or $n_3>5$ are added to the paragraph [2.5.3], this paragraph is deleted.

## 3. Scantling impact due to modifications

For scantling of inner bottom plating and ordinary stiffeners there is less impact due to this modification.

For thickness of bilge hopper sloping plate and inner hull plate and section modulus of ordinary stiffeners, the conservative scantling required by the current requirement is improved by this modification.

Details of the calculation for scantling impact due to these modifications are described in Annex 2.

# Annex 1: Background of the formulae for steel coil loading

## Ch 6, Sec 1

### 2.7 Inner bottom loaded by steel coils on a wooden support

### 2.7.1 General

**2.7.1a** In dimensioning the plating and ordinary stiffeners, static and dynamic loads due to dry bulk cargoes and liquid acting on the plating and ordinary stiffeners are considered as uniformly distributed loads. On the other hand, as steel coils are loaded on a wooden support (dunnage) provided on the inner bottom plating and bilge hopper plating, the concentrated loads due to steel coils act on the plating through the dunnage. However, as the location of concentrated loads and the distance between concentrated loads depend on the loading pattern and size of dunnage, it is assumed that the concentrated load is transformed to a line load with a small breadth (hereinafter referred to as “rectangular load”) which acts on the most severe conditions (load point and distance between load points). Based on this assumption, the specific formulae for dimensioning the plating and ordinary stiffeners under steel coil loading are introduced in the Rules separately from those based on uniformly distributed loads.

**2.7.1b** The specific requirements for plating are specified in Ch 6 Sec 1 [2.7.2] and [2.7.3], and those for ordinary stiffeners are specified in Ch 6 Sec 2 [2.5.2] and [2.5.4].

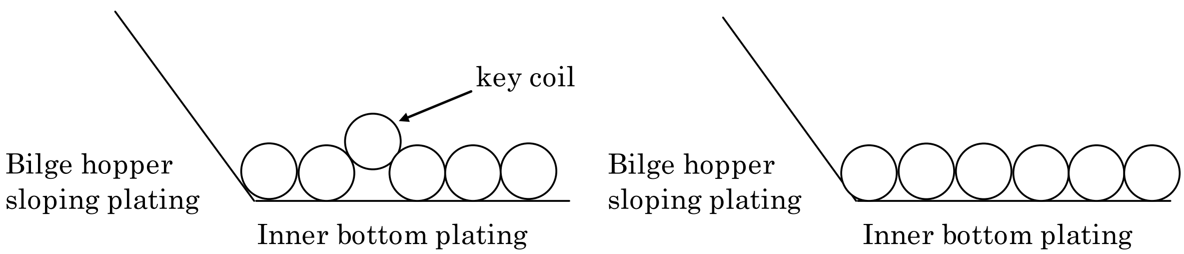
**2.7.1c** The technical background of loads due to steel coils is common for plating and ordinary stiffeners.

**2.7.1d** These requirements are based on the assumption that steel coils are loaded on a wooden support and secured in the standard manner. These assumptions are given in Figure 2 in Ch 6 Sec 1.

### 2.7.2 Inner bottom plating

**2.7.2a Load model**

Steel coils are usually secured to each other by means of steel wires. Heavier steel coils are loaded with one or two tiers, and lighter ones are loaded with two or more tiers. Examples of steel coil loading are shown in Figs.1 and 2.




(A) with key coil (B) without key coil

Fig.1 Loading conditions of one tier

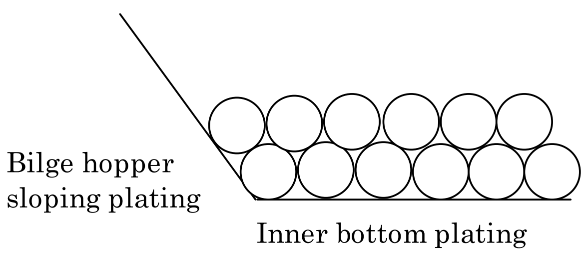



Fig.2 Loading conditions of two tiers

The load due to steel coils acts on an elementary plate panel as a concentrated load through dunnages. However, it is difficult to treat concentrated loads directly because the location of concentrated loads and the distance between concentrated loads depend on the loading pattern and size of dunnage. Then, the following assumptions regarding the loads due to steel coils are considered.

(1) Loads due to steel coils act along a centreline of a plate panel.

(2) A rectangular load instead of concentrated loads is used in order to be on the safer side considering the interaction between concentrated loads.

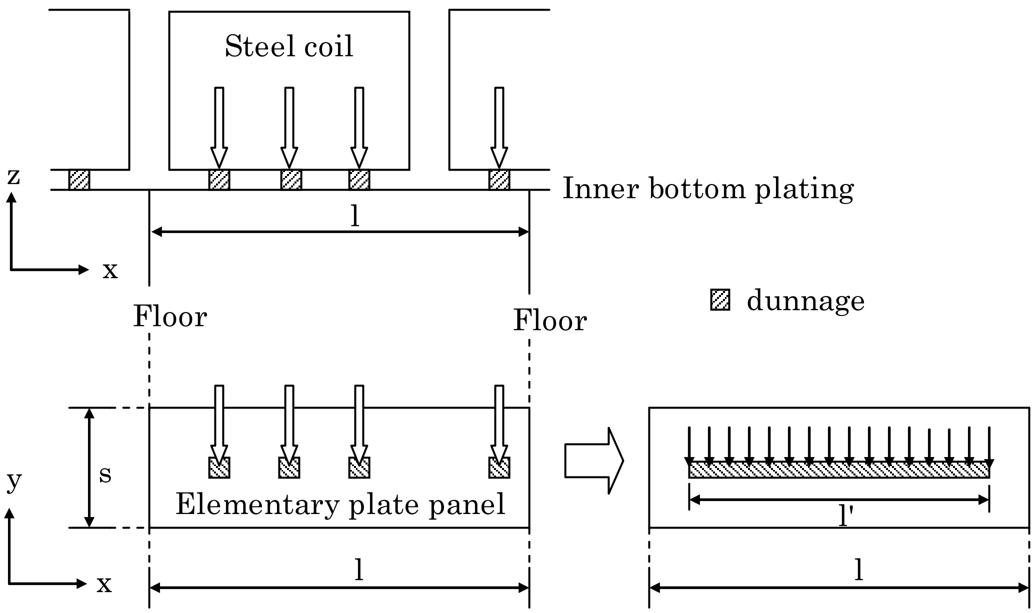



Fig.3 Convert concentrated loads to rectangular loads

As it is the most severe when loads act on the inner bottom vertically, the vertical acceleration is considered for the scantling formula of inner bottom structures. The position of the centre of gravity is given by the following.

$x$ direction: (i) for the hold of which the mid position is located forward of 0.45L from A.E.: $X_{G\_SC}$= 0.75 $\ell_H$ forward of aft bulkhead, and (ii) for the hold of which the mid position is located afterward of 0.45L from A.E.: $X_{G\_SC}$= 0.75 $\ell_H$ afterward of fore bulkhead, where $\ell_H$ is a cargo hold length

$y$ direction: $\varepsilon B_h/4$, measured from the centreline

$z$ direction: $h_{DB} + \left(1 + (n-1)\sqrt{3}/2\right) d_{SC}/2$

Where,

$d_{SC}$ : The diameter, in m, of steel coil

$h_{DB}$ : The height, in m, of double bottom

$B_h$: breadth, in m, at the mid of the hold

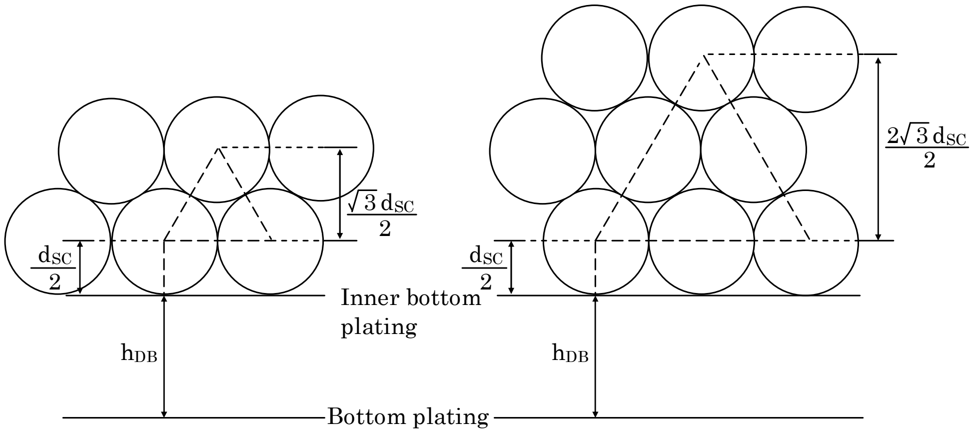



Fig.4 The height of steel coils

**2.7.2b Structural model**

As mentioned in 2.7.2a, the rectangular load acts along the centreline of the panel. Its length $l'$ is determined by the panel length $l$, the length of a steel coil $l_S$, the number of load points $n_2$ and the number of dunnages supporting one steel coil $n_3$, and its width $0.3s$ is derived from dunnage width based on the actual loading data. Of course, the axial stress due to hull girder bending is considered in addition to the lateral rectangular load due to the steel coils. An elementary plate panel is collapsed like Fig.5. The boundary conditions of an elementary plate panel are that all sides are considered fixed.

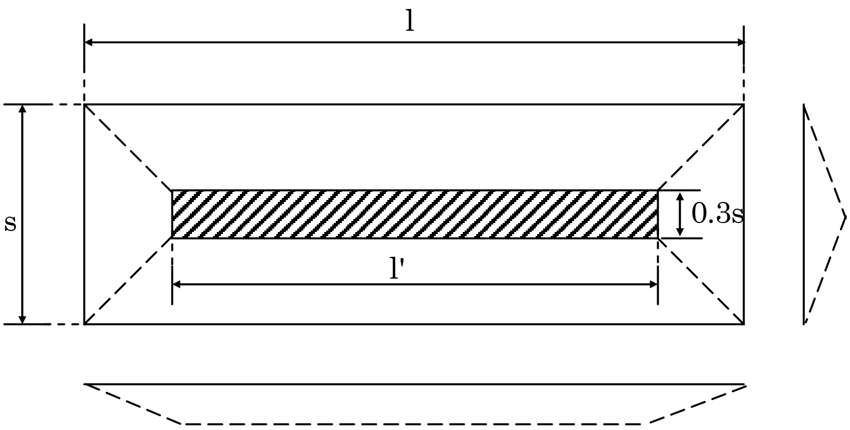



Fig.5 Rectangular load and collapsed mode

**2.7.2c Number of load points and distances between load points in ship length direction per elementary plate panel**

Tables 3 and 4 in Ch 6, Sec 1 of the Rules give the standard number of load points and distances between load points in ship length direction for the case of $n_2 \leq 10$ and/or $n_3 \leq 5$. For other cases, the current treatment as noted in Ch 6, Sec 1, [2.7.4] stipulates that loads due to steel coils are considered as a uniform distribution load and the scantling of plating is obtained according to Ch 6, Sec 1, [3.2.1]. However, it is considered that the scantlings of plating and ordinary stiffeners under steel coil loads are treated separately from those for distributed loads. Therefore, the instruction in Ch 6, Sec 1, [2.7.4] is not appropriate and it has been deleted. Instead a line load at panel centreline is assumed throughout the panel length.

The calculation results are shown in Table 1. In this calculation, the coefficient $n_3$ is changed from 3 to 6, the coefficient $n_2$ is derived from the same procedure gotten from Tables 3 and 4 in Ch 6, Sec 1 of the Rules.
The calculation results according to the generic formula for plating and ordinary stiffener specified in Ch 6, Sec 1, [3.2.1] and Sec 2, [3.2.3] of the Rules are calculated by assuming that the loads due to steel coils are treated as uniformly distributed loads defined as (Wl/ls).
It is found from this result that the required net thickness and net section modulus for uniform load is greater than those for load model specified in the Rules. In order to eliminate this difference between the case of $n_2$>10 and/or $n_3$>5 and the case of $n_2$<=10 and $n_3$<=5, the treatment of the case $n_2$>10 and/or $n_3$>5 is added to the Rules and current paragraphs [2.7.4] of Ch 6 Sec 1 and [2.5.4] of Ch 6, Sec 2 are deleted.

Table 1 Comparison of required scantlings

| | Line load according to Ch 6, Sec 1, [2.7.2] and Sec 2, [2.5.2] | | | | Uniform load according to Ch 6, Sec 1, [3.2.1] |
|---|---|---|---|---|---|
| l (m) | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 |
| s (m) | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| $n_1$ | 2 | 2 | 2 | 2 | - |
| $n_2$ | 5 | 6 | 7 | 9 | - |
| $n_3$ | 3 | 4 | 5 | 6 | |
| $l_s$ (m) | 1.5 | 1.5 | 1.5 | 1.5 | |
| l' (m) | 1.53 1 | 1.45 1 | 1.40 1 | 1.53 1 | |
| W (kg) | 15000 | 15000 | 15000 | 15000 | |
| F (kg) | 50000 | 45000 | 42000 | 45000 | 45000($n_2$=6) |
| $t_{net\ req}$ (mm) | 15.8 | 15.4 | 15.0 | 15.0 | 17.5 |
| $w_{net\ req}$ ($cm^3$) | 391 | 400 | 399 | 401 | 432 |

**2.7.2d Coefficient $K_S$**

When steel coils are lined up in one tier with a key coil as shown in Fig.1 (A), two coils support a key coil. However, it is known that half of the weight of a key coil does not act on the supporting coil due to the frictional resistance between steel coils. In order to investigate the effect of the frictional resistance between steel coils, parametric experiments were carried out by the Shipbuilding Research Association of Japan.
If the force due to steel coils is expressed by the following formula, the effect of frictional resistance ($K_S$) is given in Table 2.

$$F = K_S \frac{W n_1 n_2}{n_3}$$

Where,
$W$ : Mass of one steel coil, in kg
$n_1$ : Number of tier of steel coils
$n_2$ : Number of load points per elementary panel
$n$ : Number of dunnages supporting steel coil

Table 2 Coefficient $K_S$ derived from experiments results

| Position of key coil (m-n) | a/D | | |
|---|---|---|---|
| | 1/2 | 1/3 | 1/6 |
| 3-3 | 1.40 | 1.36 | 1.34 |
| 3-6 | 1.36 | 1.41 | 1.43 |

This result shows that the effect of the frictional resistance depends on the diameter of steel coils and distance between the centres of coils. The average value is 1.38, and therefore $K_S$ is taken to equal to 1.4 to be on the safe side.

### 2.7.2e Coefficient $K_1$ and $K_2$

The coefficients $K_1$ and $K_2$ are derived from the principle of virtual work based on material physics.

### 2.7.2f Formula for required thickness of inner bottom plating

Finally, the scantling formula for inner bottom plating is given as follows.

$$t = K_1 \sqrt{\frac{\{g(\cos(C_{ZP}\Phi)\cos(C_{ZR}\theta)) + a_z\}F}{\lambda_P R_Y}}$$

Where,

For $n_2$<=10 and $n_3$<=5, $F = K_S \frac{W n_1 n_2}{n_3}$

For $n_2$>10 or $n_3$>5 $F = K_S n_1 W \frac{l}{l_S}$

### 2.7.3 Bilge hopper sloping plate and inner hull plate

#### 2.7.3a Load model

The load model for hopper sloping and inner hull plating is very complex because the loads are supported by the inner bottom directly or by other steel coils as shown in Fig.6.

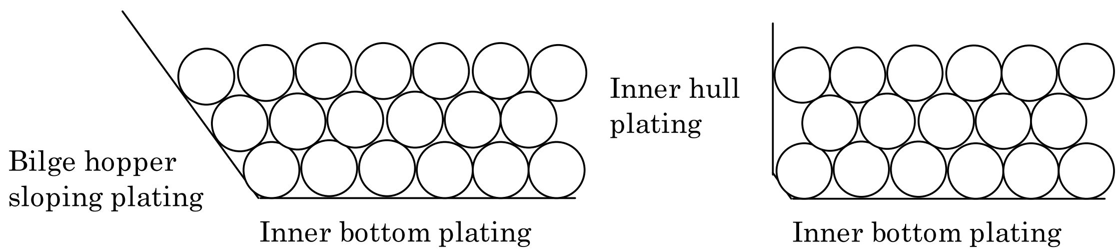



Fig.6 The examples of steel coil loading conditions

The force due to steel coils for bilge hopper sloping plate and inner hull plate is expressed by the following formula considering the effect of frictional resistance between steel coils and the support by the inner bottom.

$$F' = \frac{W n_2 C_k}{n_3}$$

Where,

$W$ , $n_2$ and $n_3$ are specified in 2.7.2d.

$C_k$ : The coefficient specified in 2.7.3c.

This load model is the same for the inner bottom. Although the vertical component of the load is supported by the inner bottom directly or by other coils, only $C_k$ is considered to derive the loads acting on the side wall.

As specified in 2.7.3c, the coefficient $C_k$ is introduced based on the experiments. This coefficient $C_k$ is based on the component of the load in the transverse direction. Therefore, the component of the load in transverse direction is only considered in the scantling formula for bilge hopper plate and inner hull plate.

In the original formula specified in the current Rule text, it was considered that the equivalent design wave (EDW) “R” was dominant in the bilge hopper sloping plate or inner hull plate. However, as the acceleration in transverse direction specified in Ch 4 Sec 2, [3.2.1] includes the static component due to roll angle, the static component due to gravity acceleration is counted in duplicate. Therefore, the term related to the transverse acceleration in scantling formula for load case R is revised.

In addition, in order to cover all load cases, the term related to the acceleration in the scantling formula is revised as follows, considering the load combination factors.

$$a_{hopper} = -C_{YR} a_R \sin\left(\tan^{-1}\left|\frac{y_{G\_SC}}{R}\right| - \theta_h\right) + g\cos(\theta_h - C_{YG}\theta)\cos(C_{XG}\Phi) + C_{YS} a_{sway} \sin\theta_h$$

Where:

$a_{roll\,y}$ $a_{sway}$ : Acceleration due to roll and sway, in m/s$^2$, defined in Ch.4 Sec.2 [3.2]

$a_R$ : Tangential roll acceleration, in m/s$^2$. (See Fig. 7)

$$a_R = \theta\frac{\pi}{180}\left(\frac{2\pi}{T_R}\right)^2\sqrt{{y_{G-sc}}^2 + R^2}$$

$y_{G-sc}$ : Centre of gravity of steel coils in transverse direction, in m. (see Fig, 7)

$R$ : Coefficient defined in Ch. 4 Sec. 2 [3.2.1]. (see Fig.7)

$T_R$ : Roll period, in s, defined in Ch 4, Sec 2, [2.1]

$g$ : Gravity acceleration, in m/s$^2$

$\theta_h$ : Angle, in degrees, between inner bottom plating and bilge hopper sloping plate or inner hull plate. (see Fig. 7)

$\theta$ : Single roll amplitude, in degrees, defined in Ch 4, Sec 2, [2.1]

$C_{YG}$, $C_{YR}$, $C_{YS}$, $C_{XG}$: Load combination factors defined in Ch 4, Sec 4, [2.2]

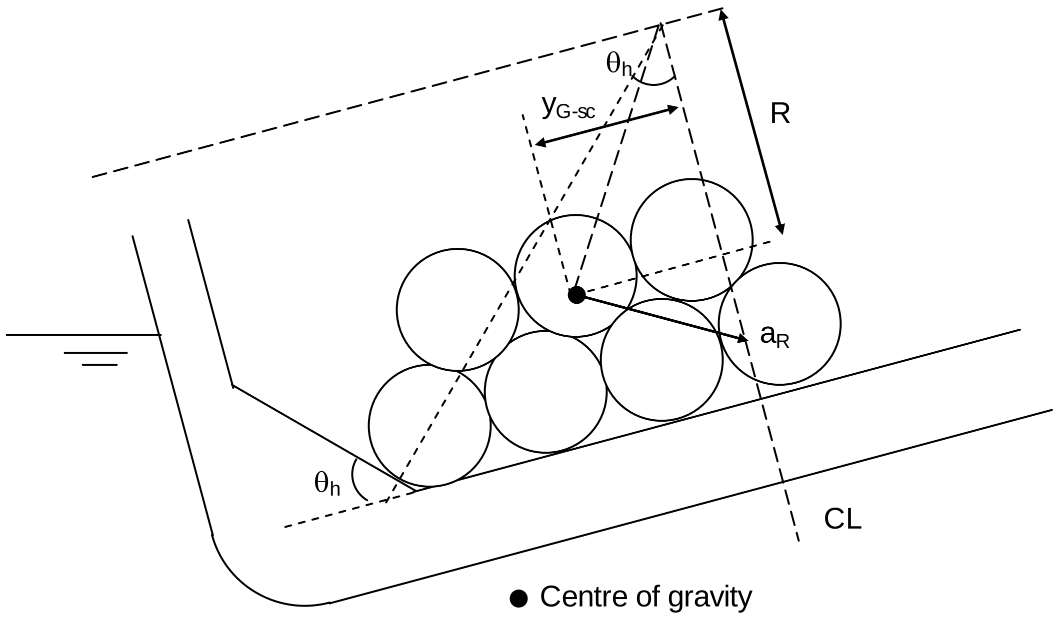


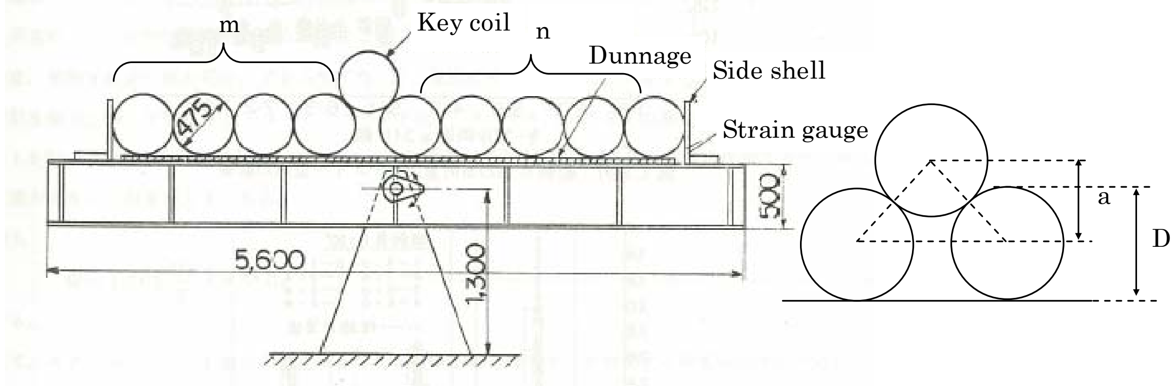

Fig.7 Definition of the acceleration $a_R$

**2.7.3b Structural model**

The structural model for bilge hopper sloping plating and inner hull plating is the same for inner bottom plating.

**2.7.3c Coefficient Ck**

In order to determine the coefficient $C_k$ specified in 2.7.3a, experiments were performed by the Shipbuilding Research Association of Japan. According to the report, the experiments were carried out under the following conditions specified in (a) to (d) and as shown in Fig.8.




Note: m and n is the number of coils counted from the key coil.

Fig.8 Experiment device and loading condition of steel coils

(a) Steel coils were loaded with one tier with key coil
(b) Roll angle was 20 degree
(c) Roll period was 60 seconds
(d) Position of key coil was changed (“m” in Fig.8 was changed from 1 to 8)

In addition, a theoretical analysis was tried and the results are shown in Fig. 9. According to the results shown in Fig. 9, the following outcomes were obtained.

i) The Ck value is obtained from the loads on side wall based on the force in transverse direction.
ii) The $C_k$ value strongly depends on the location of the key coil.
iii) The effect of the diameter of steel coils and the length between the gravity centre of steel coils is relatively small compared to the effect of the location of the key coil.
iv) The calculation results match the experimental results well.
v) In order to be on the safe side, $C_k = 3.2$ is an appropriate value when the key coil is located second or third from the side shell and $C_k = 2.0$ is appropriate in other cases.

$C_k$ : Coefficient taken to equal:

$C_k = 3.2$ when steel coils are lined up in two or more tiers, or steel coils are lined up in one tier and the key coil is located second or third from the bilge hopper sloping plating or inner hull plating

$C_k = 2.0$ for other cases

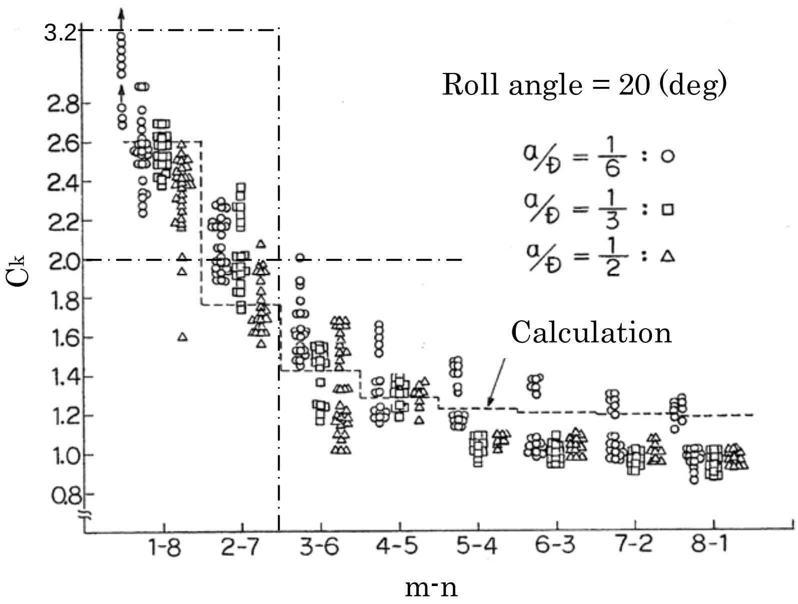



Fig.9 Experimental results

**2.7.4**
**2.7.4a** The current text is deleted.

# Ch 6, Sec 2

### 2.5 Ordinary stiffeners of inner bottom loaded with steel coils on a wooden support

### 2.5.1 General

**2.5.1a** Same as specified in 2.7 for plating.

### 2.5.2 Ordinary stiffeners located on inner bottom plating

### 2.5.2a Load model

As the structural model for plating is based on the plastic theory, it is too complex to treat the concentrated load. Therefore, a rectangular load is considered in the requirement for plating mentioned in Ch 6, Sec 1, [2.7.2].

On the other hand, the structural model for ordinary stiffeners is based on the simple elastic beam theory. Therefore, the load model for ordinary stiffeners is based on concentrated loads due to steel coils acting through the dunnage.

The calculation of acceleration is based on the same assumption for plating.
The parameter and coefficients are also the same for plating.
According to the similar reason specified in 2.7.2c, Ch 6, Sec 2, [2.5.4] has been deleted.

**2.5.2b Structural model**

Structural model of ordinary stiffeners is based on the simple beam theory with the boundary condition that both ends of beams are fixed.

**2.5.2c Coefficient $K_3$**

The coefficient $K_3$ is derived from the ratios of moments at ends of ordinary stiffeners against $n_2 = 1$ when load points of the concentrated loads are located evenly between $l'$ as shown in Fig.10 When $n_2$ is over 10, the coefficient $K_3$ is 2/3.

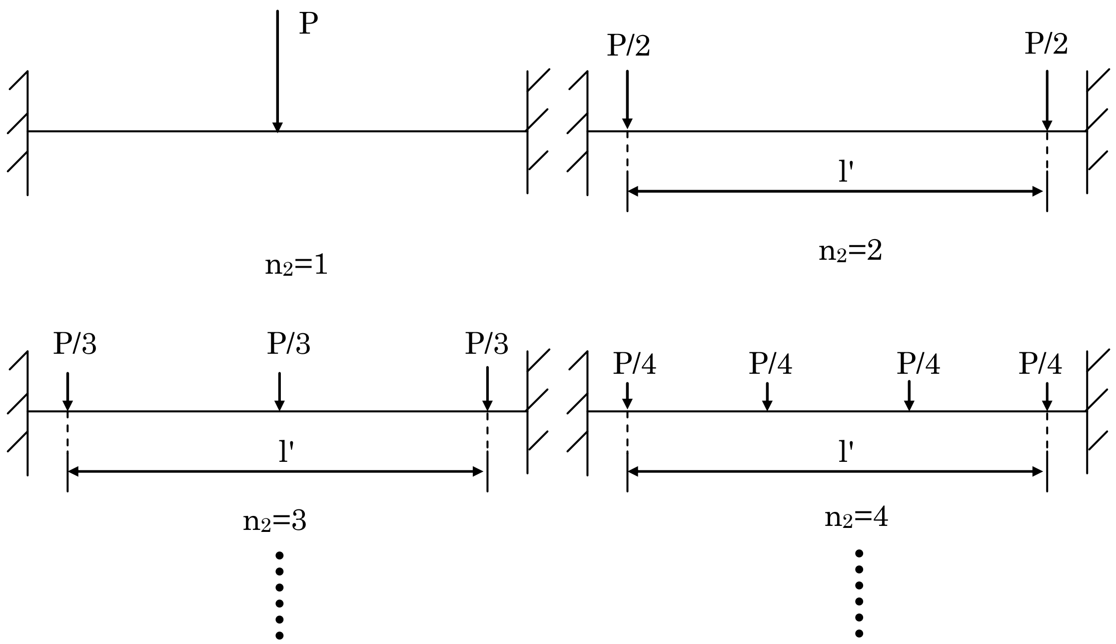



Fig.10 Load points on an ordinary stiffener

**2.5.3 Ordinary stiffeners located on hopper sloping plate or inner hull plating**

**2.5.3a Load model**

The concentrated load is considered as specified in 2.5.2a and the acceleration due to roll motion is considered as specified in 2.7.3a of Ch 6, Sec 1.

**2.5.3b Structural model**

Structural model of an ordinary stiffener is specified in 2.5.2b.

**2.5.4**

**2.5.4a** This item is deleted.

# Annex 2: Scantling impact due to modifications

**Ramification studies**

In order to quantify the impact due to the modification of the scantling formula for plating and ordinary stiffeners, ramification studies were performed using the following 6 ships listed in Table 2-1.

The data of the steel coils listed in Table 2-2 taken from the loading manuals of the considered ships was used for the ramification study.

Table 2-1 Principal dimensions of subject ships

| Pre-CSR ship | | | | CSR ship | |
|---|---|---|---|---|---|
| Ship 1 | Ship 2 | Ship 3 | Ship 4 | Ship 5 | Ship 6 |
| Handy max | Small | Small | Handymax | Handymax | Handy |

Table 2-2 Data of steel coils

| | Ship 1 | Ship 2 | Ship 3 | Ship 4 | Ship 5 | Ship 6 |
|---|---|---|---|---|---|---|
| $W$ (kg) | 15000 | 20000 | 15000 | 20000 | 15000 | 15000 |
| $l_S$ (m) | 1.5 | 1.8 | 1.5 | 1.5 | 1.5 | 1.5 |
| Number of tiers | 2 | 1 | 1 | 2 | 2 | 2 |
| Key coil | not used | used | used | Not used | Not used | Not used |

## 1. Scantling changes at inner bottom structures

Where the number of load points is not greater than 10 and/or number of dunnages is not greater than 5, the scantling formulae for inner bottom plating and ordinary stiffeners are not changed by the Rule Change proposal 3. However, as the calculation point of acceleration is modified and the default value of $GM$ and $k_r$ are newly added, the scantling impact calculations were carried out in order to grasp the changes.

Calculation results are shown in Figs.2-1 to 2-3. These results show that the required scantlings are not that different between the current CSR and the modification because the vertical acceleration in EDW “H” which is dominant for the scantlings of inner bottom plating and longitudinals is not affected by the y- and z- coordinate of the gravity centre.

For reference, the required thickness of inner bottom plating was increased by 3 to 4mm compared to that of pre-CSR designs because the corrosion additions specified in CSR are larger by 3 to 4 mm than those used in Pre-CSR designs.

Regarding inner bottom longitudinals, the difference between the required section modulus and the actual one of pre-CSR designs varies largely depending on the design.

The required shear area is smaller than the actual one of pre-CSR designs.

On the other hand, as the offered scantlings of inner bottom structure for CSR design ships are greater than those determined by the requirement for steel coil loading, they may be determined by the requirement other than that for steel coil loading.

Therefore, there is no scantling impact for inner bottom plate and longitudinals due to his change.

## 2. Scantling changes at bilge hopper and inner hull structures

### 2.1 Scantlings of plating

Required gross thicknesses of bilge hopper sloping plating are shown in Fig.2-4. This figure shows that the modification improves the formula by providing the appropriate thickness compared to that of inner bottom plating.

For reference, the required thicknesses of bilge hopper sloping plating was increased by 3 to 4mm compared to those of pre-CSR designs because the corrosion additions specified in CSR are larger by 3 to 4mm than those used in the pre-CSR designs.

For CSR ships, the thicknesses of bilge hopper plating are determined by the requirement for steel coil loading, but, the scantling of longitudinal attached to the hopper sloping plate may be determined by the requirement other than that for steel coil loading. As a result, only thickness of hopper sloping plate according to the proposed formula becomes that similar to inner bottom plating and decreased about 4mm for these example cases.

If the thicknesses of hopper sloping plate would be determined by the proposed requirement for steel coil loading, the total steel weight is decreased about 20 tons for ship 5 and 15 tons for ship 6 by this change.

## 2.2 Scantlings of ordinary stiffeners

### 2.2.1 Section modulus

Required net section moduli of ordinary stiffeners attached to bilge hopper sloping plating are shown in Fig. 2-5. This figure shows that the modification improves the formula by providing the appropriate section modulus compared to that of inner bottom longitudinals.

Regarding the bilge hopper longitudinal, the difference between the required section modulus and actual one of Pre-CSR designs varies largely depending on the design.

For CSR ships, the scantlings of longitudinal attached to hopper sloping plate become about 60% of those required current rules in terms of section modulus by this change. Therefore, the final scantlings of the longitudinal may be determined by other requirements.

If the scantling of longitudinals would be determined by the proposed formula, the steel weight will be decreased about 4 tons for ship 5 and 2 tons for ship 6 by this change.

### 2.2.2 Section area

Required net section areas of ordinary stiffeners fitted to the bilge hopper sloping plating are shown in Fig.2-6. The required section area according to modified formulae is larger than those of current CSR. This increase is caused by the correction of a mistake in the formula.

For reference, the required shear area according to the modified formula is smaller than the actual one of both pre-CSR designs and CSR ships.

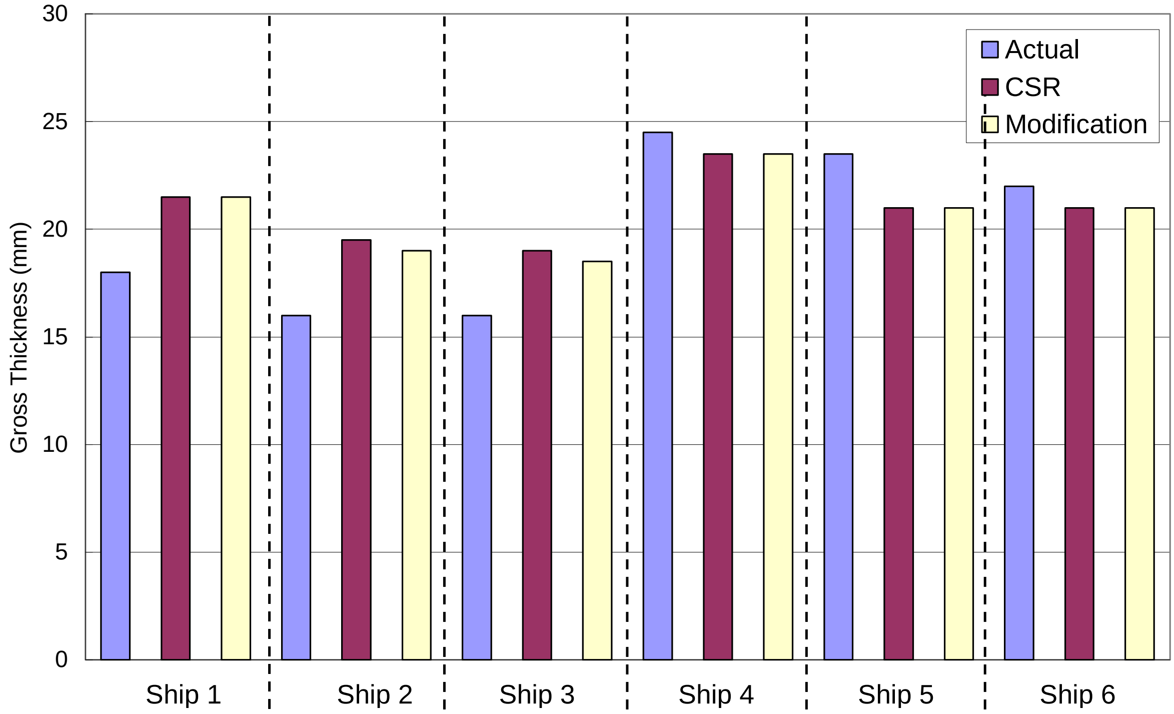



Fig.2-1 Comparison of gross thickness of inner bottom plate

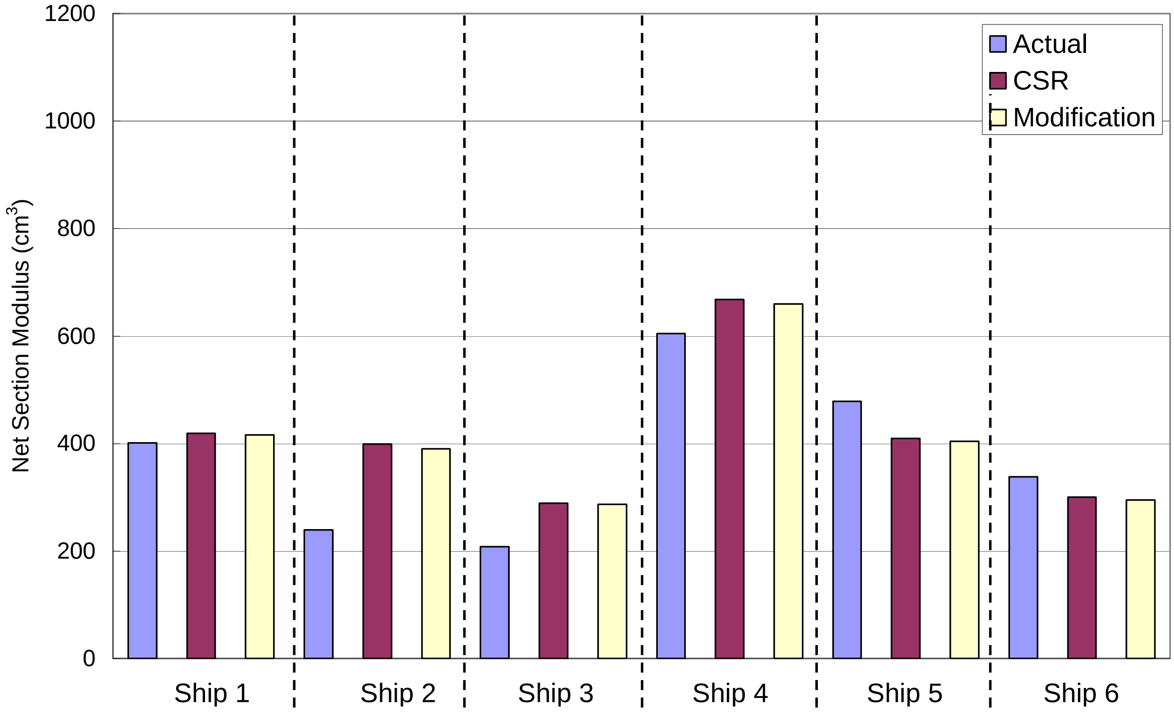



Fig. 2-2 Comparison of net section moduli of inner bottom longitudinals

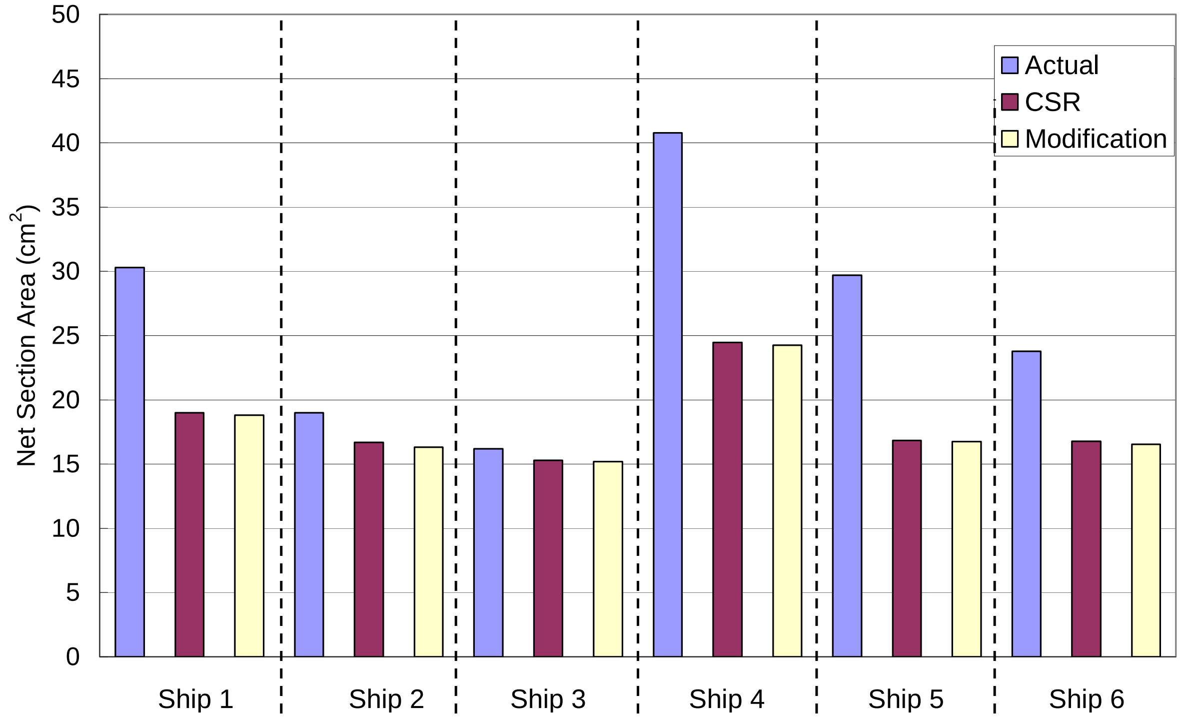



Fig.2-3 Comparison of net section area of inner bottom longitudinals

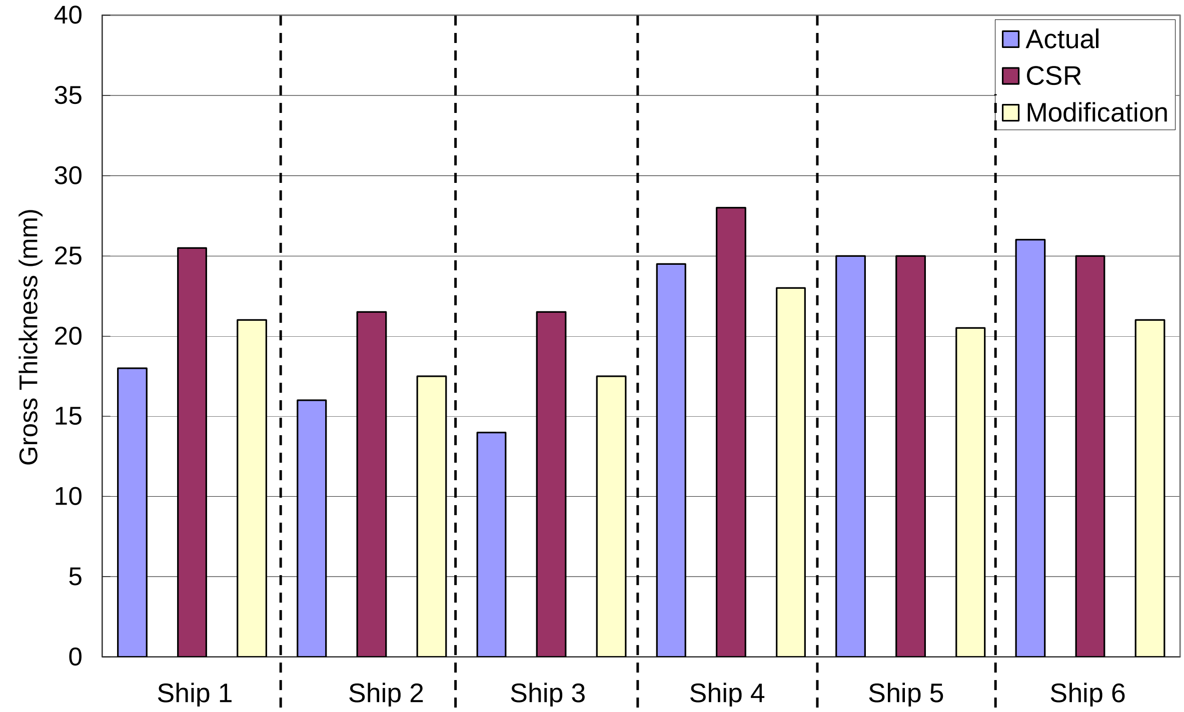



Fig. 2-4 Comparison of gross thickness of bilge hopper sloping plate

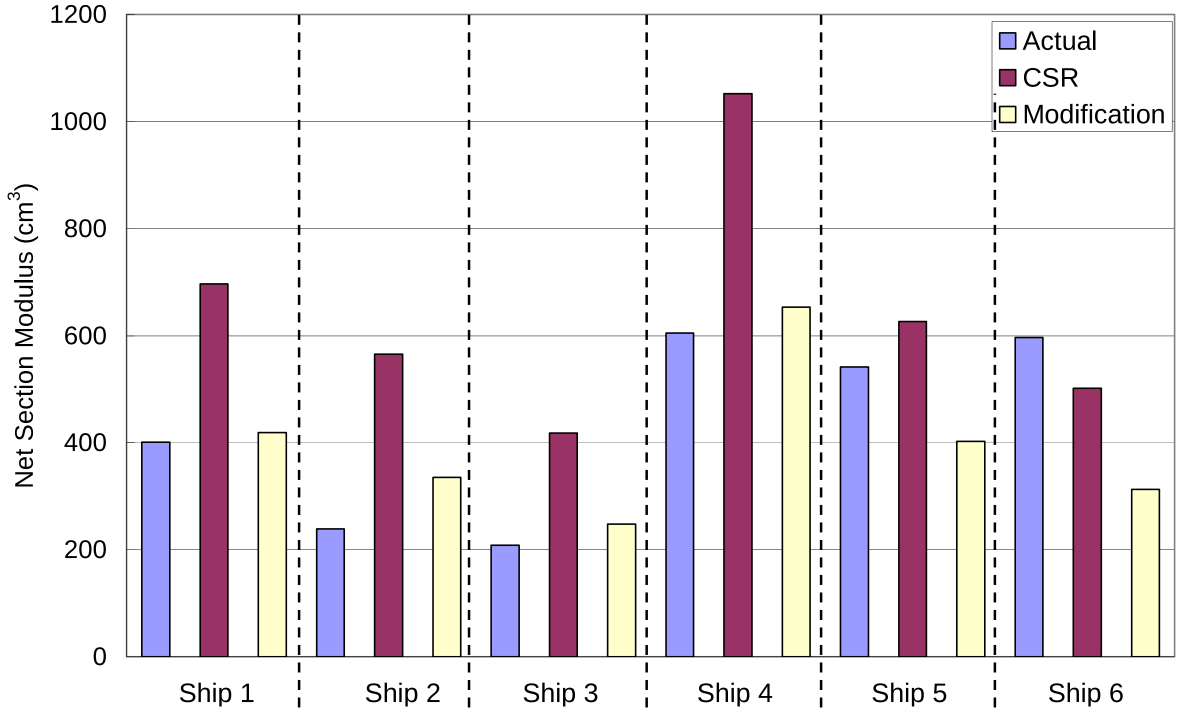



Fig.2-5 Comparison of net section moduli of longitudinals attached to bilge hopper sloping plate

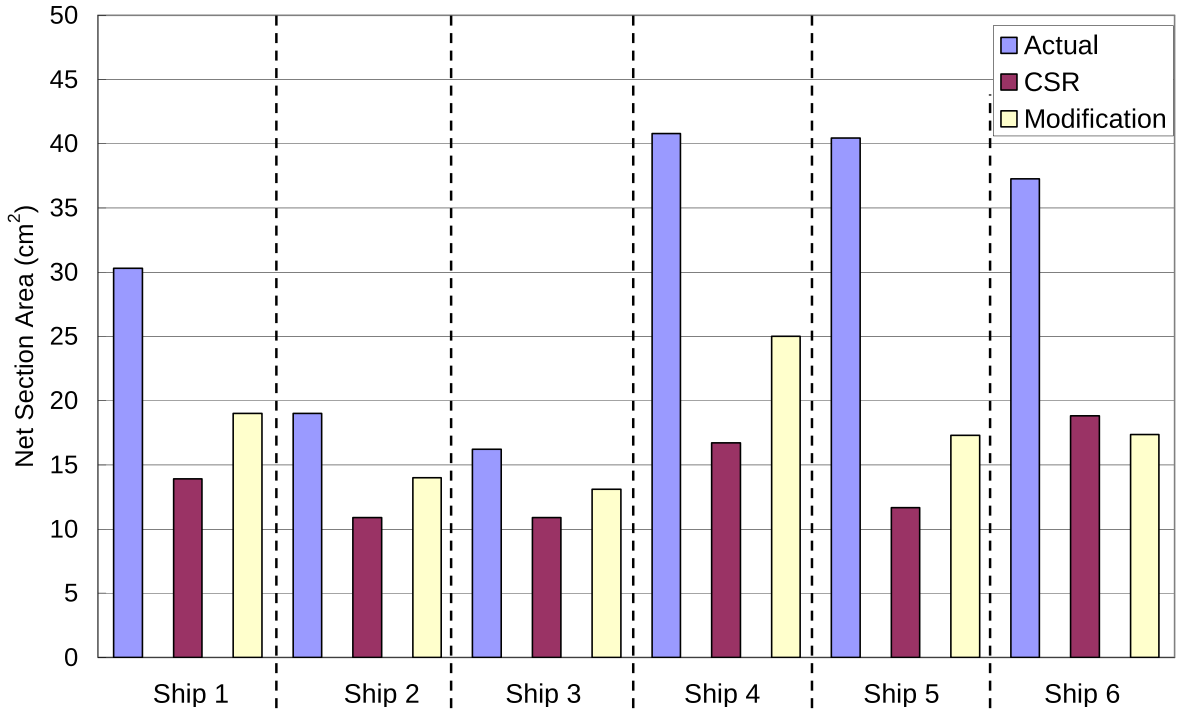



Fig.2-6 Comparison of net section area of longitudinals attached to bilge hopper sloping plate

Common Structural Rules for
Bulk Carriers, July 2008

# Rule Change Notice No.1-4 (Minimum Scantling, Side Frame and Grab)

Notes: (1) These Rule Changes enter into force on 1 July 2009.

For technical background for Rule Changes in this present document, reference is made to separate document Technical Background for Rule Change Notice No.1-4.

# Chapter 6 HULL SCANTLING

## Section 2 ORDINARY STIFFENERS

## 2. General requirements

### 2.2 ~~Minimum n~~Net thicknesses of webs of ordinary stiffeners

#### 2.2.1 Minimum net thicknesses of webs of o~~O~~rdinary stiffeners other than side frames of single side bulk carriers

The net thickness of the web of ordinary stiffeners, in mm, is to be not less than the greater of:

- $t = 3.0 + 0.015L_2$
- 40% of the net required ~~offered~~ thickness of the attached plating, to be determined according to Ch.6, Sec.1.

~~and is to be less than 2 times the net offered thickness of the attached plating~~

#### 2.2.2 Minimum net thicknesses of s~~S~~ide frames of single side bulk carriers

The net thickness of side frame webs within the cargo area, in mm, is to be not less than the value obtained from the following formula:

$t_{MIN} = 0.75\,\alpha\,(7 + 0.03L)$

where:

$\alpha$ : Coefficient taken equal to:

$\alpha$ = 1.15 for the frame webs in way of the foremost hold

$\alpha$ = 1.00 for the frame webs in way of other holds.

#### 2.2.3 Maximum net thickness of web of ordinary stiffener

The net thickness of the web of ordinary stiffeners, in mm, is to be less than 2 times the net offered thickness of the attached plating.

## 3. Yielding check

### 3.3 Strength criteria for side frames of single side bulk carriers

#### 3.3.1 Net section modulus and net shear sectional area of side frames

The net section modulus $w$, in cm$^3$, and the net shear sectional area $A_{sh}$, in cm$^2$, of side frames subjected to lateral pressure are to be not less, in the mid-span area, than the values obtained from the following formulae:

$$w = 1.125\alpha_m \frac{(p_S + p_W)s\ell^2}{m\lambda_S R_Y}10^3$$

$$A_{sh} = 1.1\alpha_S \frac{5(p_S + p_W)s\ell}{\tau_a \sin\phi}\left(\frac{\ell - 2\ell_B}{\ell}\right)$$

where:

$\alpha_m$ : Coefficient taken equal to:

$\alpha_m = 0.42$ for **BC-A** ships

$\alpha_m = 0.36$ for other ships

$\lambda_S$ : Coefficient taken equal to 0.9

$\ell$ : Side frame span, in m, defined in Ch 3, Sec 6, Fig 19, to be taken not less than 0.25$D$

$\alpha_S$ : Coefficient taken equal to:

$\alpha_S = 1.1$ for side frames of holds specified to be empty in **BC-A** ships

$\alpha_S = 1.0$ for other side frames

$\ell_B$ : Lower bracket length, in m, defined in Fig 7

$p_S$, $p_W$ : Still water and wave pressures, in kN/m², in intact conditions calculated as defined in [1.3] and [1.4.2].

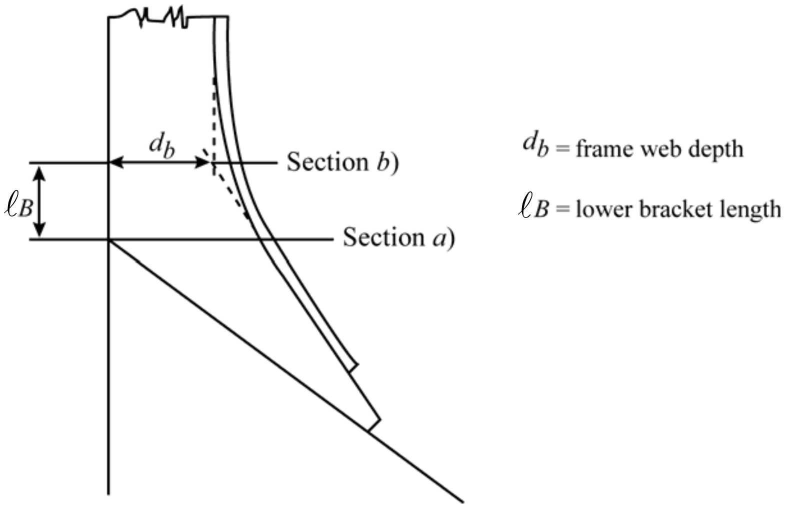



**Figure 7 Side frame lower bracket length**

In addition ~~to the above provision~~, for side frames of holds intended to carry ballast water in heavy ballast condition, the net section modulus $w$, in cm$^3$, and the net shear sectional area $A_{sh}$, in cm$^2$, all along the span ~~of side frames subjected to lateral pressure in holds intended to carry ballast water~~ are to be in accordance with [3.2.3], $\ell$ being the span of the side frame as defined in Ch.3 Sec.6 [4.2], with consideration to brackets at ends.

### 3.3.3 Lower bracket of side frame

~~In addition, a~~At the level of lower bracket as shown in Ch 3, Sec 6, Fig 19, the net section modulus of the frame and bracket, or integral bracket, with associated shell plating, is to be not less than twice the net section modulus $w$ required for the frame mid-span area obtained from [3.3.1].

In addition, for holds intended to carry ballast water in heavy ballast condition, the net section modulus $w$, in cm$^3$, at the level of lower bracket is to be not less than twice the greater of the net sections moduli obtained from [3.3.1] and [3.2.3].

The net thickness $t_{LB}$ of the frame lower bracket, in mm, is to be not less than the net thickness of the side frame web plus 1.5 mm.

Moreover, the net thickness $t_{LB}$ of the frame lower bracket is to comply with the following formula:

- for symmetrically flanged frames: $\frac{h_{LB}}{t_{LB}} \leq 87\sqrt{k}$
- for asymmetrically flanged frames : $\frac{h_{LB}}{t_{LB}} \leq 73\sqrt{k}$

The web depth $h_{LB}$ of lower bracket may be measured from the intersection between the sloped bulkhead of the hopper tank and the side shell plate, perpendicularly to the face plate of the lower bracket (see Ch 3, Sec 6, Fig 22).

For the 3 side frames located immediately abaft the collision bulkhead, whose scantlings are increased according to [3.3.2], when $t_{LB}$ is greater than $1.73t_w$, the thickness $t_{LB}$ may be taken as the value $t'_{LB}$ obtained from the following formula:

$$t'_{LB} = \left(t_{LB}{}^2 t_w\right)^{1/3}$$

where $t_w$ is the net thickness of the side frame web, in mm, corresponding to $A_{sh}$ determined in accordance to [3.3.1].

The flange outstand is not to exceed $12k^{0.5}$ times the net flange thickness.

### 3.3.4 Upper bracket of side frame

~~In addition, a~~At the level of upper bracket as shown in Ch 3, Sec 6, Fig 19, the net section modulus of the frame and bracket, or integral bracket, with associated shell plating, is to be not less than twice the net section modulus *w* required for the frame mid-span area obtained from [3.3.1].

In addition, for holds intended to carry ballast water in heavy ballast condition, the net section modulus $w$, in $cm^3$, at the level of upper bracket is not to be less than twice the greater of the net sections moduli obtained from [3.2.3] and [3.3.1].

The net thickness $t_{UB}$ of the frame upper bracket, in mm, is to be not less than the net thickness of the side frame web.

# CHAPTER 9 OTHER STRUCTURES

## Section 1 FORE PART

### 4. Scantlings

### 4.3 Ordinary stiffeners

#### 4.3.3

The net thickness of the web of ordinary stiffeners, in mm, is to be not less than the greater of:

- $t = 3.0 + 0.015L_2$
- 40% of the net ~~offered~~ required thickness of the attached plating, to be determined according to [4.2] and [5.2].

~~and is to be less than twice the net offered thickness of the attached plating~~.

The net dimensions of ordinary stiffeners are to comply with the requirement in Ch 6, Sec 2, [2.2.2] and [2.3].

# Section 2 AFT PART

## 4. Scantlings

### 4.2 Ordinary stiffeners

#### 4.2.3

The net thickness of the web of ordinary stiffeners, in mm, is to be not less than the greater of:

- $t = 3.0 + 0.015L_2$
- 40% of the net ~~offered~~ required thickness of the attached plating, to be determined according to [4.1].

~~and is to be less than twice the net offered thickness of the attached plating.~~

The net dimensions of ordinary stiffeners are to comply with the requirement in Ch 6, Sec 2, [2.2.2] and [2.3].

# CHAPTER 12 ADDITIONAL CLASS NOTATIONS

## Section 1 GRAB ADDITIONAL CLASS NOTATION

## 2. SCANTLINGS

### 2.1. Plating

#### 2.1.1

The net thickness of plating of inner bottom, ~~lower strake of~~ hopper tank sloping plate, ~~and~~ transverse lower stool ~~plating~~, transverse bulkhead plating and inner hull up to a height of 3.0m above the lowest point of the ~~from~~ inner bottom, excluding bilge wells, is to be taken as the greater of the following values:

- $t$ , as obtained according to requirements in Ch 6 and Ch 7
- $t_{GR}$ , as defined in [2.1.2] and [2.1.3].

#### 2.1.2

The net thickness $t_{GR}$, in mm, of the inner bottom plating is to be obtained from the following formula:

$$t_{GR} = 0.28(M_{GR} + 50)\sqrt{sk}$$

#### 2.1.3

The net thickness $t_{GR}$, in mm, ~~within the lower 3 m~~ of hopper tank sloping plate, ~~and of~~ transverse lower stool, transverse bulkhead plating and inner hull up to a height of 3.0m above the lowest point of the inner bottom, excluding bilge wells, is to be obtained from the following formula:

$$t_{GR} = 0.28(M_{GR} + 42)\sqrt{sk}$$

# Common Structural Rules for Bulk Carriers, July 2008

# Technical Background for Rule Change Notice No.1-4 (Minimum Scantling, Side Frame and Grab)

# Technical Background for the Changes Regarding Scantling Requirement for Ordinary stiffener, Side Frame and Grab

## 1. Reason for the Rule Change:

### 1.1 Ch 6, Sec 2, [2.2]

The current CSR requires the minimum thickness of webs of ordinary stiffeners is not to be less than 40% of the net offered thickness of the attached plating. However, there are some cases where the thickness of plating is increased due to buckling check of the plating and hull girder strength check and so on. In such cases, the thickness of web of ordinary stiffener is determined by the increased offered thickness of the attached plating and sometimes scantling of the angle type stiffener is remarkable large in order to satisfy with this requirement. This rule change is made to avoid such cases. (KC ID 213).

In addition, the maximum thickness of webs of ordinary stiffeners is mentioned in [2.2.1], although the title of this requirement is minimum thickness requirement.
This requirement is based on the consideration of the proportion of thickness between the attached plating and webs of ordinary stiffener. Accordingly, [2.2] will be modified to be applicable both on minimum and maximum thickness, as follows:

- Title of [2.2] should be "Net thicknesses of webs of ordinary stiffeners"
- Title of [2.2.1] should be "Minimum net thicknesses of webs of ordinary stiffeners other than side frames of single side bulk carriers"
- Title of [2.2.2] should be "Minimum net thicknesses of side frames of single side bulk carriers"
- New [2.2.3] with the following title: "Maximum net thickness of web of ordinary stiffener".

### 1.2 Ch 6 Sec 2, [3.3.1]

This change is made to clarify the requirement by specifying the extent of the span to use and the calculation point for still water and wave pressures (refer to KC ID 216 and 217).
It specifies also that the requirements of Ch6. Sec2 [3.2.3] are to be asserted along the whole span of the frames for holds intended to carry ballast water in heavy ballast condition (KC ID 356).

### 1.3 Ch 6 Sec 2, [3.3.3]

This change is made to clarify the requirement by specifying the requirements to be met for side frame's lower bracket in holds intended to carry ballast water in heavy ballast condition (KC ID 356).

### 1.4 Ch 6 Sec 2, [3.3.4]

This change is made to clarify the requirement by specifying the requirements to be met for side frame's upper bracket in holds intended to carry ballast water in heavy ballast condition (KC ID 356).

### 1.5 Ch 9 Sec 1, [4.3.3] and Sec 2, [4.2.3]

The requirements in Ch 9 Sec 1, [4.3.3] and Sec 2 [4.2.3] are same required in Ch 6 Sec 2, [2.2.1].

### 1.6 Ch 12 Sec 1, [2.1]

This change is made to clarify the requirement by specifying the areas concerned by this calculation (refer to KC ID 313 and 544).

## 2. Summary of Rule Changes

### 2.1 Ch 6, Sec 2, [2.2.1], [2.2.3], Ch 9 Sec 1, [4.3.3] and Sec 2, [4.2.3]

(1) The "net offered thickness" is changed to "net required thickness" and the required thickness is determined according to Ch 6 Sec 1.
(2) The maximum net offered thickness is deleted from the requirement in [2.2.1] and the formula with the same meaning are added to new paragraph [2.2.3].
(3) The requirements in Ch 9 Sec 1, [4.3.3] and Sec 2, [4.2.3] are revised in order to be same for Ch 6 Sec 2, [2.2.1].

### 2.2 Ch 6, Sec 2, [3.3.1]

(1) The definition of the pressures for side frames is added.
(2) For side frames in ballast hold, the scantling check is carried out as an ordinary stiffener with span defined in Ch 3 Sec 6 [4.2].

### 2.3 Ch 6, Sec 2, [3.3.3] and [3.3.4]

For lower and upper brackets of side frame in ballast hold, the net section modulus at the level of brackets of side frame is to be not less than twice of the net section moduli obtained by the requirements for both side frames and ordinary stiffeners.

### 2.4 Ch 12 Sec 1, [2.1]

Inner hull up to a height of 3.0m from the lowest point of inner bottom is applied to this requirement.

## 3. Impact on Scantling

### 3.1 Ch 6, Sec 2, [2.2.1], [2.2.3], Ch 9 Sec 1, [4.3.3] and Sec 2, [4.2.3]

Regarding the minimum thickness requirement of webs of ordinary stiffeners, the scantling impact depends on the stiffener type used. If the angle type stiffener is used, the scantling is decrease by this change but steel weight decrease is negligible.

### 3.2 Ch 6 Sec 2 [3.3.1], [3.3.3] and [3.3.4]

There is no change in terms of the steel weight by comparing that before and after the proposed Rule change.

### 3.3 Ch 12 Sec 1, [2.1]

For double side skin bulk carrier having the height of the bilge hopper tanks less than 3.0m or hybrid bulk carrier with cargo hold without hopper tank, it is considered that the thickness of inner hull may be increased by this rule change. However, as there is no CSR ships with such design, the scantling impact cannot be compared that before and after the proposed Rule change.

# Common Structural Rules for Bulk Carriers, July 2008

# Rule Change Notice No.1-5 (Direct Strength Analysis)

Notes: (1) These Rule Changes enter into force on 1 July 2009.

For technical background for Rule Changes in this present document, reference is made to separate document Technical Background for Rule Change Notice No.1-5.

# CHAPTER 7 DIRECT STRENGTH ANALYSIS

## Section 2 GLOBAL STRENGTH FE ANALYSIS OF CARGO HOLD STRUCTURES

### 2. Analysis model

### 2.2 Finite element modeling

#### 2.2.4

When orthotropic elements are not used in FE model:

- mesh size is to be equal to or less than the representative spacing of longitudinal stiffeners or transverse side frames
- stiffeners are to be modeled by using rod and/or beam/bar elements
- ~~where a double hull is fitted,~~ webs of primary supporting members are to be divided by at least three elements height-wise. However, for transverse primary supporting members inside hopper tank and top side tank, which are less in height than the space between ordinary longitudinal stiffeners, two elements on the height of primary supporting members are accepted.
- ~~where no double hull construction is fitted,~~ side shell frames and their end brackets are to be modeled by using shell elements for web and shell/beam/rod elements for face plate. Webs of side shell frames need not be divided along the direction of depth
- aspect ratio of elements is not to exceed 1:4.

An example of typical mesh is given in App 1.

### 2.3 Boundary conditions

#### 2.3.1

Both ends of the model are to be simply supported according to Tab 1 and Tab 2. The nodes on the longitudinal members at both end sections are to be rigidly linked to independent points at the neutral axis on the centreline as shown in Tab 1. The independent points of both ends are to be fixed as shown in Tab 2.

**Table 1: Rigid-link of both ends**

| Nodes on longitudinal members at both ends of the model | Translational | | | Rotational | | |
|---|---|---|---|---|---|---|
| | Dx | Dy | Dz | Rx | Ry | Rz |
| All longitudinal members | RL | RL | RL | - | - | - |
| RL means rigidly linked to the relevant degrees of freedom of the independent point | | | | | | |

**Table 2: Support condition of the independent point**

| Location of the independent point | Translational | | | Rotational | | |
|---|---|---|---|---|---|---|
| | **Dx** | **Dy** | **Dz** | **Rx** | **Ry** | **Rz** |
| Independent point on aft end of model | - | Fix | Fix | ~~-~~ Fix | - | - |
| Independent point on fore end of model | Fix | Fix | Fix | Fix | - | - |

# 3. Analysis criteria

## 3.2 Yielding strength assessment

### 3.2.1 Reference stresses

Reference stress is Von Mises equivalent stress at the centre of a plane element (shell or membrane) or axial stress of a line element (bar, beam or rod) obtained by FE analysis through considering hull girder loads according to [2.5.4] or [2.5.5].

Where the effects of openings are not considered in the FE model, the reference stresses in way of the openings are to be properly modified with adjusting shear stresses in proportion to the ratio of web height and opening height.

Where elements under assessment are smaller than the standard mesh size specified in [2.2.4] or [2.2.5], the reference stress may be obtained from the averaged stress over the elements within the standard mesh size.

## 3.4 Deflection of primary supporting members

The relative deflection, $\delta_{max}$ in mm, in the outer bottom plate obtained by FEA is not to exceed the following criteria:

~~The maximum relative deflection between the double bottom and the forward (or afterward) transverse bulkhead obtained from the FE analysis is not to exceed the following criteria:~~

$$\delta_{\max} \le \frac{\ell_i}{150}$$

where:

$\delta_{\max}$ : Maximum relative deflection, in mm, obtained by the following formula, and not including secondary deflection ~~between the double bottom and the forward (or afterward) transverse bulkhead, in mm~~

$$\delta_{\max} = \max(|\delta_{B1}|, |\delta_{B2}|)$$

where, $\delta_{B1}$ and $\delta_{B2}$ are shown in Fig 3.

$\ell_i$ : Length or breadth of the flat part of the double bottom, in mm, whichever is the shorter.

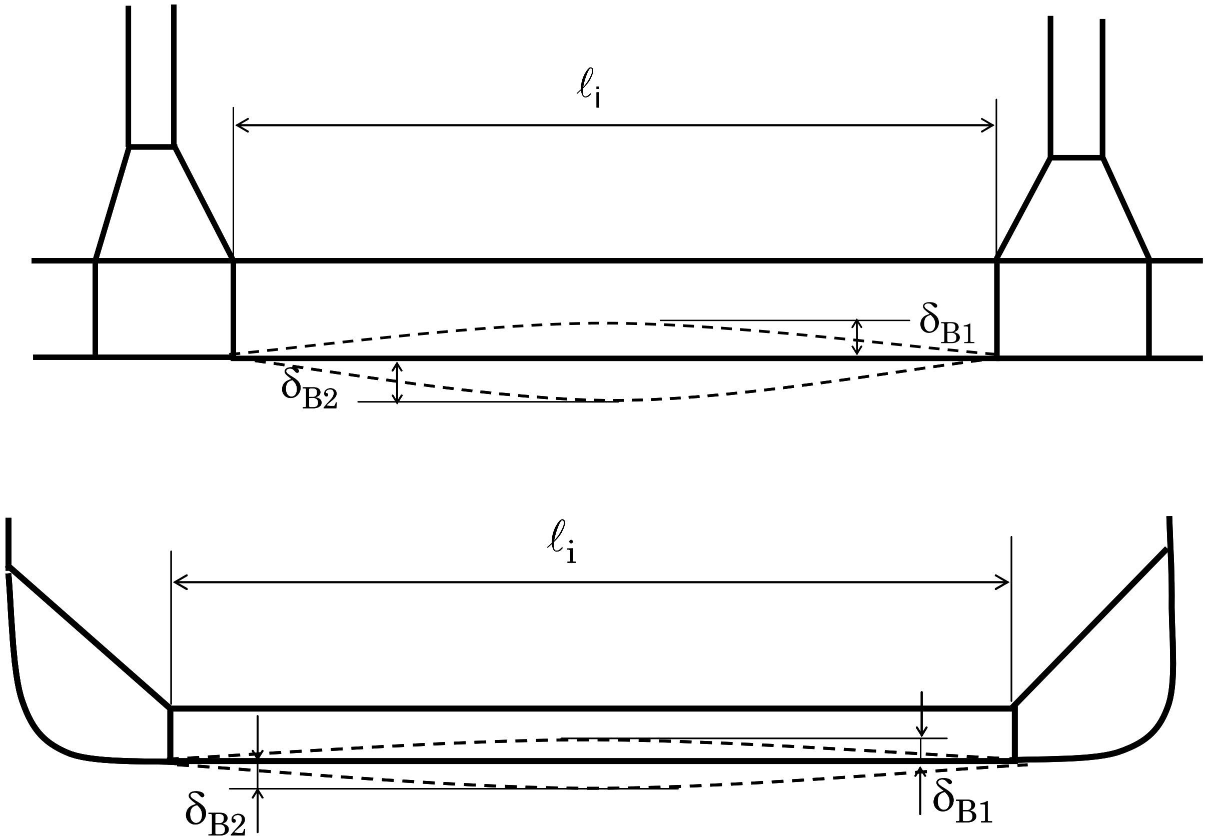



**Figure 3: Definition of relative deflection**

# Section 3 DETAILED STRESS ASSESSMENT

## 1. General

### 1.1 Application

#### 1.1.1

This Section describes the procedure for the detailed stress assessment with refined meshes to evaluate highly stressed areas of primary supporting members.

Where the global cargo hold analysis of Sec 2 is carried out using a model complying with the modelling criteria of Sec 2, [2.2.4], the areas listed in Tab 1 are to be refined at the locations whose calculated stresses exceed 95% for non-orthotropic elements or 85 % for orthotropic element but do not exceed 100% of the allowable stress as specified in Sec 2, [3.2.3].

# Common Structural Rules for Bulk Carriers, July 2008

# Technical Background for Rule Change Notice No.1-5 (Direct Strength Analysis)

# Technical Background for the Changes Regarding the Direct Strength Analysis:

## 1. Reason for the Rule Change:

### 1.1 Ch 7, Sec 2, [2.2.4] and [3.2.1]

In a transverse ring in bilge hopper tank, there are some cases where the web height is smaller than the space between ordinary stiffeners. Where the web is divided by three elements, the element size is relative small. In addition, the element sometimes becomes smaller so that the aspect ratio of element does not exceed 1:4. It is not considered that such smaller elements are appropriate for applying the global strength analysis of cargo hold structures.

Therefore this rule change is made to clarify the requirements according to the interpretation in KC ID 149.

### 1.2 Ch 7, Sec 2, Table 2

The boundary condition in FEA, which restricts rotation along x-axis at fore end of FE model but allow free rotation at aft end, specified in Table 2. However, this boundary condition may cause unexpected warping deformation under beam sea condition because the one end of FE model is rotated about x-axis.

It has been noticed that the stress level induced by the warping deformation is sometimes unreasonable severe, especially, in case of smaller bulk carrier as handy size and Panamax BCs.

This rule change is an interim solution made to avoid the unexpected rotation in FEA due to this boundary condition. (Refer to KC ID 340).

A definitive agreement on boundary conditions has later to be made through further studies that will use same basis in order to make effective comparisons and impact evaluations.

### 1.3 Ch 7, Sec 2, [3.2.1]

Stress level of all elements in FE model should be within the allowable criteria specified in the Rules, in principle. However, the elements having relative small size are often used in FEA. In this case, the averaged stresses among these elements are normally used where deemed reasonable by the Society.

This change is made to clarify the requirements for such a case.(Refer to KC ID 340)

### 1.4 Ch 7, Sec 2, [3.4]

The maximum relative deflection is not clear in the current text.

In order to clarify the relative deflection, which does not include the deflection of ordinary stiffeners, the editorial correction is made and new figure which gives a definition of the deflection of the outer bottom plate is added.

### 1.5 Ch 7, Sec 3, [1.1.1]

This rule change is made to clarify the requirement for the application of the detailed stress assessment. (Refer to KC ID 341)

# 2. Summary of Rule Change

### 2.1 Ch 7, Sec 2, [2.2.4]

Considering the actual design for the transverses in bilge hopper or topside tank, the height of transverse web is smaller than the spacing between longitudinals. In order to avoid the smaller mesh size in such structural members as far as practicable, the rule change is so made that two shell elements can be accepted.

### 2.2 Ch 7, Sec 2, [2.3.1] Table 2

As an interim solution the rotational boundary condition $R_X$ of independent point on at end of model is changed to “Fix” from “-“.

### 2.3 Ch 7, Sec 2, [3.2.1] Reference stresses

Where the cargo hold FE model includes the smaller mesh size than the standard mesh size specified in the Rules, the reference stress can be obtained from the averaged stress over the elements within the standard mesh size.

### 2.4 Ch 7, Sec 2 [3.4] Deflection of primary supporting members

In order to clarify the definition of the relative deflection of outer bottom structure, the figure is added in the text and the relevant texts are modified.

### 2.5 Ch 7, Sec 3, [1.1]

Where the stresses calculated according to the global strength analysis of cargo hold structures specified in Ch 7 Sec 2 exceed 95% for non-orthotropic elements or 85% for orthotropic elements but not exceed allowable stress, detailed stress analysis specified in Sec 3 is required.

# 3. Impact on Scantling

### 3.1 Impact on scantling due to the change in Ch 7, Sec 2, [2.2.4], [3.2.1], [3.4] and Sec 3, [1.1]

As these rule changes specified in 2.1, 2.3, 2.4 and 2.5 above are made for the clarification, there is no scantling impact due to these changes.

### 3.2 Impact on scantling due to the changes in Ch 7, Sec 2, Table 2 regarding the correction of the boundary conditions

The cargo hold FEA using the boundary condition specified in the current text gives too unreasonable stress in cross deck.

Due to the unreasonable stresses, the required thickness for cross deck may be than that for upper deck plating.

For example, the required thickness for cross deck is 22.5mm (AH32) and 15mm (AH32) for upper deck according to KC ID 343.

From the engineering point of view, this result caused by the boundary condition which gives unrealistic warping effect in FE model obviously.

Therefore, the scantling impact due to this change is not carried out.

However, the unreasonable and excessive stresses around the hatch opening and in cross deck are improved drastically by this modification.

The details of the effect due to the modification of the boundary condition are mentioned in Annex 1.

# Annex 1: Details of the effect due to the modification of the boundary conditions

## 1. FE Analysis and results

In order t to examine the effect due to the modification of the boundary condition regarding the rotational restriction Rx along x-axe, the FE analysis for one Handy max buck carrier is carried out as a typical example.

Applied boundary condition is given in Table 1-1.

**Table 1-1 Applied boundary condition**

(1) Case-1 Boundary condition as per CSR

| Independent Point | Translational | | | Rotational | | |
|---|---|---|---|---|---|---|
| | Dx | Dy | Dz | Rx | Ry | Rz |
| Aft End of Model | - | Fx | Fix | - | - | - |
| Fore End of Model | Fix | Fix | Fix | Fix | - | - |

(2) Case-2 Modified boundary condition

| Independent Point | Translational | | | Rotational | | |
|---|---|---|---|---|---|---|
| | Dx | Dy | Dz | Rx | Ry | Rz |
| Aft End of Model | - | Fx | Fix | **Fix** | - | - |
| Fore End of Model | Fix | Fix | Fix | Fix | - | - |

Applied loading condition and load case are full load homogeneous condition and EDW "P1". As the effect due to the boundary condition is mainly appeared in the stresses of structures around the hatch opening and cross deck under beam sea condition, the calculated stresses in cross deck and deformations for full load condition under beam sea (P1) as a typical example. The sampling point of the stress of cross deck is shown in Fig. 1-1.

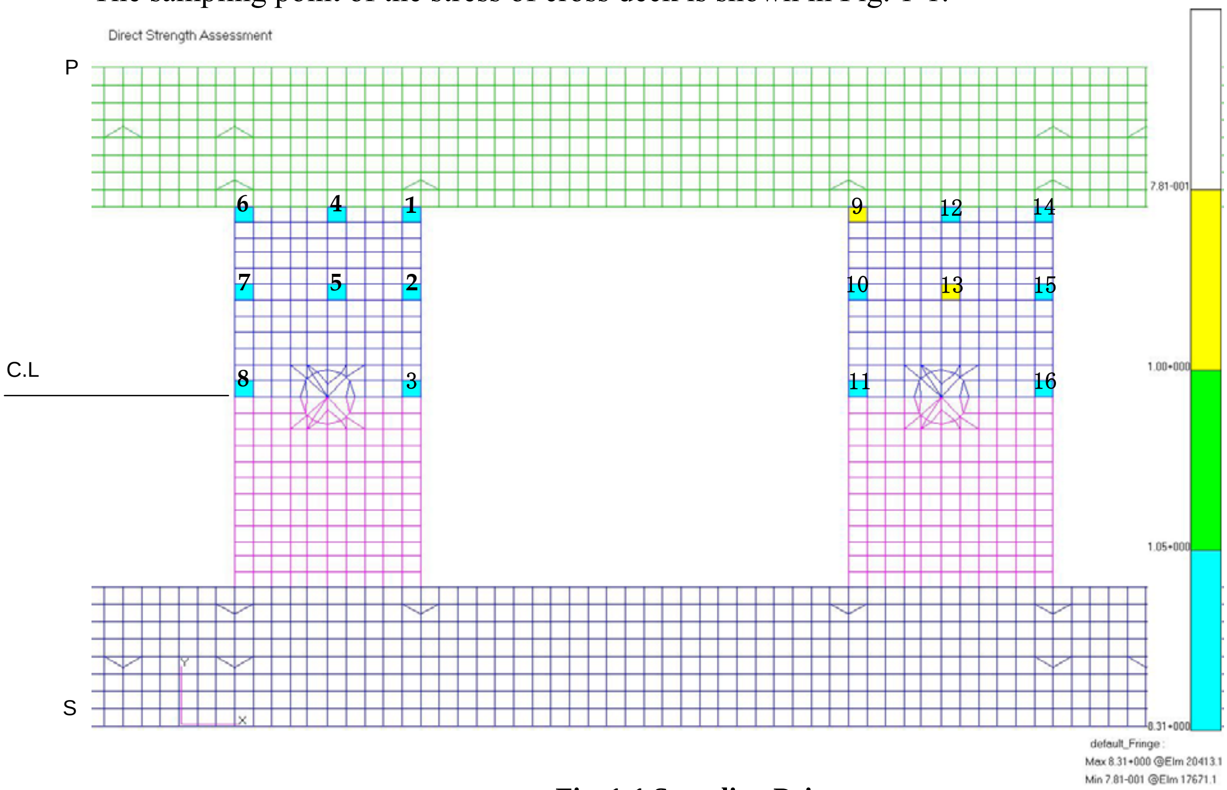
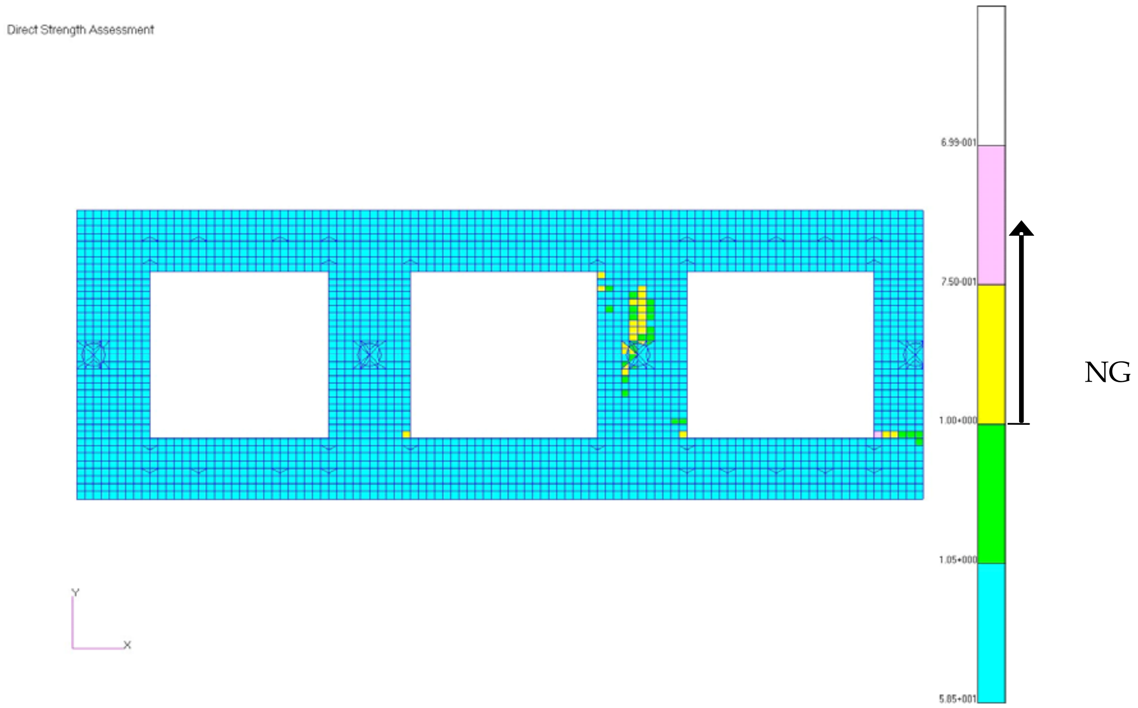



**Fig. 1-1 Sampling Point**

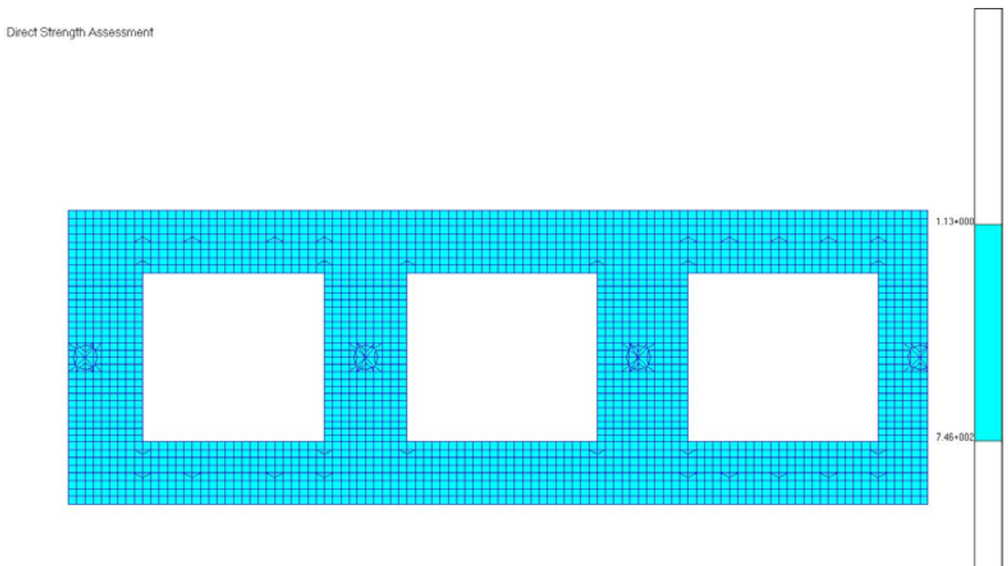
The stresses of the sampling points for case 1 and case 2 are shown in Table 1-2. The stress level in cross deck is given in Figure 1-2 and the deformation of the FE model is given in Fig. 1-3.

**Table 1-2 Stresses at the sampling points in Cross Deck in full load condition under beam sea (P1)**

| ID | $\sigma_{allowable}$ | $\sigma e$ (N/mm$^2$) | |
|---|---|---|---|
| | (N/mm$^2$) | Case-1 (CSR) | Case-2 (Modified) |
| 1 | 326 | 41 | 229 |
| 2 | 235 | 103 | 145 |
| 3 | 235 | 165 | 137 |
| 4 | 326 | 145 | 109 |
| 5 | 235 | 195 | 168 |
| 6 | 326 | 246 | 94 |
| 7 | 235 | 167 | 112 |
| 8 | 235 | 144 | 153 |
| 9 | 326 | 439 | 224 |
| 10 | 235 | 213 | 141 |
| 11 | 235 | 153 | 134 |
| 12 | 326 | 201 | 132 |
| 13 | 235 | 249 | 174 |
| 14 | 326 | 108 | 68 |
| 15 | 235 | 103 | 91 |
| 16 | 235 | 205 | 150 |

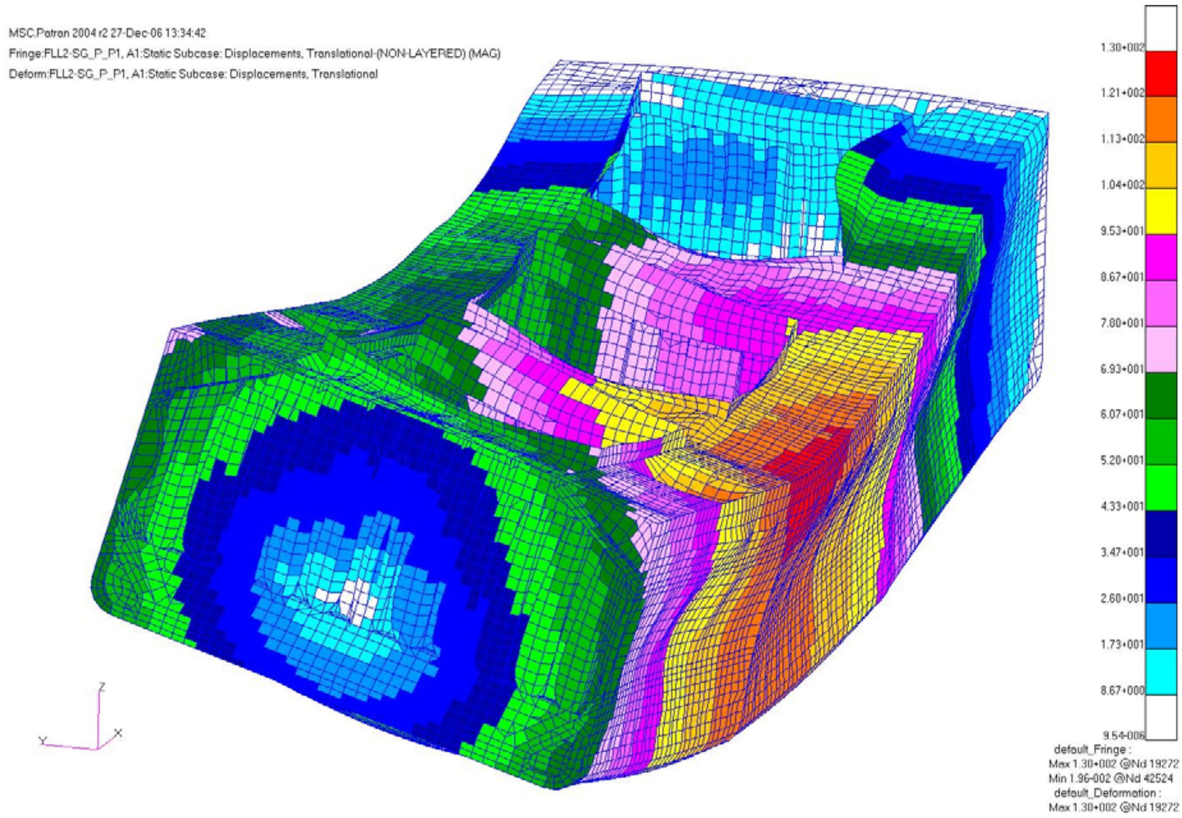



(1) Case 1

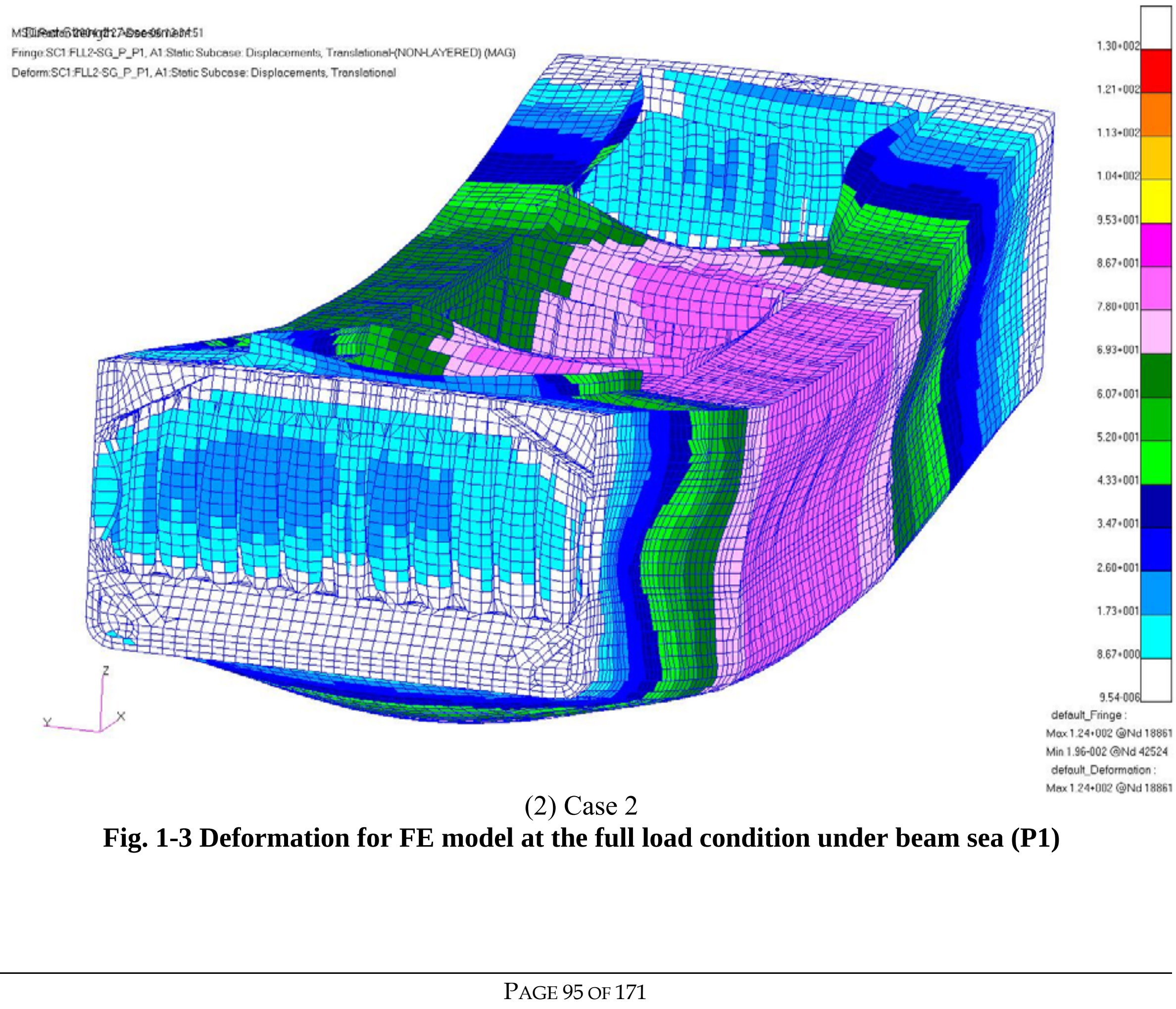



(2) Case 2

**Fig. 1-2 Stress level in the cross deck in full load condition under beam sea (P1)**




(1) Case 1




(2) Case 2

**Fig. 1-3 Deformation for FE model at the full load condition under beam sea (P1)**

**2. Conclusion**

According to Fig 1-3(1), the deformation of FE model is warped unreasonably due to the boundary condition that is the aft end of FE model is free. Hence, the stress distribution in cross deck forward the mid hold of FE model is different from that of afterward the mid hold and the stress value in cross deck seems to be excessive as shown in Fig 1-2(1) and Table 1-1. On the other hand, the deformation of FE model for case 2 is not observed the unreasonable warp because the rotational restriction of both ends of FE model is applied, as shown in Fig 1-3(2). Hence, the stress distribution in forward cross deck forward the mid hold of FE model is similar to that afterward the mid hold and excessive stress values are not appeared in cross deck as shown in Fig. 1-2(2) and Table 1-1.

Then, it is concluded that

(1) The boundary in current text gives excessive and unreasonable results.
(2) The corrected boundary condition does not give excessive and unreasonable results.

In order to evaluate the FEA results properly, the incorrect boundary condition should be revised to avoid the unreasonable warping deformation in FE model.

# Common Structural Rules for Bulk Carriers, July 2008

# Rule Change Notice No.1-6 (Fatigue Check for Longitudinals)

Notes: (1) These Rule Changes enter into force on 1 July 2009.

For technical background for Rule Changes in this present document, reference is made to separate document Technical Background for Rule Change Notice No.1-6.

# CHAPTER 4 DESIGN LOADS

## Section 5 EXTERNAL PRESSURES

### 2. External pressures on exposed decks

#### 2.1 General

**2.1.1**

The external pressures on exposed decks are to be applied for the local scantling check of the structures on exposed deck but not applied for fatigue strength assessment.

If a breakwater is fitted on the exposed deck, no reduction in the external pressures defined in [2.2] and [2.3] is allowed for the area of the exposed deck located aft of the breakwater.

# Section 6 INTERNAL PRESSURES AND FORCES

## 2. Lateral pressure due to liquid

### 2.1 Pressure due to liquid in still water

**2.1.3**

For fatigue strength assessment, the liquid pressure in still water $p_{BS}$, in kN/m$^2$, is given by the following formula.

$$p_{BS} = \rho_L g(z_{TOP} - z)$$

If the $p_{BS}$ is negative, $p_{BS}$ is to be taken equal to 0.

Where the considered load point is located in the fuel oil, other oils or fresh water tanks, liquids are assumed to be fulfilled up to the half height of the tanks and $z_{TOP}$ is taken to the Z coordinate of the liquid surface at the upright condition

# CHAPTER 8 FATIGUE CHECK OF STRUCTURAL DETAILS

## Section 1 GENERAL CONSIDERATION

### 1. General

#### 1.3 Subject members

**1.3.1**

Fatigue strength is to be assessed, in cargo hold area, for members described in Tab 1, at the considered locations.

**Table 1: Members and locations subjected to fatigue strength assessment**

| Members | Details |
|---|---|
| Inner bottom plating | Connection with sloping and /or vertical plate of lower stool |
| | Connection with sloping plate of hopper tank |
| Inner side plating | Connection with sloping plate of hopper tank |
| Transverse bulkhead | Connection with sloping plate of lower stool |
| | Connection with sloping plate of upper stool |
| Hold frames of single side bulk carriers | Connection to the upper and lower wing tank |
| Ordinary stiffeners in double side space | Connection of longitudinal stiffeners with web frames and transverse bulkhead |
| | Connection of transverse stiffeners with stringer or similar |
| Ordinary stiffeners in upper and lower wing tank | Connection of longitudinal stiffeners with web frames and transverse bulkhead |
| Ordinary stiffeners in double bottom | Connection of longitudinal stiffeners with floors and floors in way of lower stool or transverse bulkhead |
| Hatch corners | Free edges of hatch corners |

### 3. Loading

#### 3.1 Loading condition

**3.1.1**

The loading conditions to be considered are defined in Tab 2 depending on the ship type. The standard loading conditions illustrated in Ch 4, App 3 are to be considered.

**Table 2: Loading conditions**

| Ship type | Full load condition | | Ballast condition | |
|---|---|---|---|---|
| | Homogeneous | Alternate | Normal ballast | Heavy ballast |
| BC-A | ✓ | ✓ | ✓ | ✓ |
| BC-B | ✓ | --- | ✓ | ✓ |
| BC-C | ✓ | --- | ✓ | ✓ |

# Section 4 STRESS ASSESSMENT OF STIFFENERS

## 1. General

### 1.1 Application

#### 1.1.1

Hot spot stress ranges and structural hot spot mean stresses of longitudinal stiffeners are to be assessed in line with the requirements of this Section.

#### 1.1.2

The hot spot stress ranges and structural hot spot mean stresses of longitudinal stiffeners are to be evaluated at the face plate of the longitudinal considering the type of longitudinal end connection and the following locations.

(1) Transverse webs or floors other than those at transverse bulkhead of cargo hold or in way of stools, such that additional hot spot stress due to the relative displacement may not be considered. These longitudinal end connections are defined in Tab 1. When transverse webs or floors are watertight, the coefficients $K_{gl}$ and $K_{gh}$ as defined in Tab 2 are to be considered instead of those defined in Tab 1

(2) Transverse webs or floors at transverse bulkhead of cargo hold in way of stools, such that additional hot spot stress due to the relative displacement should be considered. These longitudinal end connections are defined in Tab 2. When transverse webs or floors at transverse bulkhead of cargo hold or in way of stools are not watertight, the coefficients $K_{gl}$ and $K_{gh}$ as defined in Tab 1 are to be considered instead of those defined in Tab 2.

## 2. Hot spot stress range

### 2.3 Stress range according to the simplified procedure

#### 2.3.1 Hot spot stress ranges

The hot spot stress range, in N/mm$^2$, due to dynamic loads in load case "*i*" of loading condition "(*k*)" is to be obtained from the following formula:

$$\Delta\sigma_{W,i(k)} = \left|\left(\sigma_{GW,i1(k)} + \sigma_{W1,i1(k)} - \sigma_{W2,i1(k)} + \sigma_{d,i1(k)}\right) - \left(\sigma_{GW,i2(k)} + \sigma_{W1,i2(k)} - \sigma_{W2,i2(k)} + \sigma_{d,i2(k)}\right)\right|$$

where

$\sigma_{GW,i1(k)}$, $\sigma_{GW,i2(k)}$ : Stress due to hull girder moment, defined in [2.3.2]

$\sigma_{W1,i1(k)}$, $\sigma_{W1,i2(k)}$ : Stress $\sigma_{LW,ij(k)}$ , $\sigma_{CW,ij(k)}$ and $\sigma_{LCW,ij(k)}$ due to hydrodynamic or inertial pressure when the pressure is applied on the same side as the ordinary stiffener depending on the considered case

$\sigma_{W2,i1(k)}$, $\sigma_{W2,i2(k)}$ : Stress $\sigma_{LW,ij(k)}$ , $\sigma_{CW,ij(k)}$ and $\sigma_{LCW,ij(k)}$ due to hydrodynamic or inertial pressure when the pressure is applied on the side opposite to the stiffener depending on the considered case

$\sigma_{LW,i1(k)}$, $\sigma_{LW,i2(k)}$ : Stresses due to wave pressure, defined in [2.3.3]

$\sigma_{CW,i1(k)}$, $\sigma_{CW,i2(k)}$ : Stresses due to liquid pressure, defined in [2.3.4]

$\sigma_{LCW,i1(k)}$, $\sigma_{LCW,i2(k)}$ : Stresses due to dry bulk cargo pressure, defined in [2.3.5]

$\sigma_{d,i1(k)}$, $\sigma_{d,i2(k)}$ : Stress due to relative displacement of transverse bulkhead or floor in way of stools, defined in [2.3.6].

#### 2.3.2 Stress due to hull girder moments

The hull girder hot spot stress, in N/mm$^2$, in load case "$i1$" and "$i2$" for loading condition "($k$)" is to be obtained from the following formula:

$$\sigma_{GW,ij(k)} = K_{gh} \cdot \left( C_{WV,ij}\, \sigma_{WV,ij} - C_{WH,ij}\, \sigma_{WH,(k)} \right) \qquad (j = 1, 2)$$

where:

$K_{gh}$ : Geometrical stress concentration factor for nominal hull girder stress ~~depending on the detail of end connection as defined in Tab 1~~. $K_{gh}$ is given in Tab 1 and Tab 2 for the longitudinal end connection specified in [1.1.2](1) and [1.1.2](2), respectively.

The stress concentration factor can be evaluated directly by the FE analysis.

$C_{WV,i1}$, $C_{WV,i2}$, $C_{WH,i1}$, $C_{WH,i2}$ : Load combination factors for each load case defined in Ch 4, Sec 4, [2.2]

$\sigma_{WV,i1}$, $\sigma_{WV,i2}$, $\sigma_{WH,(k)}$ : Nominal hull girder stresses, in N/mm$^2$, defined in Sec 3, [2.2.2]

#### 2.3.3 Stress due to wave pressure

The hot spot stress, in N/mm$^2$, due to the wave pressure in load case "$i1$" and "$i2$" for loading condition "($k$)" is to be obtained from the following formula:

$$\sigma_{LW,ij(k)} = \frac{K_{gl} K_s C_{NE,ij(k)} p_{W,ij(k)} s \ell^2 \left(1 - \frac{6x_f}{\ell} + \frac{6x_f^2}{\ell^2}\right)}{12w} 10^3 \qquad (j = 1, 2)$$

$$\sigma_{LW,ij(k)} = \frac{K_{gl} K_s p_{CW,ij(k)} s \ell^2 \left(1 - \frac{6x_f}{\ell} + \frac{6x_f^2}{\ell^2}\right)}{12w} 10^3 \qquad (j = 1, 2)$$

$$p_{CW,i1(k)} = \begin{cases} 2C_{NE,i1(k)} p_{W,i1(k)} & ;\ C_{NE,i1(k)} < 0.5 \\ p_{W,i1(k)} & ;\ C_{NE,i1(k)} \geq 0.5 \end{cases}$$

$$p_{CW,i2(k)} = \begin{cases} 0 & ;\ C_{NE,i2(k)} < 0.5 \\ (2C_{NE,i2(k)} - 1) p_{W,i2(k)} & ;\ C_{NE,i2(k)} \geq 0.5 \end{cases}$$

where:

$p_{W,ij(k)}$ : Hydrodynamic pressure, in kN/m$^2$, specified in Ch 4, Sec 5, [1.3], [1.4] and [1.5] , with $f_p$ = 0.5, in load case "$i1$" and "$i2$" for loading condition "($k$)". When the location of the considered member is above the waterline, the hydrodynamic pressure is to be taken as the pressure at waterline.

$K_{gl}$ : Geometrical stress concentration factor for stress due to lateral pressure ~~depending on the detail of end connection as defined in Tab 1~~. $K_{gl}$ is given in Tab. 1 and Tab. 2 for the longitudinal end connection specified in [1.1.2] (1) and [1.1.2] (2), respectively

The stress concentration factor can be evaluated directly by the FE analysis ~~when the detail of end connection is not defined in Tab 1.~~

$K_s$ : Geometrical stress concentration factor due to stiffener geometry

$$K_s = 1 + \left[\frac{t_f (a^2 - b^2)}{2 w_b}\right]\left[1 - \frac{b}{b_f}\left(1 + \frac{w_b}{w_a}\right)\right] 10^{-3}$$

$a$ , $b$ : Eccentricity, in mm, of the face plate as defined in Fig 1. For angle profile, "$b$" is to be taken as half the net actual thickness of the web.

$t_f$, $b_f$ : thickness and breadth of face plate, in mm, respectively, as defined in Fig 1

$w_a$ , $w_b$ : Net section modulus in A and B respectively(see Fig.1), in cm$^3$, of the stiffener about the neutral axis parallel to $Z$ axis without attached plating.

$C_{NE\,,\,i\,j(k)}$ : Correction factor for the non linearity of the wave pressure range in load case "$i$1" and "$i$2" of loading condition "($k$)"

$$C_{NE,\,i\,j(k)} = \begin{cases} \exp\left[-\left(\dfrac{z - T_{LC(k)} + \dfrac{\left|p_{W,\,i\,j(k),WL}\right|}{\rho g}}{\dfrac{\left|p_{W,\,i\,j(k),WL}\right|}{\rho g}\left(-\ln 0.5\right)^{-1/2.5}}\right)^{2.5}\right] & \text{for} \quad z > T_{LC(k)} - \dfrac{\left|p_{W,\,i\,j(k),WL}\right|}{\rho g} \\ 1.0 & \text{for} \quad z \le T_{LC(k)} - \dfrac{\left|p_{W,\,i\,j(k),WL}\right|}{\rho g} \end{cases}$$

$T_{LC(k)}$ : Draught, in m, of the considered loading condition "($k$)"

$p_{W\,,\,i\,j(k)\,,\,WL}$ : Hydrodynamic pressure, in kN/m$^2$, at water line in load case "$i$1" and "$i$2" of loading condition "($k$)"

$z$ : $Z$ co-ordinate, in m, of the point considered

$s$ : Stiffener spacing, in m

$\ell$ : Span, in m, to be measured as shown in Fig 2. The ends of the span are to be taken at points where the depth of the end bracket, measured from the face plate of the stiffener is equal to half the depth of the stiffener.

$x_f$ : Distance, in m, to the hot spot from the closest end of the span $\ell$ (see Fig 2)

$w$ : Net section modulus, in cm$^3$, of the considered stiffener. The section modulus $w$ is to be calculated considering an effective breadth $s_e$, in m, of attached plating obtained from the following formulae:

$$s_e = \begin{cases} 0.67 s \cdot \sin\left[\dfrac{\pi}{6}\left(\dfrac{\ell\left(1 - 1/\sqrt{3}\right)}{2s}\right)\right] & \text{for} \quad \dfrac{\ell}{s} \le \dfrac{6}{1 - 1/\sqrt{3}} \\ 0.67 s & \text{for} \quad \dfrac{\ell}{s} > \dfrac{6}{1 - 1/\sqrt{3}} \end{cases}$$

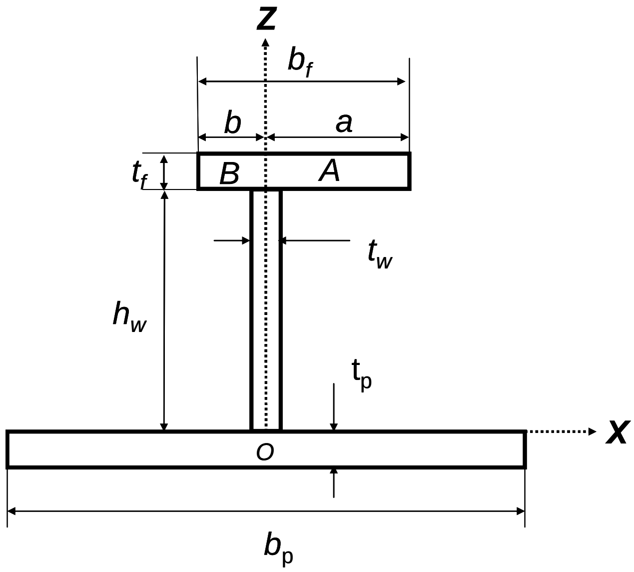



**Figure 1: Sectional parameters of a stiffener**

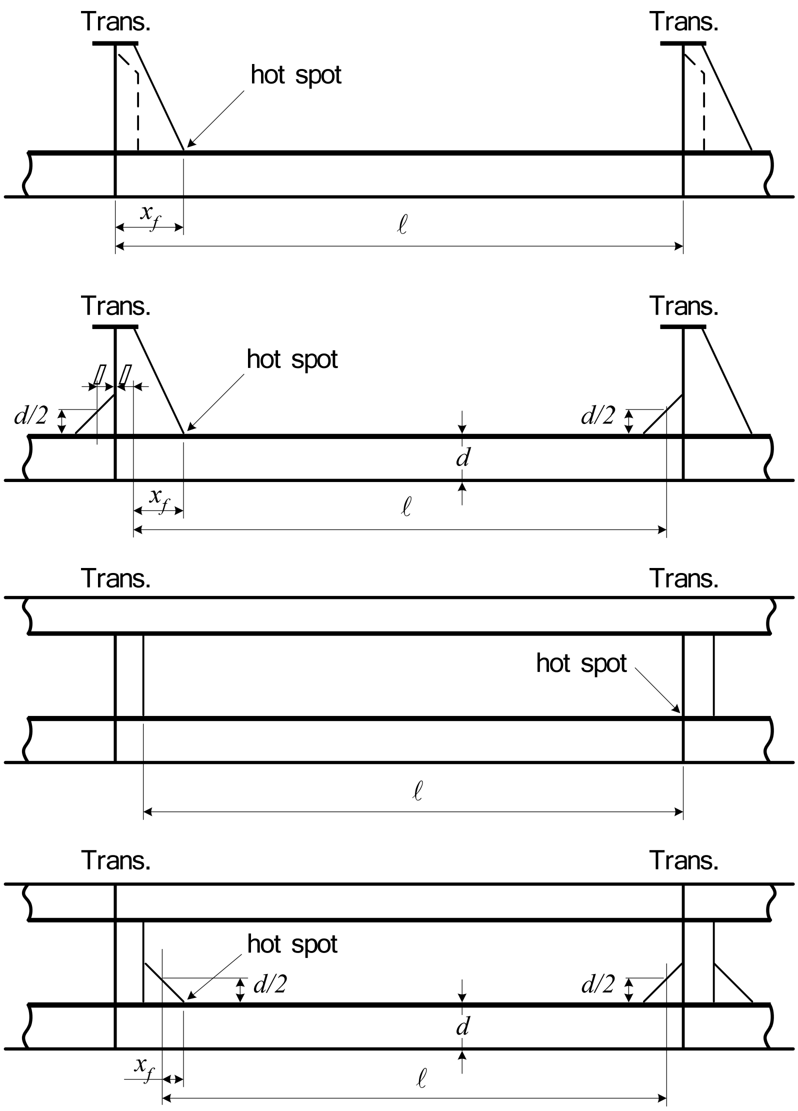



**Figure 2: Span and hot spot of longitudinal stiffeners**

### 2.3.4 Stress due to liquid pressure

The hot spot stress, in N/mm², due to the liquid pressure in load case "*i*1" and "*i*2" for loading condition "(*k*)" is to be obtained from the following formula:

$$\sigma_{CW,\,i\,j(k)} = \frac{K_{gl} K_s C_{NI,\,i\,j(k)}\, p_{BW,\,i\,j(k)}\, s\ell^2 \left(1 - \dfrac{6x_f}{\ell} + \dfrac{6{x_f}^2}{\ell^2}\right)}{12w} \cdot 10^3 \qquad (j = 1, 2)$$

where:

$p_{BW,\,i\,j(k)}$ : Inertial pressure, in kN/m², due to liquid specified in Ch 4, Sec 6, [2.2], with $f_p$ = 0.5, in load case "*i*1" and "*i*2" for loading condition "(*k*)". Where the considered location is located in fuel oil, other oil or fresh water tanks, no inertial pressure is considered for the tank top longitudinals and when the location of the considered member is above the liquid surface in static and upright condition, the inertial pressure is to be taken at the liquid surface line.

$C_{NI,\,i\,j(k)}$ : Correction factor for the non linearity of the inertial pressure range due to liquid in load case "*i*1" and "*i*2" for loading condition "(*k*)"

$$C_{NI,\,i\,j(k)} = \begin{cases} \exp\left[-\left(\dfrac{z - z_{SF} + \dfrac{\left|p_{BW,\,i\,j(k),\,SF}\right|}{\rho g}}{\dfrac{\left|p_{BW,\,i\,j(k),\,SF}\right|}{\rho g}\left(-\ln 0.5\right)^{-1/2.5}}\right)^{2.5}\right] & \text{for} \quad z > z_{SF} - \dfrac{\left|p_{BW,\,i\,j(k),\,SF}\right|}{\rho g} \\ 1.0 & \text{for} \quad z \le z_{SF} - \dfrac{\left|p_{BW,\,i\,j(k),\,SF}\right|}{\rho g} \end{cases}$$

$z_{SF}$ : $Z$ co-ordinate, in m, of the liquid surface. In general, it is taken equal to "$z_{top}$" defined in Ch 4 Sec 6. If the considered location is located in fuel oil, other oil or fresh water tanks, it may be taken as the distance to the half height of the tank. ~~In general, it is taken as the distance to the top of the tank. In case of fuel oil tank, it may be taken as the distance to the half height of the tank~~

$z$ : $Z$ co-ordinate, in m, of the point considered

$p_{BW,\,i\,j(k),\,SF}$ : Inertial pressure due to liquid, in kN/m², taken at the liquid surface in load case "*i*1" and "*i*2" for loading condition "(*k*)". In calculating the inertial pressure according to Ch 4 Sec 6, [2.2.1], x and y coordinates of the reference point are to be taken as liquid surface instead of tank top.

$K_{gl}$, $K_s$ : the stress concentration factor defined in [2.3.3]

### 2.3.6 Stress due to relative displacement of transverse bulkhead or floor in way of transverse bulkhead or stool

For longitudinal end connection specified in [1.1.2] (2), t~~T~~he additional hot spot stress, in N/mm², due to the relative displacement in the~~ transverse ~~direction perpendicular to the attached plate between the transverse bulkhead or floor in way of stools and the adjacent transverse web or floor in load case "*i*1" and "*i*2" for loading condition "(*k*)" is to be obtained from the following formula.

$$\sigma_{d,\,i\,j(k)} = \begin{cases} K_{dF-a}\sigma_{dF-a,\,i\,j(k)} + K_{dA-a}\sigma_{dA-a,\,i\,j(k)} & \text{for point "}a\text{"} \\ K_{dF-f}\sigma_{dF-f,\,i\,j(k)} + K_{dA-f}\sigma_{dA-f,\,i\,j(k)} & \text{for point "}f\text{"} \end{cases} \qquad (j = 1, 2)$$

where:

$a$ , $f$ : Suffix which denotes the location considered as indicated in Tab ~~1~~2.

$A$ , $F$ : Suffix which denotes the direction, forward ($F$) and afterward ($A$), of the transverse web or floor where the relative displacement is occurred as indicated in Tab ~~1~~2.(see Fig 3)

$\sigma_{dF\text{-}a\,,\,i\,j(k)}$ , $\sigma_{dA\text{-}a\,,\,i\,j(k)}$ , $\sigma_{dF\text{-}f\,,\,i\,j(k)}$ , $\sigma_{dA\text{-}f\,,\,i\,j(k)}$ : Additional stress at point "$a$" and "$f$", in N/mm$^2$, due to the relative displacement between the transverse bulkhead or floors in way of stools and the forward ($F$) and afterward ($A$) transverse web or floor respectively in load case "$i$1" and "$i$2" for loading condition "($k$)"

$$\sigma_{dF-a,\,i\,j(k)} = \frac{3.9\delta_{F,\,i\,j(k)} E I_A I_F}{w_A \ell_F \left(\ell_A I_F + \ell_F I_A\right)} \left(1 - 1.15\frac{|x_{fA}|}{\ell_A}\right) 10^{-5}$$

$$\sigma_{dA-a,\,i\,j(k)} = \left[\frac{3.9\delta_{A,\,i\,j(k)} E I_A I_F}{w_A \ell_A \left(\ell_A I_F + \ell_F I_A\right)} \left(1 - 1.15\frac{|x_{fA}|}{\ell_A}\right) - \frac{0.9\delta_{A,\,i\,j(k)} E I_A |x_{fA}|}{w_A {\ell_A}^3}\right] 10^{-5}$$

$$\sigma_{dF-f,\,i\,j(k)} = \left[\frac{3.9\delta_{F,\,i\,j(k)} E I_A I_F}{w_F \ell_F \left(\ell_A I_F + \ell_F I_A\right)} \left(1 - 1.15\frac{|x_{fF}|}{\ell_F}\right) - \frac{0.9\delta_{F,\,i\,j(k)} E I_F |x_{fF}|}{w_F {\ell_F}^3}\right] 10^{-5}$$

$$\sigma_{dA-f,\,i\,j(k)} = \frac{3.9\delta_{A,\,i\,j(k)} E I_A I_F}{w_F \ell_A \left(\ell_A I_F + \ell_F I_A\right)} \left(1 - 1.15\frac{|x_{fF}|}{\ell_F}\right) 10^{-5}$$

$\delta_{F\,,\,i\,j(k)}$ , $\delta_{A\,,\,i\,j(k)}$ : Relative displacement, in mm, in the ~~transverse~~ direction perpendicular to the attached plate between the transverse bulkhead or floor in way of stools and the forward ($F$) and afterward ($A$) transverse web or floor in load case "$i$1" and "$i$2" for loading condition "($k$)" (see Fig 3)

(a) For longitudinals penetrating floors in way of stools

Relative displacement is defined as the displacement of the longitudinal in relation to the line passing through the stiffener end connection at the base of the stool measured at the first floor forward (F) or afterward (A) of the stool.

(b) For longitudinals other than (a)

Relative displacement is defined as the displacement of the longitudinal in relation to its original position measured at the first forward (F) or afterward (A) of the transverse bulkhead.

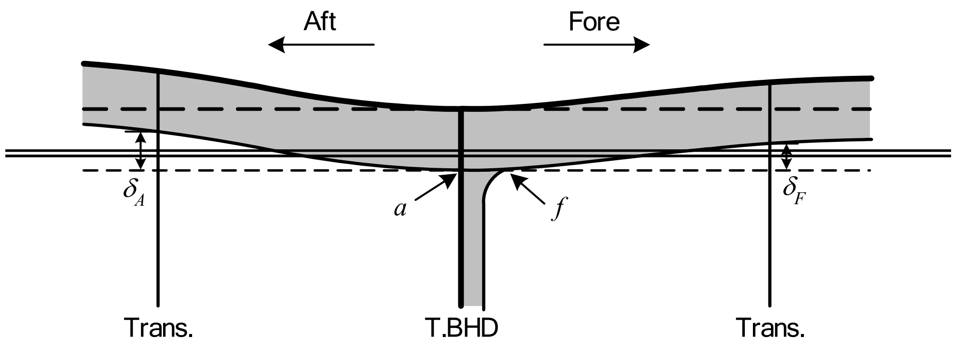
Where the stress of the face of longitudinal at the assessment point due to relative displacement is tension, the sign of the relative displacement is positive.

$I_F$ , $I_A$ : Net moment of inertia, in cm$^4$, of forward ($F$) and afterward ($A$) longitudinal

$K_{dF\text{-}a}$ , $K_{dA\text{-}a}$ , $K_{dF\text{-}f}$ , $K_{dA\text{-}f}$ : Stress concentration factor for stiffener end connection at point "$a$" and "$f$" subject to relative displacement between the transverse bulkhead and the forward ($F$) and afterward ($A$) transverse web or floors in way of stool respectively as defined in Tab ~~1~~2. The stress concentration can be evaluated directly by the FE analysis when the detail of end connection is not defined in Tab ~~1~~2.

$\ell_F$ , $\ell_A$ : Span, in m, of forward ($F$) and afterward ($A$) longitudinal to be measured as shown in Fig 2

$x_{fF}$ , $x_{fA}$ : Distance, in m, to the hot spot from the closest end of $\ell_F$ and $\ell_A$ respectively (see Fig 2).



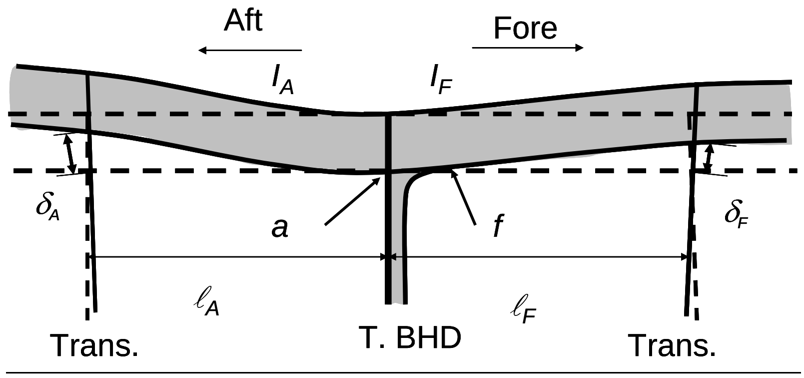




**Figure 3 ~~Relative displacement between the transverse bulkhead and the transverse web or floor~~ Definition of the relative displacement (Example of the side longitudinal)**

# 3. Hot Spot Mean Stress

## 3.3 Mean stress according to the simplified procedure

### 3.3.1 Hot spot mean stresses

The structural hot spot mean stress, in N/mm$^2$, in loading condition "($k$)" regardless of load case "$i$" is to be obtained from the following formula:

$$\sigma_{mean,(k)} = \sigma_{GS,(k)} + \sigma_{S1,(k)} - \sigma_{S2,(k)} + \sigma_{dS,(k)}$$

where

$\sigma_{GS,(k)}$ : Stress due to still water hull girder moment, defined in [3.3.2]

$\sigma_{S1,(k)}$ : Stress due to static pressure when the pressure is applied on the same side as the ordinary stiffener depending on the considered case, with consideration of the stresses defined in [3.3.3] to [3.3.5]

$\sigma_{S2,(k)}$ : Stress due to static pressure when the pressure is applied on the side opposite to the stiffener depending on the considered case, with consideration of the stresses defined in [3.3.3] to [3.3.5]

~~$\sigma_{LS,(k)}$ : Stress due to hydrostatic pressure, defined in [3.3.3]~~

~~$\sigma_{CS,(k)}$ : Stress due to liquid pressure in still water, defined in [3.3.4]~~

~~$\sigma_{LCS,(k)}$ : Stress due to dry bulk cargo pressure in still water, defined in [3.3.5]~~

$\sigma_{dS,(k)}$ : Stress due to relative displacement of transverse bulkhead in still water, defined in [3.3.6].

### 3.3.2 Stress due to still water hull girder moment

The hot spot stress due to still water bending moment, in N/mm², in loading condition "(*k*)" is to be obtained with the following formula:

$$\sigma_{GS,(k)} = K_{gh} \frac{M_{S,(k)}(z-N)}{I_Y} 10^{-3}$$

where:

$M_{S,(k)}$ : Still water vertical bending moment, in kN.m, defined in Sec 3, [3.2.2].

### 3.3.3 Stress due to hydrostatic and hydrodynamic pressure

The hot spot stress due to hydrostatic and hydrodynamic pressure, in N/mm², in loading condition "(*k*)" is to be obtained with the following formula:

$$\sigma_{LS,(k)} = \frac{K_{gl} K_s p_{S,(k)} s\ell^2 \left(1 - \frac{6x_f}{\ell} + \frac{6x_f^2}{\ell^2}\right)}{12w} 10^3$$

$$\sigma_{LS,(k)} = \frac{K_{gl} K_s \left\{ p_{S,(k)} + \frac{p_{CW,i1(k)} + p_{CW,i2(k)}}{2} \right\} s\ell^2 \left(1 - \frac{6x_f}{\ell} + \frac{6x_f^2}{\ell^2}\right)}{12w} \cdot 10^3$$

where:

$p_{S,(k)}$ : Hydrostatic pressure, in kN/m², in loading condition "(*k*)" specified in Ch 4, Sec 5, [1.2].

$p_{CW,ij(k)}$ : Corrected hydrodynamic pressure, in kN/m², according to [2.3.3], with $f_p$ = 0.5, in load case "*i*1" and "*i*2" for loading condition "(*k*)"

*i* : Suffix which denotes the load case specified in Sec 2 [2.1.1], when calculating the mean stress, "*I*" is to be used.

### 3.3.4 Stress due to liquid pressure in still water

The structural hot spot mean stress due to liquid pressure, in N/mm², in loading condition "(*k*)" is to be obtained with the following formula:

$$\sigma_{CS,(k)} = \frac{K_{gl} K_s p_{CS,(k)} s\ell^2 \left(1 - \frac{6x_f}{\ell} + \frac{6x_f^2}{\ell^2}\right)}{12w} 10^3$$

where:

$p_{CS,(k)}$ : Liquid pressure in still water, in kN/m², in loading condition "*(k)*" specified in Ch 4, Sec 6, [2.1]. Where the considered location is located in fuel oil, other oil or fresh water tanks, $d_{AP}$ and $P_{PV}$ defined in Ch 4 Sec 6 are to be taken equal to 0 and $z_{TOP}$ specified in Ch 4 Sec 6, [2.1] is to be taken equal to $z_{SF}$ specified in [2.3.4].

~~**Table 1: Stress concentration factors for the stiffener end connection**~~

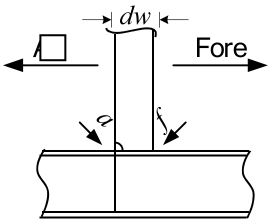
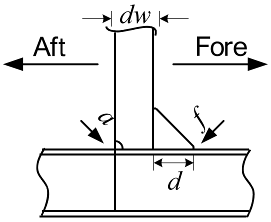
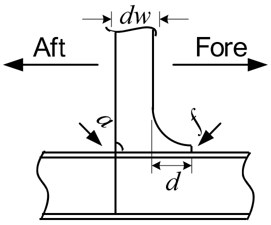
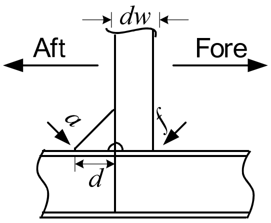
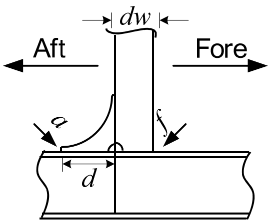
| ~~Structural type~~ | ~~Assessed point~~ | ~~Collar plate~~ | ~~Bracket size~~ | ~~Stress concentration factors~~ | | | |
|---|---|---|---|---|---|---|---|
| | | | | ~~$K_{gl}$~~ | ~~$K_{gh}$~~ | ~~$K_{dF}$~~ | ~~$K_{dA}$~~ |
| ~~1~~   | ~~*A*~~ | ~~watertight~~ | ~~—~~ | ~~1.5~~ | ~~1.1~~ | ~~1.15~~ | ~~1.5~~ |
| | | ~~non-watertight~~ | ~~—~~ | ~~1.65~~ | ~~1.1~~ | ~~—~~ | ~~—~~ |
| | ~~*F*~~ | ~~watertight~~ | ~~—~~ | ~~1.1~~ | ~~1.05~~ | ~~1.55~~ | ~~1.05~~ |
| ~~2~~   | ~~*A*~~ | ~~watertight~~ | ~~$dw \le d < 1.5dw$~~ | ~~1.45~~ | ~~1.1~~ | ~~1.15~~ | ~~1.4~~ |
| | | | ~~$1.5dw \le d$~~ | ~~1.4~~ | ~~1.05~~ | ~~1.15~~ | ~~1.35~~ |
| | | ~~non-watertight~~ | ~~$dw \le d < 1.5dw$~~ | ~~1.55~~ | ~~1.1~~ | ~~—~~ | ~~—~~ |
| | | | ~~$1.5dw \le d$~~ | ~~1.5~~ | ~~1.05~~ | ~~—~~ | ~~—~~ |
| | ~~*F*~~ | ~~watertight~~ | ~~$dw \le d < 1.5dw$~~ | ~~1.1~~ | ~~1.05~~ | ~~1.15~~ | ~~1.1~~ |
| | | | ~~$1.5dw \le d$~~ | ~~1.05~~ | ~~1.05~~ | ~~1.1~~ | ~~1.05~~ |
| ~~3~~   | ~~*a*~~ | ~~watertight~~ | ~~$dw \le d < 1.5dw$~~ | ~~1.4~~ | ~~1.1~~ | ~~1.1~~ | ~~1.35~~ |
| | | | ~~$1.5dw \le d$~~ | ~~1.35~~ | ~~1.05~~ | ~~1.05~~ | ~~1.3~~ |
| | | ~~non-watertight~~ | ~~$dw \le d < 1.5dw$~~ | ~~1.5~~ | ~~1.1~~ | ~~—~~ | ~~—~~ |
| | | | ~~$1.5dw \le d$~~ | ~~1.45~~ | ~~1.05~~ | ~~—~~ | ~~—~~ |
| | ~~*f*~~ | ~~watertight~~ | ~~$dw \le d < 1.5dw$~~ | ~~1.05~~ | ~~1.05~~ | ~~1.1~~ | ~~1.05~~ |
| | | | ~~$1.5dw \le d$~~ | ~~1.05~~ | ~~1.05~~ | ~~1.05~~ | ~~1.05~~ |
| ~~4~~   | ~~*a*~~ | ~~watertight~~ | ~~$dw \le d < 1.5dw$~~ | ~~1.1~~ | ~~1.05~~ | ~~1.05~~ | ~~1.25~~ |
| | | | ~~$1.5dw \le d$~~ | ~~1.05~~ | ~~1.05~~ | ~~1.05~~ | ~~1.2~~ |
| | ~~*f*~~ | ~~watertight~~ | ~~$dw \le d < 1.5dw$~~ | ~~1.3~~ | ~~1.1~~ | ~~1.35~~ | ~~1.05~~ |
| | | | ~~$1.5dw \le d$~~ | ~~1.3~~ | ~~1.05~~ | ~~1.3~~ | ~~1.05~~ |
| | | ~~non-watertight~~ | ~~$dw \le d < 1.5dw$~~ | ~~1.4~~ | ~~1.1~~ | ~~—~~ | ~~—~~ |
| | | | ~~$1.5dw \le d$~~ | ~~1.4~~ | ~~1.05~~ | ~~—~~ | ~~—~~ |
| ~~5~~   | ~~*a*~~ | ~~watertight~~ | ~~$dw \le d < 1.5dw$~~ | ~~1.1~~ | ~~1.05~~ | ~~1.05~~ | ~~1.2~~ |
| | | | ~~$1.5dw \le d$~~ | ~~1.05~~ | ~~1.05~~ | ~~1.05~~ | ~~1.15~~ |
| | ~~*f*~~ | ~~watertight~~ | ~~$dw \le d < 1.5dw$~~ | ~~1.3~~ | ~~1.1~~ | ~~1.55~~ | ~~1.1~~ |
| | | | ~~$1.5dw \le d$~~ | ~~1.3~~ | ~~1.05~~ | ~~1.5~~ | ~~1.05~~ |
| | | ~~non-watertight~~ | ~~$dw \le d < 1.5dw$~~ | ~~1.35~~ | ~~1.1~~ | ~~—~~ | ~~—~~ |
| | | | ~~$1.5dw \le d$~~ | ~~1.35~~ | ~~1.05~~ | ~~—~~ | ~~—~~ |

**Table 1: Stress concentration factors for the stiffener end connection (continued)**

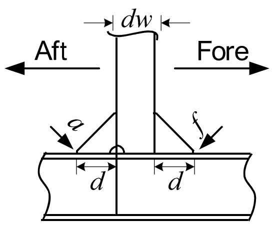
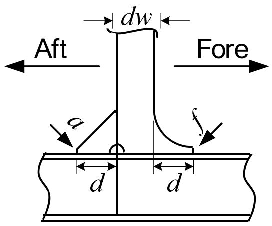
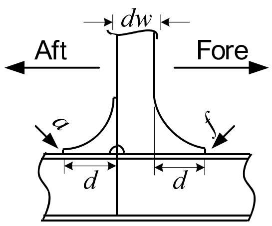
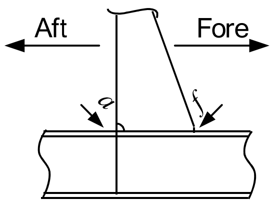
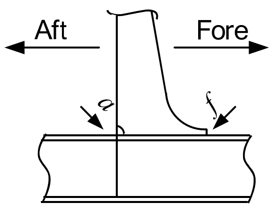
| Structural type | Assessed point | Collar plate | Bracket size | Stress concentration factors $K_{gl}$ | $K_{gh}$ | $K_{dF}$ | $K_{dA}$ |
|---|---|---|---|---|---|---|---|
| 6  | a | watertight | $dw \le d < 1.5dw$ | 1.1 | 1.05 | 1.05 | 1.1 |
| | | | $1.5dw \le d$ | 1.05 | 1.05 | 1.05 | 1.05 |
| | | non-watertight | $dw \le d < 1.5dw$ | 1.15 | 1.05 | ----- | ----- |
| | | | $1.5dw \le d$ | 1.1 | 1.05 | ----- | ----- |
| | f | watertight | $dw \le d < 1.5dw$ | 1.05 | 1.05 | 1.1 | 1.05 |
| | | | $1.5dw \le d$ | 1.05 | 1.05 | 1.05 | 1.05 |
| 7  | a | watertight | $dw \le d < 1.5dw$ | 1.1 | 1.05 | 1.05 | 1.2 |
| | | | $1.5dw \le d$ | 1.05 | 1.05 | 1.05 | 1.15 |
| | | non-watertight | $dw \le d < 1.5dw$ | 1.15 | 1.05 | ----- | ----- |
| | | | $1.5dw \le d$ | 1.1 | 1.05 | ----- | ----- |
| | f | watertight | $dw \le d < 1.5dw$ | 1.05 | 1.05 | 1.05 | 1.05 |
| | | | $1.5dw \le d$ | 1.05 | 1.05 | 1.05 | 1.05 |
| 8  | a | watertight | $dw \le d < 1.5dw$ | 1.1 | 1.1 | 1.05 | 1.15 |
| | | | $1.5dw \le d$ | 1.05 | 1.05 | 1.05 | 1.1 |
| | | non-watertight | $dw \le d < 1.5dw$ | 1.1 | 1.1 | ----- | ----- |
| | | | $1.5dw \le d$ | 1.05 | 1.05 | ----- | ----- |
| | f | watertight | $dw \le d < 1.5dw$ | 1.05 | 1.05 | 1.1 | 1.05 |
| | | | $1.5dw \le d$ | 1.05 | 1.05 | 1.05 | 1.05 |
| 9  | a | watertight | ----- | 1.4 | 1.05 | 1.05 | 1.75 |
| | f | watertight | ----- | 1.6 | 1.05 | 1.7 | 1.05 |
| 10  | a | watertight | ----- | 1.3 | 1.05 | 1.05 | 1.75 |
| | f | watertight | ----- | 1.55 | 1.05 | 1.3 | 1.05 |

**Table 1: Stress concentration factors for the stiffener end connection (continued)**

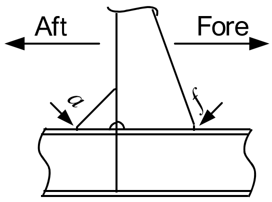
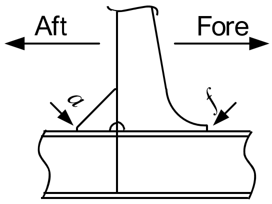
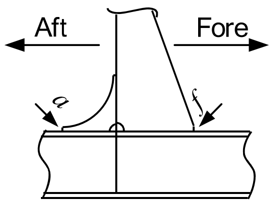
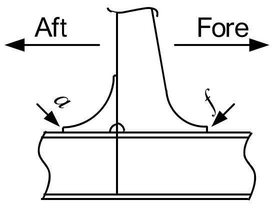
| Structural type | Assessed point | Collar plate | Bracket size | Stress concentration factors | | | |
|---|---|---|---|---|---|---|---|
| | | | | $K_{gl}$ | $K_{gh}$ | $K_{dF}$ | $K_{dA}$ |
| 11   | a | watertight | ----- | 1.1 | 1.05 | 1.05 | 1.2 |
| | f | watertight | ----- | 1.75 | 1.05 | 1.4 | 1.05 |
| 12   | a | watertight | ----- | 1.1 | 1.05 | 1.05 | 1.2 |
| | f | watertight | ----- | 1.3 | 1.05 | 1.05 | 1.05 |
| 13   | a | watertight | ----- | 1.05 | 1.05 | 1.05 | 1.15 |
| | f | watertight | ----- | 1.95 | 1.05 | 1.55 | 1.05 |
| 14   | a | watertight | ----- | 1.05 | 1.05 | 1.05 | 1.15 |
| | f | watertight | ----- | 1.7 | 1.05 | 1.15 | 1.05 |

**Table 1: Stress concentration factors for non-watertight longitudinal end connection at transverse webs or floors other than transverse bulkheads or floors in way of stools**

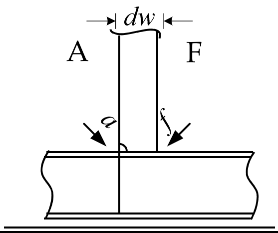
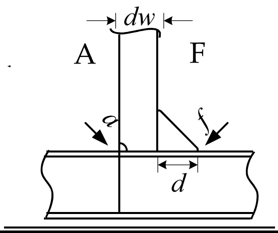
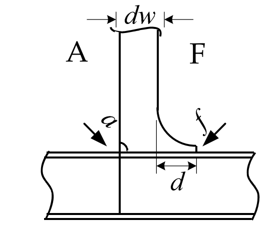
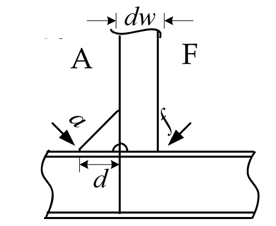
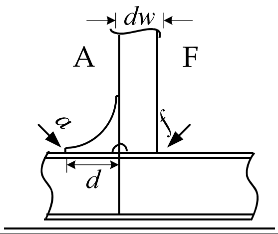
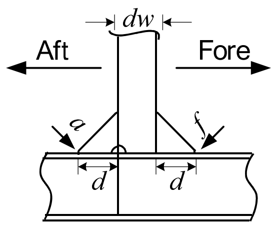
| Bracket type | Assessed point | Bracket size | Stress concentration factors | |
|---|---|---|---|---|
| | | | $K_{gl}$ | $K_{gh}$ |
| 1  | *a* | ----- | 1.65 | 1.1 |
| 2  | *a* | $dw \le d < 1.5dw$ | 1.55 | 1.1 |
| | | $1.5dw \le d$ | 1.5 | 1.05 |
| 3  | *a* | $dw \le d < 1.5dw$ | 1.5 | 1.1 |
| | | $1.5dw \le d$ | 1.45 | 1.05 |
| 4  | *f* | $dw \le d < 1.5dw$ | 1.4 | 1.1 |
| | | $1.5dw \le d$ | 1.4 | 1.05 |
| 5  | *f* | $dw \le d < 1.5dw$ | 1.35 | 1.1 |
| | | $1.5dw \le d$ | 1.35 | 1.05 |
| 6  | *a* | $dw \le d < 1.5dw$ | 1.15 | 1.05 |
| | | $1.5dw \le d$ | 1.1 | 1.05 |

**Table 1: Stress concentration factors for non-watertight longitudinal end connection at transverse webs or floors other than transverse bulkheads or floors in way of stools (continued)**

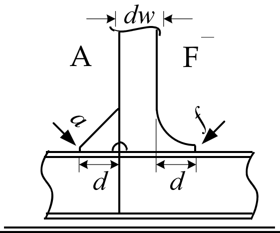
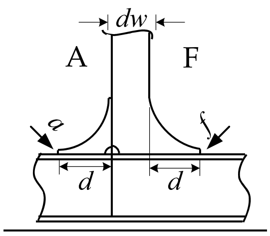
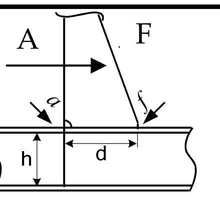
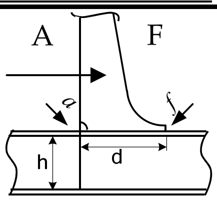
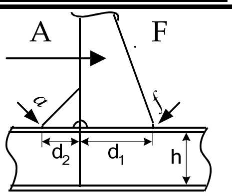
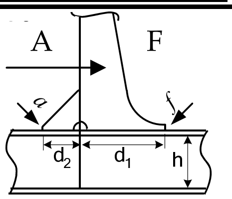
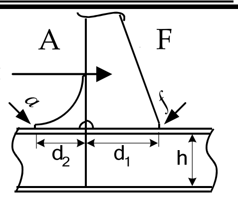
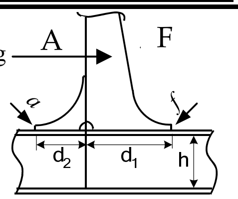
| Bracket type | Assessed point | Bracket size | Stress concentration factors | |
|---|---|---|---|---|
| | | | $K_{gl}$ | $K_{gh}$ |
| 7  | *a* | $dw \le d < 1.5dw$ | 1.15 | 1.05 |
| | | $1.5dw \le d$ | 1.1 | 1.05 |
| 8  | *a* | $dw \le d < 1.5dw$ | 1.1 | 1.1 |
| | | $1.5dw \le d$ | 1.05 | 1.05 |
| 9 Tripping bracket  | *a* | $d \le 2h$ | 1.45 | 1.1 |
| 10 Tripping bracket  | *a* | $d \le 2.5h$ | 1.35 | 1.1 |
| 11 Tripping bracket  | *a* | $d_1 \le 2h$ and $h \le d_2$ | 1.15 | 1.1 |
| | *f* | | 1.85 | 1.1 |
| 12 Tripping bracket  | *a* | $d_1 \le 2.5h$ and $h \le d_2$ | 1.15 | 1.1 |
| | *f* | | 1.35 | 1.1 |
| 13 Tripping bracket  | *a* | $d_1 \le 2h$ and $h \le d_2$ | 1.1 | 1.1 |
| | *f* | | 2.05 | 1.1 |
| 14 Tripping bracket  | *a* | $d_1 \le 2.5h$ and $h \le d_2$ | 1.1 | 1.1 |
| | *f* | | 1.8 | 1.1 |

**Table 2: Stress concentration factors for watertight longitudinal end connection at transverse bulkheads and floors in way of stools**

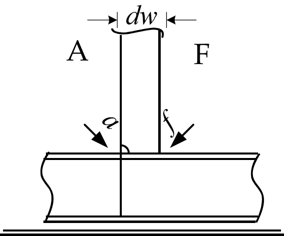
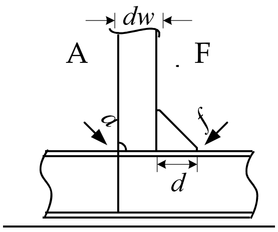
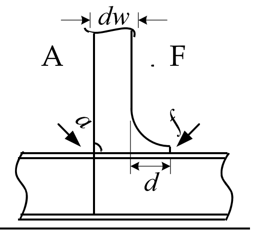
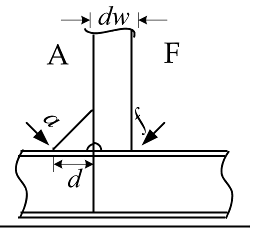
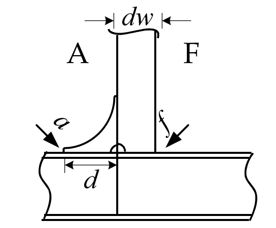
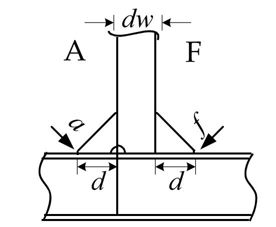
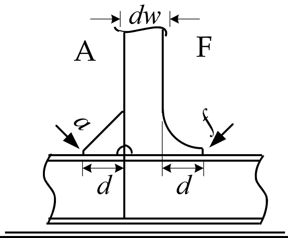
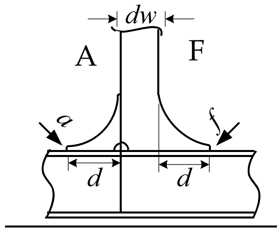
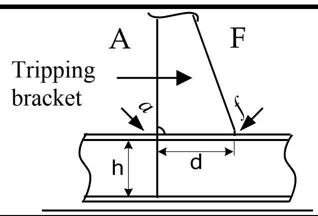
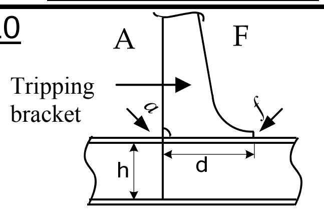
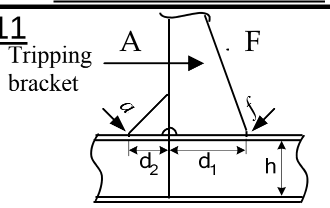
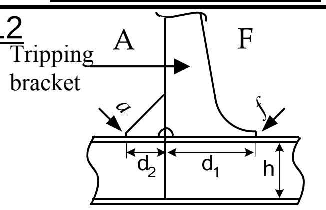
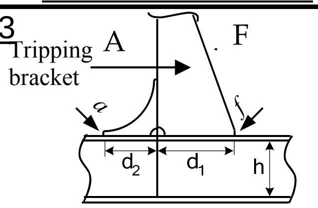
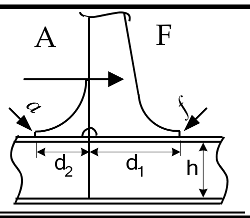
| Bracket type | Assessed point | Bracket size | Stress concentration factors | | | |
|---|---|---|---|---|---|---|
| | | | $K_{gl}$ | $K_{gh}$ | $K_{dF}$ | $K_{dA}$ |
| 1   | a | ----- | 1.5 | 1.1 | 1.15 | 1.5 |
| | f | ----- | 1.1 | 1.05 | 1.55 | 1.05 |
| 2   | a | dw ≤ d<1.5dw | 1.45 | 1.1 | 1.15 | 1.4 |
| | | 1.5dw ≤ d | 1.4 | 1.05 | 1.15 | 1.35 |
| | f | dw ≤ d<1.5dw | 1.1 | 1.05 | 1.15 | 1.1 |
| | | 1.5dw ≤ d | 1.05 | 1.05 | 1.1 | 1.05 |
| 3   | a | dw ≤ d < 1.5dw | 1.4 | 1.1 | 1.1 | 1.35 |
| | | 1.5dw ≤ d | 1.35 | 1.05 | 1.05 | 1.3 |
| | f | dw ≤ d<1.5dw | 1.05 | 1.05 | 1.1 | 1.05 |
| | | 1.5dw ≤ d | 1.05 | 1.05 | 1.05 | 1.05 |
| 4   | a | dw ≤ d<1.5dw | 1.1 | 1.05 | 1.05 | 1.25 |
| | | 1.5dw ≤ d | 1.05 | 1.05 | 1.05 | 1.2 |
| | f | dw ≤ d < 1.5dw | 1.3 | 1.1 | 1.35 | 1.05 |
| | | 1.5dw ≤d | 1.3 | 1.05 | 1.3 | 1.05 |
| 5   | a | dw ≤ d < 1.5dw | 1.1 | 1.05 | 1.05 | 1.2 |
| | | 1.5dw ≤ d | 1.05 | 1.05 | 1.05 | 1.15 |
| | f | dw ≤ d < 1.5dw | 1.3 | 1.1 | 1.55 | 1.1 |
| | | 1.5dw ≤ d | 1.3 | 1.05 | 1.5 | 1.05 |
| 6   | a | dw ≤ d < 1.5dw | 1.1 | 1.05 | 1.05 | 1.1 |
| | | 1.5dw ≤ d | 1.05 | 1.05 | 1.05 | 1.05 |
| | f | dw ≤ d < 1.5dw | 1.05 | 1.05 | 1.1 | 1.05 |
| | | 1.5dw ≤ d | 1.05 | 1.05 | 1.05 | 1.05 |

**Table 2: Stress concentration factors for watertight longitudinal end connection at transverse bulkheads and floors in way of stools (continued)**

<table>
<tr><th rowspan="2">Bracket type</th><th rowspan="2">Assessed point</th><th rowspan="2">Bracket size</th><th colspan="4">Stress concentration factors</th></tr>
<tr><th>$K_{gl}$</th><th>$K_{gh}$</th><th>$K_{dF}$</th><th>$K_{dA}$</th></tr>
<tr><td rowspan="4">7<br></td><td rowspan="2">a</td><td>$dw \le d < 1.5dw$</td><td>1.1</td><td>1.05</td><td>1.05</td><td>1.2</td></tr>
<tr><td>$1.5dw \le d$</td><td>1.05</td><td>1.05</td><td>1.05</td><td>1.15</td></tr>
<tr><td rowspan="2">f</td><td>$dw \le d < 1.5dw$</td><td>1.05</td><td>1.05</td><td>1.05</td><td>1.05</td></tr>
<tr><td>$1.5dw \le d$</td><td>1.05</td><td>1.05</td><td>1.05</td><td>1.05</td></tr>
<tr><td rowspan="4">8<br></td><td rowspan="2">a</td><td>$dw \le d < 1.5dw$</td><td>1.1</td><td>1.1</td><td>1.05</td><td>1.15</td></tr>
<tr><td>$1.5dw \le d$</td><td>1.05</td><td>1.05</td><td>1.05</td><td>1.1</td></tr>
<tr><td rowspan="2">f</td><td>$dw \le d < 1.5dw$</td><td>1.05</td><td>1.05</td><td>1.1</td><td>1.05</td></tr>
<tr><td>$1.5dw \le d$</td><td>1.05</td><td>1.05</td><td>1.05</td><td>1.05</td></tr>
<tr><td rowspan="2">9<br></td><td>a</td><td rowspan="2">$d \le 2h$</td><td>1.4</td><td>1.05</td><td>1.05</td><td>1.75</td></tr>
<tr><td>f</td><td>1.6</td><td>1.05</td><td>1.7</td><td>1.05</td></tr>
<tr><td rowspan="2">10<br></td><td>a</td><td rowspan="2">$d \le 2.5h$</td><td>1.3</td><td>1.05</td><td>1.05</td><td>1.75</td></tr>
<tr><td>f</td><td>1.55</td><td>1.05</td><td>1.3</td><td>1.05</td></tr>
<tr><td rowspan="2">11<br></td><td>a</td><td rowspan="2">$d_1 \le 2h$<br>and<br>$h \le d_2$</td><td>1.1</td><td>1.05</td><td>1.05</td><td>1.2</td></tr>
<tr><td>f</td><td>1.75</td><td>1.05</td><td>1.4</td><td>1.05</td></tr>
<tr><td rowspan="2">12<br></td><td>a</td><td rowspan="2">$d_1 \le 2.5h$<br>and<br>$h \le d_2$</td><td>1.1</td><td>1.05</td><td>1.05</td><td>1.2</td></tr>
<tr><td>f</td><td>1.3</td><td>1.05</td><td>1.05</td><td>1.05</td></tr>
<tr><td rowspan="2">13<br></td><td>a</td><td rowspan="2">$d_1 \le 2h$<br>and<br>$h \le d_2$</td><td>1.05</td><td>1.05</td><td>1.05</td><td>1.15</td></tr>
<tr><td>f</td><td>1.95</td><td>1.05</td><td>1.55</td><td>1.05</td></tr>
</table>

| | | | | | | |
|---|---|---|---|---|---|---|
| 14 Tripping bracket   | *a* | $d_1 \leq 2.5h$ and $h \leq d_2$ | 1.05 | 1.05 | 1.05 | 1.15 |
| | *f* | | 1.7 | 1.05 | 1.15 | 1.05 |

# Common Structural Rules for Bulk Carriers, July 2008

# Technical Background for Rule Change Notice No.1-6 (Fatigue Check for Longitudinals)

# Technical Background for the Changes Regarding Fatigue Check for Longitudinals

## 1. Reason for the Rule Change in:

### 1.1 Chapter 4, Section 5, [2.1.1]

Since the external pressures on exposed deck are set up in order to check the local scantling considering the effect on green water and are not referenced in the pressures specified in Ch 8 Sec 4, [2.3.3], the clarification is made that these pressures are not necessary to consider for the fatigue check.

### 1.2 Chapter 4, Section 6, [2.1.3]

For fatigue strength assessment, the filling height of liquid in the tank is to consider the average one because the fatigue strength of the structures is dominant to the most frequent condition in the representative loading condition. Generally, for water ballast tanks, the most frequent condition is assumed that the upper surface of liquid matches to upper level of the tank according to KC ID 359.

### 1.3 Chapter 8, Section 1, Table 1 and [3.1.1]

These changes are made in order to clarify the requirements.

### 1.4 Chapter 8, Section 4, [2.3.3] and [3.3.3]

To consider the nonlinear relation between wave pressure and wave height, the correction factor of the pressure range is specified in Ch8 Sec4 [2.3.3] of the current CSR. This correction factor is introduced to define an equivalent linear long term distribution of stress range which gives a fatigue damage equivalent to the damage according to the nonlinear distribution of stress range. However, the consideration of this nonlinearity on the evaluation of mean stress was not included.

This consideration is naturally necessary to consider the nonlinear effect of wave pressure on the fatigue damage of side longitudinals. Consequently, Ch8 Sec4 [2.3.3] is to be modified so that this consideration can be taken into account. And Ch8 Sec4 [3.3.3] is also to be modified so that the mean stress considering the nonlinear effect can be evaluated.

### 1.5 Chapter 8, Section 4, [2.3.4] and [3.3.4]

The interpretation is added to the text for the case where the considered locations are located in fuel oil tank, other oil tank or fresh water tank, according to KC ID 359.

### 1.6 Chapter 8, Section 4, [2.3.6]

The clarification is made for the relative displacement according to the answer in KC ID 342.

### 1.7 Chapter 8, Section 4, Table 1

The table gives the stress concentration factors for representative stiffener end connections. However, some types of stiffener end connection not defined in the table are used for non watertight transverses and size of bracket was not defined in the table.

The modification of the table is made to clarify the application of the types of stiffener end connections and the size of bracket based on the investigation result of actual ship design, according to KC IDs 255, 256, 257, 258 and 259.

## 2. Summary of Rule Change

### 2.1 Chapter 4, Section 5, [2.1.1]

The sentence regarding the external pressure on exposed deck is added to the paragraph [2.1.1].

**2.2 Chapter 4, Section 6, [2.1.3]**
The new paragraph [2.1.3] regarding the liquid pressure in still water is added.

**2.3 Chapter 8, Section 1, Table 1 and [3.1.1]**
The word “floors in way of lower stool” is added to the details for ordinary stiffener in double bottom in Table 1 and the sentence regarding standard loading condition for fatigue strength assessment is added to [3.1.1].

**2.4 Chapter 8, Section 4, [2.3.3] and [3.3.3]**
In order to consider the nonlinearity on the evaluation of mean stress, the formulae are modified as follows.
(1) [2.3.3]

$$\sigma_{LW,ij(k)} = \frac{K_{gl} K_s C_{NE,ij(k)} p_{W,ij(k)} s\ell^2 \left(1 - \frac{6x_f}{\ell} + \frac{6x_f^{\,2}}{\ell^2}\right)}{12w} 10^3 \qquad (j = 1, 2)$$

$$\sigma_{LW,ij(k)} = \frac{K_{gl} K_s p_{CW,ij(k)} s\ell^2 \left(1 - \frac{6x_f}{\ell} + \frac{6x_f^{\,2}}{\ell^2}\right)}{12w} 10^3 \qquad (j = 1, 2)$$

$$p_{CW,i1(k)} = \begin{cases} 2C_{NE,i1(k)} p_{W,i1(k)} & ; C_{NE,i1(k)} < 0.5 \\ p_{W,i1(k)} & ; C_{NE,i1(k)} \geq 0.5 \end{cases}$$

$$p_{CW,i2(k)} = \begin{cases} 0 & ; \quad C_{NE,i2(k)} < 0.5 \\ (2C_{NE,i2(k)} - 1) p_{W,i2(k)} & ; \quad C_{NE,i2(k)} \geq 0.5 \end{cases}$$

(2) [3.3.3]

$$\sigma_{LS,(k)} = \frac{K_{gl} K_s p_{S,(k)} s\ell^2 \left(1 - \frac{6x_f}{\ell} + \frac{6x_f^{\,2}}{\ell^2}\right)}{12w} 10^3$$

$$\sigma_{LS,(k)} = \frac{K_{gl} K_s \left\{ p_{S,(k)} + \frac{p_{CW,i1(k)} + p_{CW,i2(k)}}{2} \right\} s\ell^2 \left(1 - \frac{6x_f}{\ell} + \frac{6x_f^{\,2}}{\ell^2}\right)}{12w} \cdot 10^3$$

In addition, the texts referring to Table 1 and Table 2 are changed according to the modification of these tables. The background of these formulae is given in Annex 1.

**2.5 Chapter 8, Section 4, [2.3.4] and [3.3.4]**
Where the considered locations are located in fuel oil tank, other oil tank or fresh water tank, $Z_{SF}$ may be taken as the distance to the half height of the tank.
In addition, where the hydrostatic pressure of the considered member located in fuel oil tank, other oil tank or fresh water tank is calculated according to Ch 4 Sec 6 [2.1.1], $d_{AP}$ and $P_{PV}$ defined in Ch 4 Sec 6 are to be taken equal to 0.

**2.6 Chapter 8, Section 4, [2.3.6]**
The text on the definition of relative displacement is added.

### 2.7 Chapter 8, Section 4 Table 1

The current Table 1 is divided into two tables. One is for stress concentration factor for non-watertight longitudinal end connection and the other is for stress concentration factor for watertight longitudinal connection. In addition, the bracket size is added based on the actual design.

## 3. Effect due to this change

### 3.1 Clarification of the rules specified in 2.1, 2.2, 2.4 and 2.5

As these changes are made for clarification, there is no scantling impact due to this clarification.

### 3.2 Chapter 8, Section 4, [2.3.3] and [3.3.3]

The effect on assessed fatigue damage due to the modification was examined. Sample ships are listed in Table G1. Fatigue damages of side longitudinal stiffener with as-built scantling according to the current rule and the modified proposal were assessed and compared in Figs. 1(a) and (b).

Assessed fatigue damages are well improved to agree with the current experiences that the side longitudinal stiffeners were hardly fatigue damaged.

Table 1: List of Examined Ships

| Vessel ID | | D1 | D2 | D3 | S1 | S3 | S7 |
|---|---|---|---|---|---|---|---|
| Type | | Cape | Handymax | Handymax | Cape | Handymax | Cape |
| Lpp (Rule) | | 275.48 | 178.48 | 178.29 | 275.00 | 182.85 | 286.91 |
| B | | 45.00 | 32.20 | 31.00 | 45.00 | 32.26 | 50.00 |
| D | | 24.30 | 16.50 | 16.50 | 24.40 | 17.80 | 24.10 |
| d | Max. | 17.80 | 11.68 | 11.66 | 17.93 | 12.45 | 17.88 |
| | Homo. | 17.80 | 11.68 | 11.66 | 17.93 | 12.45 | 17.88 |
| | Alt. | 17.80 | 11.68 | 11.66 | 17.93 | 12.45 | 17.88 |
| | N.B. | 7.59 | 5.87 | 6.19 | 8.06 | 5.02 | 7.01 |
| | H.B. | 9.78 | 7.91 | 8.67 | 9.14 | 8.02 | 8.92 |
| | NA | 10.56 | 6.16 | 6.08 | 11.31 | 7.00 | 10.67 |

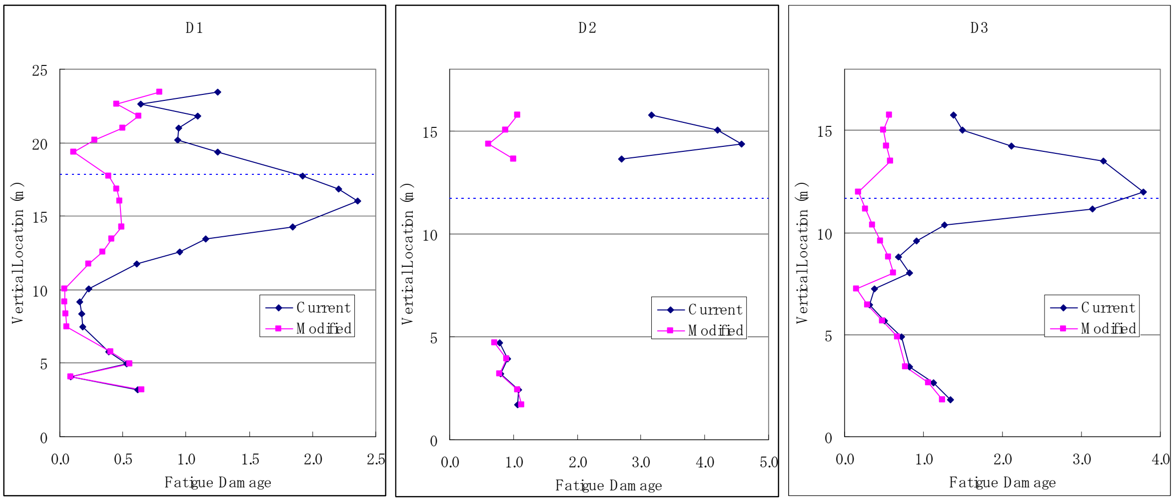



Fig. 1(a) Comparison of Fatigue Damages of DSS BCs

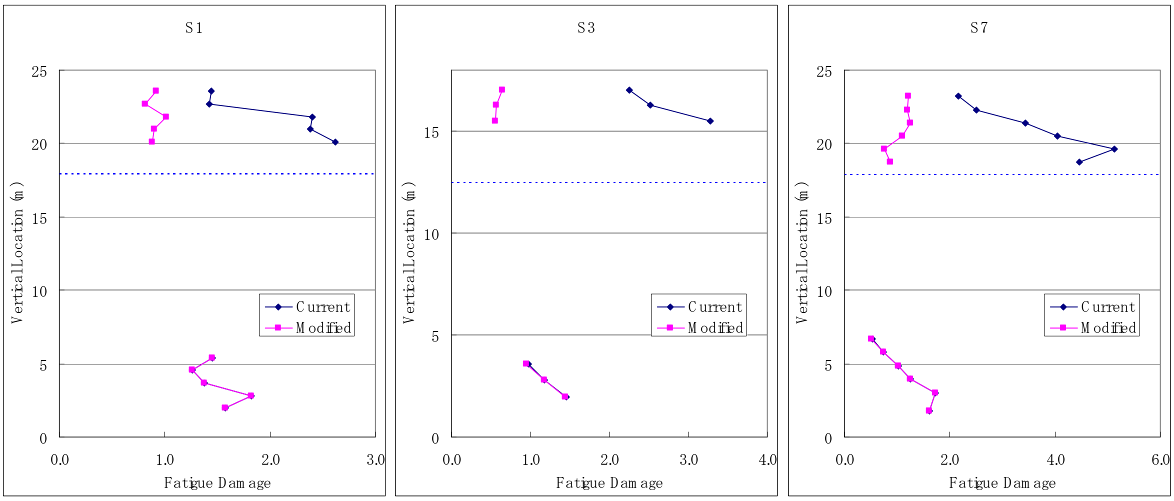



Fig. 1(b) Comparison of Fatigue Damages of SSS BCs

**3.3 Scantling impact due to the change in Chapter 8, Section 4, [2.3.3] and [3.3.3]**

3.3.1 Procedure for impact calculation

(1) Original scantlings of side longitudinals are checked by the requirement of Ch 6, Sec 2 of the Rules. If the original scantlings do not meet the requirement of Ch 6, Sec 2, the modified scantlings are considered.

(2) Fatigue check for the longitudinals with modified scantlings is carried out by the current CSR.

(3) Scantling impact in terms of sectional area due to fatigue check is evaluated.

(4) Fatigue check for the longitudinal with the modified scantling is carried out by the proposed requirement.

(5) Scantling impact in terms of sectional area due to the proposed fatigue check requirement is evaluated.

3.3.2 Scantling impact due to proposed fatigue check requirement

The scantling impact in terms of sectional area of longitudinal is evaluated according to the procedure mentioned above for D1 ship and S1 ship for an example and the results are given in Table 2 and 3.

Table 2 Scantling impact of side longitudinals for D1 ships

| ID | Scantling impact according to the requirement in Ch 6 Sec 2 | Current Rule | | Proposed Rule | | Scantling impact due to modification |
|---|---|---|---|---|---|---|
| | | Cumulative fatigue damage | Scantling effect due to fatigue check | Cumulative fatigue damage | Scantling effect due to fatigue check | |
| 1 (Upper) | 0.0% | 1.25 | 0.0% (IA to T-type) | 0.79 | 0.0% (T-type to IA) | 0.0% |
| 2 | 0.0% | 0.64 | 0.0% | 0.45 | 0.0% | 0.0% |
| 3 | 0.0% | 1.09 | +2.3% | 0.62 | -2.3% | -2.3% |
| 4 | 0.0% | 0.94 | 0.0% | 0.50 | 0.0% | 0.0% |
| 5 | 0.0% | 0.94 | 0.0% | 0.27 | 0.0% | 0.0% |
| 6 | 0.0% | 1.25 | +9.3% | 0.11 | -9.3% | -9.3% |
| 7 | 0.0% | 1.92 | +23.7% | 0.39 | -23.7% | -23.7% |
| 8 | 0.0% | 2.21 | +20.6% | 0.45 | -20.6% | -20.6% |
| 9 | 0.0% | 2.35 | +23.9% | 0.48 | -23.9% | -23.9% |
| 10 | 0.0% | 1.85 | +13.7% | 0.49 | -13.7% | -13.7% |
| 11 | 0.0% | 1.15 | +4.9% | 0.41 | -4.9% | -4.9% |
| 12 | 0.0% | 0.95 | 0.0% | 0.34 | 0.0% | 0.0% |
| 13 | 0.0% | 0.61 | 0.0% | 0.23 | 0.0% | 0.0% |
| 14 | 0.0% | 0.23 | 0.0% | 0.04 | 0.0% | 0.0% |
| 15 | 0.0% | 0.16 | 0.0% | 0.04 | 0.0% | 0.0% |
| 16 | 0.0% | 0.17 | 0.0% | 0.05 | 0.0% | 0.0% |
| 17 | 0.0% | 0.18 | 0.0% | 0.06 | 0.0% | 0.0% |
| 18 | 0.0% | 0.39 | 0.0% | 0.40 | 0.0% | 0.0% |
| 19 | 0.0% | 0.53 | 0.0% | 0.55 | 0.0% | 0.0% |
| 20 | 0.0% | 0.08 | 0.0% | 0.09 | 0.0% | 0.0% |
| 21(Lower) | 0.0% | 0.62 | 0.0% | 0.65 | 0.0% | 0.0% |
| Average | 0.0% | - | 4.3% up | - | -4.3% | -4.3% |

Table 2 Scantling impact of side longitudinals for S1 ships

| ID | | Current Rule | | Proposed Rule | | Scantling impact due to modification |
|---|---|---|---|---|---|---|
| | Scantling impact according to the requirement in Ch 6 Sec 2 | Cumulative fatigue damage | Scantling effect due to fatigue check | Cumulative fatigue damage | Scantling effect due to fatigue check | |
| 1 (Upper) | +8.4% | 0.64 | 0.0% | 0.52 | 0.0% | 0.0% |
| 2 | +5.8% | 0.54 | 0.0% | 0.42 | 0.0% | 0.0% |
| 3 | +27.9% | 0.81 | 0.0% | 0.54 | 0.0% | 0.0% |
| 4 | +23.8% | 0.74 | 0.0% | 0.45 | 0.0% | 0.0% |
| 5 | +28.0% | 0.76 | 0.0% | 0.53 | 0.0% | 0.0% |
| 6 | +29.0% | 1.21 | +5.3% | 1.21 | +5.3% | 0.0% |
| 7 | +26.5% | 1.10 | +3.2% | 1.10 | +3.2% | 0.0% |
| 8 | +26.5% | 1.20 | +6.2% | 1.20 | +6.2% | 0.0% |
| 9 | +30.9% | 1.54 | +17.0% | 1.54 | +17.0 | 0.0% |
| 10(Lower) | +30.9% | 1.33 | +12.1% | 1.33 | +12.1% | 0.0% |
| Average | 23.8% up | - | +4.4% | - | +4.4% | 0.0% |

For double side skin bulk carrier whose side structure is longitudinal frame system, scantlings of a few side longitudinals located below the load water line are affected by the rule change proposal.

For singe side skin bulk carriers, fatigue check result for side longitudinals in top side tank located above load water line are affected by the rule change proposal, however, there is no scantling impact due to the rule change proposal where side longitudinals have the scantlings satisfied with the requirements of Ch 6, Sec 2.

## 4. Technical Background

Technical backgrounds of nonlinear effect on wave pressure and stress concentration factor of longitudinal end connection are described in Annex 1 and Annex 2, respectively.

# Annex 1: Technical background of nonlinear effect on wave pressure

## 1. Current Treatment of mean stress

In the current rule, correction factor for the non linearity of the wave pressure range is introduced to define an equivalent linear long term distribution of stress range which gives a fatigue damage equivalent to the damage according to the nonlinear distribution of stress range. Fig. 1-1 shows the calculated correction factor in accordance with the distance from the base line.

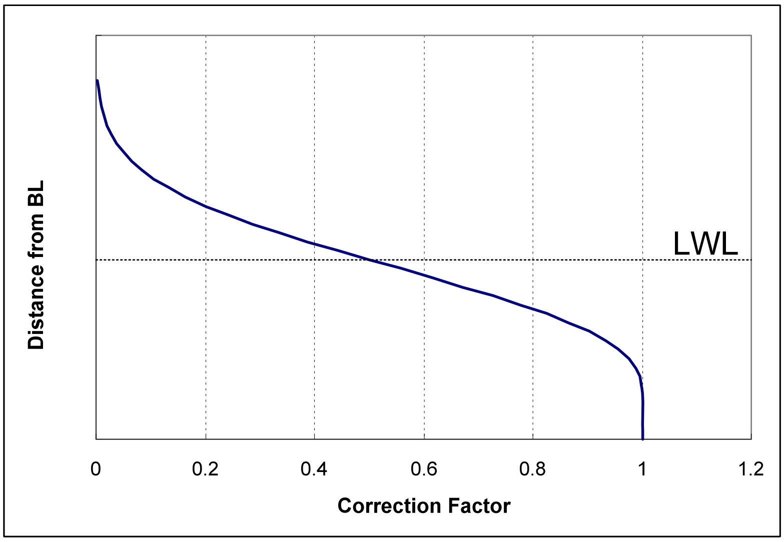



Fig. 1-1 Correction Factor for Non Linearity of the Wave Pressure Range

By multiplying this correction factor by the linear wave pressures for wave crest and wave trough conditions, wave pressure range considering non linear effect can be obtained from the difference of both pressures. In the current rule, because the mean value of the fluctuating pressure is evaluated as the mean of the pressures for wave crest and wave trough conditions, negative pressure will work at the position above water line as shown in Fig. 1-2.

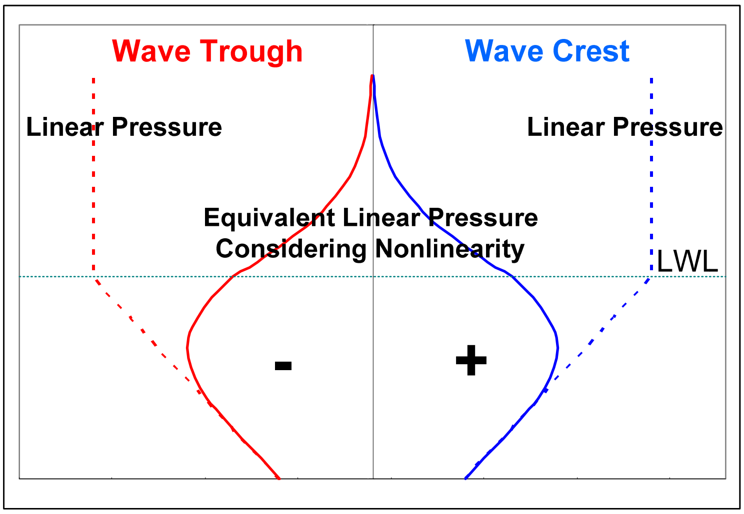



Fig. 1-2 Current Condition of Fluctuating Non Linear Pressure

## 2. Correct Treatment of Mean Stress

Since the negative pressure is not acting at the position above waterline due to the wave fluctuation, the actual fluctuation of nonlinear pressure is illustrated as Fig. 1-3.

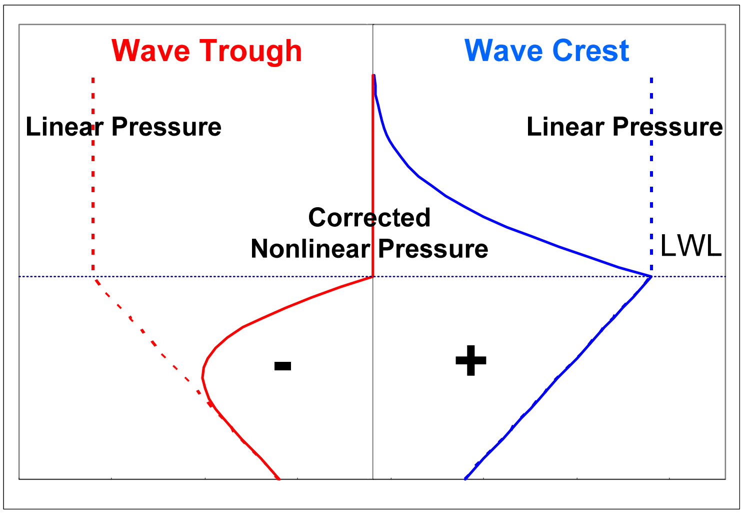


Fig. 1-3 Actual Condition of Fluctuating Non Linear Pressure

In order to reflect above mentioned condition of fluctuating nonlinear pressure, the equation specified in Ch 8, Sec 4, [2.3.3] is to be modified as below:

$$\sigma_{LW,ij(k)} = \frac{K_{gl} K_s p_{CW,ij(k)} s \ell^2 \left(1 - \frac{6x_f}{\ell} + \frac{6{x_f}^2}{\ell^2}\right)}{12w} \cdot 10^3 \qquad (j = 1, 2)$$

$$p_{CW,i1(k)} = \begin{cases} 2C_{NE,i1(k)} p_{W,i1(k)} & ; \quad C_{NE,i1(k)} < 0.5 \\ p_{W,i1(k)} & ; \quad C_{NE,i1(k)} \geq 0.5 \end{cases}$$

$$p_{CW,i2(k)} = \begin{cases} 0 & ; \quad C_{NE,i2(k)} < 0.5 \\ \left(2C_{NE,i2(k)} - 1\right) p_{W,i2(k)} & ; \quad C_{NE,i2(k)} \geq 0.5 \end{cases}$$

According to this modification, the evaluated wave induced stress condition of the stiffeners can be illustrated as Fig. 1-4. The magnitude of stress range hold same as the one by current rule. Only the evaluation of mean stress considering the non linearity of the wave pressure has been improved.

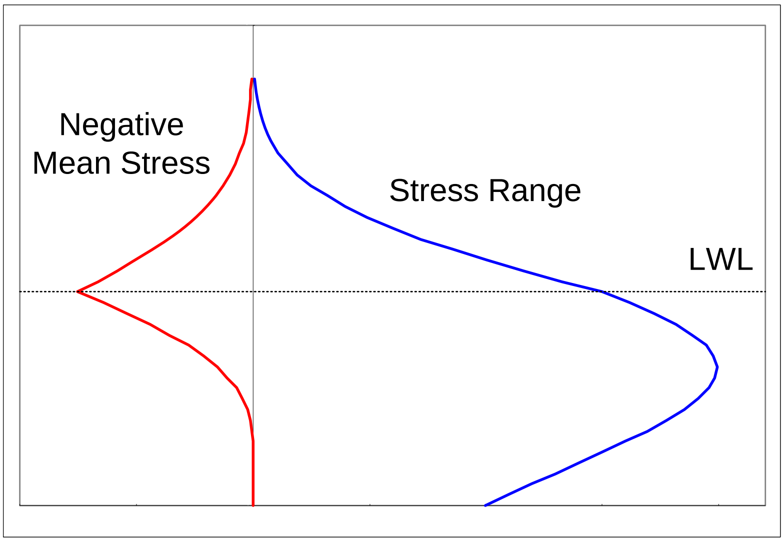


Fig. 1-4 Wave induced Stress Condition along Ship Side

In order to take the nonlinear fluctuating pressure condition into account in the evaluation of mean stress, the equation specified in Ch 8, Sec 4, [3.3.3] is to be modified as below:

$$\sigma_{LS,(k)} = \frac{K_{gl} K_s \left\{ p_{S,(k)} + \dfrac{p_{CW,i1(k)} + p_{CW,i2(k)}}{2} \right\} s\ell^2 \left( 1 - \dfrac{6x_f}{\ell} + \dfrac{6x_f{}^2}{\ell^2} \right)}{12w} \cdot 10^3$$

If fluctuating pressure is linear, $p_{S,(k)} + \dfrac{p_{CW,i1(k)} + p_{CW,i2(k)}}{2} = p_{S,(k)}$ , then, above equation would be same as the current equation.

# Annex 2: Technical background of stress concentration factors for the stiffeners end connection

SCFs(Stress Concentration Factors) in Table 1 of Ch 8, Sec 4, CSR for Bulker are the ratio of the hot spot stress obtained by the very fine FE analysis to the nominal stress calculated by the simple formulae.

### 1. FE analysis

Considering difference of the stiffener end connection detail, following 2 kinds of hot spot stress are calculated for each detail Nos.1-14.

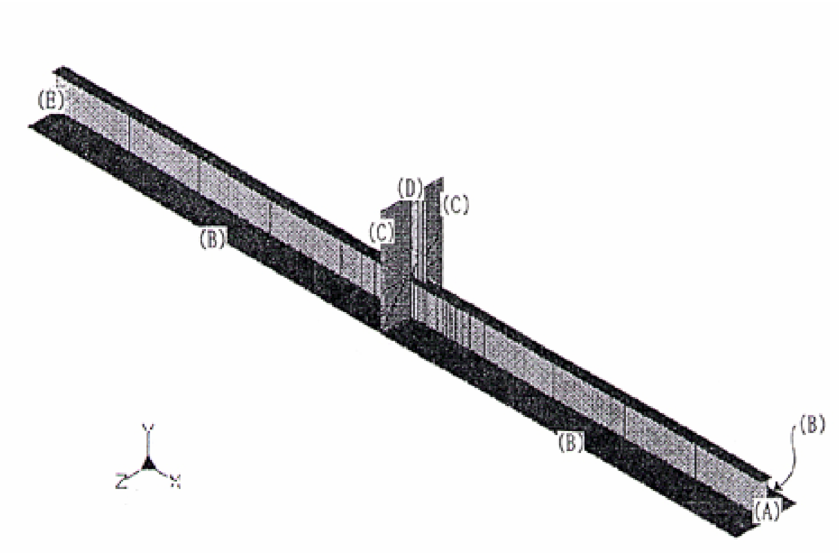
$\sigma_{gl\_hotspot}$ : hot spot stress due to out-of-plane load

$\sigma_{dF\_hotspot}$, $\sigma_{dA\_hotspot}$ : hot spot stress due to forced displacement

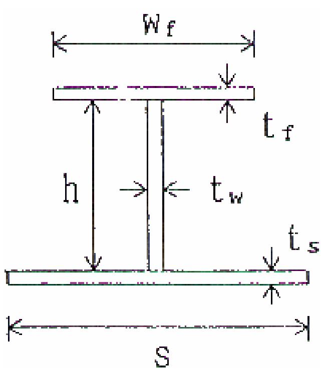
### 1.1 Analysis model

The T type longitudinal stiffener with shell penetrating Transverse Bulkhead is considered. According to each detail number in Table 1 of Ch 8, Sec 4, CSR for Bulker, the hot spot stresses (position ‘a’ and position ‘f’) at stiffener end connection are calculated.

Fig. 2-1 shows the analysis model and the size of stiffener. Fig. 2-2 shows the stiffener end connection of each detail No.




**(a) Analysis model**




**Stiffener Size (mm)**

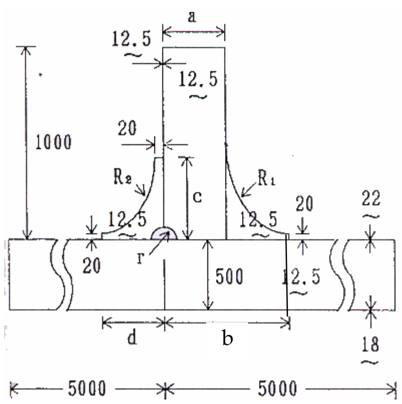
| h | tw | wf | Tf | S | ts |
|---|---|---|---|---|---|
| 500 | 12.5 | 150 | 22 | 850 | 18 |

Moment of inertia I= 99,482 (cm$^4$)
Section modulus Z= 2,507 (cm$^3$)
Span length l0= 5,000 (mm)

**(b)**

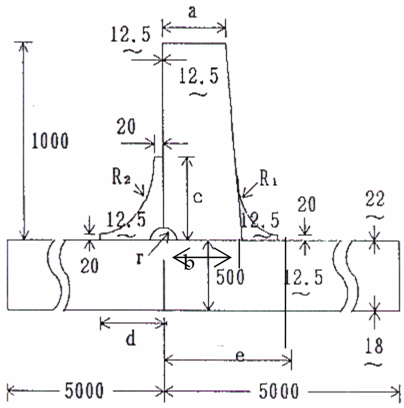
**Stiffener shape and size**

**Fig. 2-1 Analysis model and Stiffener details**




**Flat Bar Part**

| detail no | a/b | b/h | R1/b | c/d | d/h | R2/d | r (mm) |
|---|---|---|---|---|---|---|---|
| 1 | 1.0 | 0.4 | | | | | 30 |
| 3 | 0.4 | 1.0 | 0.7 | | | | 50 |
| 4 | 1.0 | 0.4 | | 1.0 | 0.7 | | 50 |
| 5 | 1.0 | 0.4 | | 1.0 | 0.7 | 1.3 | 50 |
| 6 | 0.36 | 1.1 | | 1.0 | 0.7 | | 50 |
| 7 | 0.4 | 1.0 | 0.7 | 1.0 | 0.7 | | 50 |
| 8 | 0.4 | 1.0 | 0.7 | 1.0 | 0.7 | 1.3 | 50 |




**Tripping Bracket Part**

| detail no | a/b | b/h | e/b | R1/b | c/d | d/h | R2/d | r(mm) |
|---|---|---|---|---|---|---|---|---|
| 9 | 0.29 | 1.4 | | | | | | 50 |
| 10 | 0.33 | 1.2 | 1.5 | 0.75 | | | | 50 |
| 11 | 0.29 | 1.4 | | | 1.0 | 1.0 | | 50 |
| 12 | 0.33 | 1.2 | 1.5 | 0.75 | 1.0 | 1.0 | | 50 |
| 13 | 0.29 | 1.4 | | | 1.0 | 0.9 | 1.22 | 50 |
| 14 | 0.33 | 1.2 | 1.5 | 0.75 | 1.0 | 0.9 | 1.22 | 50 |

**Fig. 2-2 Stiffener end connection of each detail number**

**1.2 Loads**

a) Out-of-plane loading

A certain out-of-plane uniformly distributing load is loaded, which makes the nominal stress of stiffener end connection 200N/mm$^2$ in tension side at $l_0$=5m, $x_f$=0. Fig. 2-3 shows the loading condition of a).

Considering the bracket size (shown in Fig. 2-2), the hot spot stress of stiffener end connection, $\sigma_{gl\_hotspot}$, is analyzed for each detail No.

b) Forced displacement

Forced displacement (23.7mm) is added to the position (A) or (E) in Fig. 2-1, which makes also the nominal stress of stiffener end connection 200N/mm$^2$ in tension side at $l_0$=5m, $x_f$=0.

Considering the bracket size, the hot spot stresses of stiffener end connection, $\sigma_{dF\_hotspot}$, $\sigma_{dA\_hotspot}$, are analyzed for each detail No (shown in Fig. 2-2).

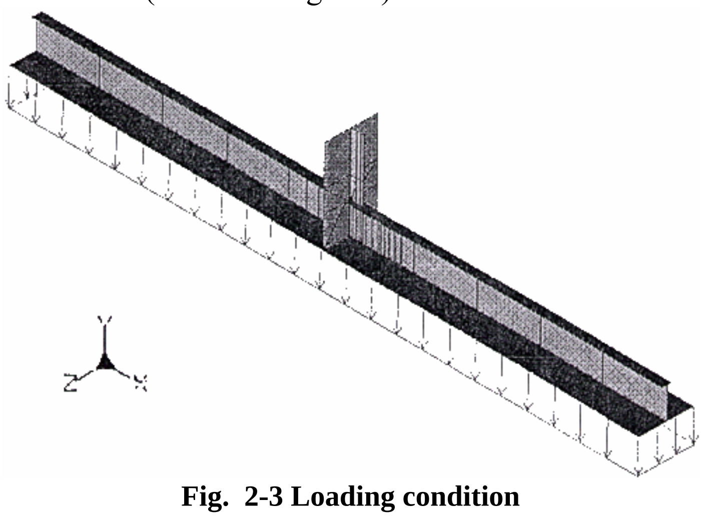



**Fig. 2-3 Loading condition**

### 1.3 Boundary condition

The boundary conditions at each position in each analysis load condition are shown in Table 2-1. In this Table, (a) means out-of-plane loading, and the others mean forced displacement. The position (A) to (E) is shown in Fig. 2-1.

**Table 2-1 Boundary condition**

| Load condition | Position (A) | (B) | (C) | (D) | (E) |
|---|---|---|---|---|---|
| (a) | Complete restraint | Symmetry | Complete restraint | Y: Rotation restraint | Complete restraint |
| (b1) | Y: Forced displacement | Symmetry | Complete restraint | Y: Rotation restraint | Complete restraint |
| (b2) | Complete restraint | Symmetry | Complete restraint | Y: Rotation restraint | Y: Forced displacement |

### 2. Simple beam formulae

The beam model shown in Fig. 2-1 and Fig. 2-2 is considered as well as FE analysis, whose nominal stress of the stiffener end connection is set 200N/mm$^2$ in tension side at $l_0$=5m, $x_f$=0 by out-of-plane load or forced displacement. Considering the effect of modified span length ($l_f$) and change of hot spot position by $x_f$ specified in Ch 8, Sec 4, CSR for Bulker, following 2 kinds of modified nominal stress are calculated for each detail No.1-14.

$\sigma_{gl\_nominal}$ : modified nominal stress due to out-of-plane load

$\sigma_{dF\_nominal}$, $\sigma_{dA\_nominal}$ : modified nominal stress due to forced displacement

a) Out-of-plane loading

Considering the bracket size (shown in Fig. 2-2), the modified nominal stress, $\sigma_{gl\_nominal}$, for each detail No is calculated according to the following equation.

$$\sigma_{gl-nominal} = \sigma_0 \left(\frac{l_f}{l_0}\right)^2 \left(1 - \frac{6x_f}{l_0} + \frac{6{x_f}^2}{{l_0}^2}\right) \quad (\sigma_0 = 200N/mm^2, l_0 = 5.0m)$$

b) Forced displacement

Considering the bracket size (shown in Fig. 2-2), the modified nominal stresses, $\sigma_{dF\_nominal}$, $\sigma_{dA\_nominal}$, are calculated according to the following equations. The value of relative displacement ($\delta F$, $\delta A$) is 23.7mm.

$$\sigma_{dF-a\_nominal} = \frac{1.95\delta_F EI}{w{l_f}^2}\left(1 - 1.15\frac{|x_{fA}|}{l_f}\right)10^{-5}$$

$$\sigma_{dA-a\_nominal} = \frac{1.95\delta_A EI}{w{l_f}^2}\left(1 - 1.15\frac{|x_{fA}|}{l_f}\right)10^{-5} - \frac{0.9\delta_A EI|x_{fA}|}{w{l_f}^3}10^{-5}$$

$$\sigma_{dF-a\_nominal} = \frac{1.95\delta_F EI}{w{l_f}^2}\left(1 - 1.15\frac{|x_{fF}|}{l_f}\right)10^{-5} - \frac{0.9\delta_F EI|x_{fA}|}{w{l_f}^3}10^{-5}$$

$$\sigma_{dA-f\_nominal} = \frac{1.95\delta_A EI}{w{l_f}^2}\left(1 - 1.15\frac{|x_{fF}|}{l_f}\right)10^{-5}$$

Usually, the dimension and the length of the stiffener fitted at fore of transverse bulkhead is the same of those fitted at after of transverse bulkhead, but there are some cases where they are different between fore part and after part. Then, taking into account the cases of $l_f \neq l_a$ and

$I_A \neq I_F$ in order to generalize to the formula mentioned above, the equations specified in 3.3.6 of Ch 8, Sec 4, CSR for Bulker can be obtained.

**3. Results and SCF calculation**

Table 2-2 shows the hot spot stress obtained by FE analysis and the modified nominal stress calculated by simple formulae.

As the values of SCFs for web stiffener connection depend on the analytical model, boundary condition, definition of hot spot stress, etc., each classification society specifies the different SCFs. In CSR for Bulker, in order to set up the single SCFs, we decided that the SCFs for Kgl_in detail No. 1 to 8 specified in BV rule were used. (See Table 2-2) The other SCFs in detail No. 1 to 8 were obtained by multiplying the ratio (5) in Table 2 by the value calculated by FEA.
For SCFs for tripping brackets connections in detail No. 9 to 14, the averaged ratio (5) in Table 2 which is equal to 0.83 was considered.

Furthermore, the modified SCFs value obtained by multiplying the SCFs specified in Table 2 by the correction factor is modified by the following manner.
(a) Minimum value is set to 1.05
(b) All values are expressed by 0.05 unit

Finally, SCFs of each detail No. can be obtained as shown in Table 2-3 whose values are used for Table 1 of Ch 8, Sec 4, CSR for Bulker.

**Table 2-3 Stress concentration factor**

| detail No. | point | Kgl | KdF | KdA | detail No. | point | Kgl | KdF | KdA |
|---|---|---|---|---|---|---|---|---|---|
| 1 | point 'a' | 1.50 | 1.15 | 1.50 | 9 | point 'a' | 1.40 | 1.05 | 1.75 |
| | point 'f' | 1.10 | 1.55 | 1.05 | | point 'f' | 1.60 | 1.70 | 1.05 |
| 3 | point 'a' | 1.35 | 1.05 | 1.30 | 10 | point 'a' | 1.30 | 1.05 | 1.75 |
| | point 'f' | 1.05 | 1.05 | 1.05 | | point 'f' | 1.55 | 1.30 | 1.05 |
| 4 | point 'a' | 1.05 | 1.05 | 1.20 | 11 | point 'a' | 1.10 | 1.05 | 1.20 |
| | point 'f' | 1.30 | 1.30 | 1.05 | | point 'f' | 1.75 | 1.40 | 1.05 |
| 5 | point 'a' | 1.05 | 1.05 | 1.15 | 12 | point 'a' | 1.10 | 1.05 | 1.20 |
| | point 'f' | 1.30 | 1.50 | 1.05 | | point 'f' | 1.30 | 1.05 | 1.05 |
| 6 | point 'a' | 1.05 | 1.05 | 1.05 | 13 | point 'a' | 1.05 | 1.05 | 1.15 |
| | point 'f' | 1.05 | 1.10 | 1.05 | | point 'f' | 1.95 | 1.55 | 1.05 |
| 7 | point 'a' | 1.05 | 1.05 | 1.15 | 14 | point 'a' | 1.05 | 1.05 | 1.15 |
| | point 'f' | 1.05 | 1.05 | 1.05 | | point 'f' | 1.70 | 1.15 | 1.05 |
| 8 | point 'a' | 1.05 | 1.05 | 1.10 | | | | | |
| | point 'f' | 1.05 | 1.10 | 1.05 | | | | | |

**Table 2-2 Stress obtained by FE analysis or simple formulae**

| Detail No. | point | $\sigma_{gl\_hot}$ (1) | $\sigma_{gl\_nom}$ (2) | NK's SCF (3) =(1)/(2) | BV's SCF (4) | Ratio (5) (=(4)/(3)) | Modified SCF | $\sigma_{dF\_hot}$ (6) | $\sigma_{dF\_nom}$ (7) | NK's SCF (6)/(7) | Modified SCF | $\sigma_{dA\_hot}$ (8) | $\sigma_{dA\_nom}$ (9) | NK's SCF (8)/(9) | Modified SCF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | point 'a' | 297.7 | 184.3 | 1.62 | 1.5 | 0.93 | 1.50 | 205.5 | 167.1 | 1.23 | 1.14(1.23*0.93) | 270.1 | 167.1 | 1.62 | 1.50(1.62*0.93) |
| | point 'f' | 217.5 | 184.3 | 1.18 | | | 1.09(1.18*0.93) | 280.5 | 167.1 | 1.68 | 1.55(1.68*0.93) | 150.3 | 167.1 | 0.90 | 0.83(0.90*0.93) |
| 3 | point 'a' | 299.8 | 179.1 | 1.67 | 1.35 | 0.81 | 1.35 | 223.7 | 172.0 | 1.30 | 1.05(1.30*0.81) | 272.4 | 172.0 | 1.58 | 1.28(1.58*0.81) |
| | point 'f' | 122.6 | 129.0 | 0.95 | | | 0.77(0.95*0.81) | 200.5 | 158.4 | 1.27 | 1.02(1.27*0.81) | 170.8 | 162.3 | 1.05 | 0.85(1.05*0.81) |
| 4 | point 'a' | 175.6 | 136.5 | 1.29 | | | 1.03(1.29*0.80) | 200.2 | 174.6 | 1.15 | 0.92(1.15*0.80) | 253.6 | 171.7 | 1.48 | 1.12(1.40*0.80) |
| | point 'f' | 275.8 | 169.6 | 1.63 | 1.30 | 0.80 | 1.30 | 295.7 | 181.6 | 1.63 | 1.30(1.63*0.80) | 210.1 | 181.6 | 1.16 | 0.93(1.16*0.80) |
| 5 | point 'a' | 150.5 | 123.3 | 1.22 | | | 1.03(1.22*0.84) | 190.9 | 163.7 | 1.17 | 0.99(1.17*0.84) | 214.6 | 159.4 | 1.35 | 1.13(1.35*0.84) |
| | point 'f' | 271.3 | 176.7 | 1.54 | 1.30 | 0.84 | 1.30 | 311.0 | 174.3 | 1.78 | 1.51(1.78*0.84) | 210.0 | 174.3 | 1.20 | 1.01(1.20*0.84) |
| 6 | point 'a' | 184.5 | 123.9 | 1.49 | 1.10 | 0.74 | 1.10 | 226.3 | 190.0 | 1.19 | 0.88(1.19*0.74) | 268.5 | 186.8 | 1.44 | 1.07(1.44*0.74) |
| | point 'f' | 155.3 | 123.9 | 1.25 | | | 0.93(1.25*0.74) | 255.3 | 186.8 | 1.37 | 1.01(1.37*0.74) | 208.8 | 190.0 | 1.10 | 0.81(1.10*0.74) |
| 7 | point 'a' | 182.9 | 132.1 | 1.38 | 1.05 | 0.76 | 1.05 | 209.9 | 179.7 | 1.17 | 0.88(1.17*0.76) | 264.0 | 176.8 | 1.49 | 1.13(1.49*0.76) |
| | point 'f' | 129.3 | 116.7 | 1.11 | | | 0.84(1.11*0.76) | 206.8 | 171.7 | 1.20 | 0.91(1.20*0.76) | 188.1 | 176.1 | 1.07 | 0.81(1.07*0.76) |
| 8 | point 'a' | 151.0 | 119.1 | 1.27 | 1.05 | 0.83 | 1.05 | 194.7 | 168.3 | 1.16 | 0.96(1.16*0.83) | 219.8 | 163.9 | 1.34 | 1.11(1.34*0.83) |
| | point 'f' | 129.9 | 122.6 | 1.06 | | | 0.88(1.06*0.83) | 206.0 | 165.0 | 1.25 | 1.03(1.25*0.83) | 181.3 | 169.1 | 1.07 | 0.89(1.07*0.83) |
| 9 | point 'a' | 311.9 | 200.0 | 1.56 | | | 1.30(1.56*0.83) | 198.5 | 154.0 | 1.29 | 1.07(1.29*0.83) | 320.6 | 154.0 | 2.08 | 1.73(2.08*0.83) |
| | point 'f' | 106.5 | 55.5 | 1.92 | | | 1.60(1.92*0.83) | 253.5 | 119.3 | 2.12 | 1.76(2.12*0.83) | 135.4 | 129.2 | 1.05 | 0.87(1.05*0.83) |
| 10 | point 'a' | 312.2 | 200.0 | 1.56 | | | 1.29(1.56*0.83) | 193.8 | 154.0 | 1.26 | 1.05(1.26*0.83) | 323.0 | 154.0 | 2.10 | 1.74(2.10*0.83) |
| | point 'f' | 42.8 | 22.9 | 1.87 | | | 1.55(1.87*0.83) | 169.8 | 109.4 | 1.55 | 1.29(1.55*0.83) | 121.6 | 122.2 | 1.00 | 0.83(1.00*0.83) |
| 11 | point 'a' | 150.6 | 113.9 | 1.32 | | | 1.10(1.32*0.83) | 189.0 | 186.3 | 1.01 | 0.84(1.01*0.83) | 263.7 | 182.0 | 1.45 | 1.20(1.45*0.83) |
| | point 'f' | 161.3 | 77.4 | 2.08 | | | 1.73(2.08*0.83) | 282.7 | 167.7 | 1.69 | 1.40(1.69*0.83) | 182.0 | 176.1 | 1.03 | 0.85(1.03*0.83) |
| 12 | point 'a' | 152.7 | 113.9 | 1.34 | | | 1.11(1.34*0.83) | 192.2 | 186.3 | 1.03 | 0.85(1.03*0.83) | 263.2 | 182.0 | 1.45 | 1.20(1.45*0.83) |
| | point 'f' | 69.2 | 44.7 | 1.55 | | | 1.29(1.55*0.83) | 178.6 | 153.3 | 1.17 | 0.97(1.17*0.83) | 147.8 | 165.8 | 0.89 | 0.74(0.89*0.83) |
| 13 | point 'a' | 116.6 | 113.7 | 1.03 | | | 0.85(1.03*0.83) | 167.9 | 162.4 | 1.03 | 0.85(1.03*0.83) | 219.0 | 157.3 | 1.39 | 1.15(1.39*0.83) |
| | point 'f' | 159.3 | 67.5 | 2.36 | | | 1.96(2.36*0.83) | 267.8 | 142.3 | 1.88 | 1.56(1.88*0.83) | 172.4 | 151.7 | 1.14 | 0.95(1.14*0.83) |
| 14 | point 'a' | 119.0 | 113.7 | 1.05 | | | 0.87(1.05*0.83) | 172.1 | 162.4 | 1.06 | 0.88(1.06*0.83) | 219.3 | 157.3 | 1.39 | 1.15(1.39*0.83) |
| | point 'f' | 70.2 | 34.9 | 2.01 | | | 1.67(2.01*0.83) | 176.1 | 130.3 | 1.35 | 1.12(1.35*0.83) | 143.8 | 143.1 | 1.00 | 0.83(1.00*0.83) |

Note:
(1) For detail No. 2, the ratio is taken to 0.93.
(2) For detail No. 9-14, the coefficient 0.83 is the average value obtained from the ratios for detail No. 1 to 8.

# Common Structural Rules for Bulk Carriers, July 2008

# Rule Change Notice No.1-7 (Corrosion Additions)

Notes: (1) These Rule Changes enter into force on 1 July 2009.

For technical background for Rule Changes in this present document, reference is made to separate document Technical Background for Rule Change Notice No.1-7.

# CHAPTER 3 STRUCTURAL DESIGN PRINCIPLES

## Section 3 CORROSION ADDITIONS

## 1. Corrosion additions

### 1.2 Corrosion addition determination

#### 1.2.1 Corrosion additions for steel

The corrosion addition for each of the two sides of a structural member, $t_{C1}$ or $t_{C2}$, is specified in Tab 1.

The total corrosion addition $t_C$, in mm, for both sides of the structural member is obtained by the following formula:

$$t_C = Roundup_{0.5}(t_{C1} + t_{C2}) + t_{reserve}$$

For an internal member within a given compartment, the total corrosion addition $t_C$ is obtained from the following formula:

$$t_C = Roundup_{0.5}(2t_{C1}) + t_{reserve}$$

where $t_{C1}$ is the value specified in Tab 1 for one side exposure to that compartment.

When a structural member is affected by more than one value of corrosion addition (e.g. a plate in a dry bulk cargo hold extending above the lower zone), the scantling criteria are generally to be applied considering the severest value of corrosion addition applicable to the member.

In addition, the total corrosion addition $t_C$ is not to be taken less than 2 mm, except for web and face plate of ordinary stiffeners.

### Table 1: Corrosion addition on one side of structural members

| Compartment Type | Structural member | | Corrosion addition, $t_{C1}$ or $t_{C2}$ in mm | |
|---|---|---|---|---|
| | | | BC-A or BC-B ships with $L \geq 150$ m | Other |
| Ballast water tank (2) | Face plate of primary members | Within 3m below the top of tank (3) | 2.0 | |
| | | Elsewhere | 1.5 | |
| | Other members | Within 3 m below the top of tank (3) | 1.7 | |
| | | Elsewhere | 1.2 | |
| Dry bulk cargo hold (1) | Transverse bulkhead | Upper part (4) | 2.4 | 1.0 |
| | | Lower stool: sloping plate, vertical plate and top plate | 5.2 | 2.6 |
| | | Other parts | 3.0 | 1.5 |
| | Other members | Upper part (4) | 1.8 | 1.0 |
| | | Webs and flanges of the upper end brackets of side frames of single side bulk carriers | | |
| | | Webs and flanges of lower brackets of side frames of single side bulk carriers | 2.2 | 1.2 |
| | | Other parts | 2.0 | 1.2 |
| | Sloped plating of hopper tank, inner bottom plating | Continuous wooden ceiling | 2.0 | 1.2 |
| | | No continuous wooden ceiling | 3.7 | 2.4 |
| Exposed to atmosphere | Horizontal member and weather deck (5) | | 1.7 | |
| | Non horizontal member | | 1.0 | |
| Exposed to sea water (7) | | | 1.0 | |
| Fuel oil tanks and lubricating oil tanks (2) | | | 0.7 | |
| Fresh water tanks | | | 0.7 | |
| Void spaces (6) | Spaces not normally accessed, e.g. access only through bolted manholes openings, pipe tunnels, etc. | | 0.7 | |
| Dry spaces | Internal of deck houses, machinery spaces, stores spaces, pump rooms, steering spaces, etc. | | 0.5 | |
| Other compartments than above | | | 0.5 | |

Notes

(1) Dry bulk cargo hold includes holds, intended for the carriage of dry bulk cargoes, which may carry water ballast.

(2) The corrosion addition of a plating between water ballast and heated fuel oil tanks is to be increased by 0.7 mm.

(3) This is only applicable to ballast tanks with weather deck as the tank top .~~This is not to be applied to structural members of inner bottom and located below inner bottom.~~

(4) Upper part of the cargo holds corresponds to an area above the connection between the top side and the inner hull or side shell. If there is no top side, the upper part corresponds to the upper one third of the cargo hold height.

(5) Horizontal member means a member making an angle up to 20° as regard as a horizontal line.

(6) The corrosion addition on the outer shell plating in way of pipe tunnel is to be considered as water ballast tank.

(7) Outer side shell between normal ballast draught and scantling draught is to be increased by 0.5 mm.

# CHAPTER 9 OTHER STRUCTURES

## Section 4 SUPERSTRUCTURES AND DECKHOUSES

**Symbols**

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

$L_2$ : Rule length $L$, but to be taken not greater than 300 m

$p_D$ : Lateral pressure for decks, in kN/m$^2$, as defined in [3.2.1]

$p_{SI}$ : Lateral pressure for sides of superstructures, in kN/m$^2$, as defined in [3.2.3]

$k$ : Material factor, defined in Ch 3, Sec 1, [2.2]

$s$ : Spacing, in m, of ordinary stiffeners, measured at mid-span along the chord

$\ell$ : Span, in m, of ordinary stiffeners, measured between the supporting members, see Ch 3, Sec 6, [4.2]

~~$t_C$ : Corrosion addition, defined in Ch 3, Sec 3~~

$c$ : Coefficient taken equal to:

$c$ = 0.75 for beams, girders and transverses which are simply supported on one or both ends

$c$ = 0.55 in other cases

$m_a$ : Coefficient taken equal to:

$$m_a = 0.204\frac{s}{\ell}\left[4-\left(\frac{s}{\ell}\right)^2\right], \text{ with } \frac{s}{\ell} \le 1$$

# 4. Scantlings

## 4.1 Side plating of non-effective superstructures

### 4.1.1

The gross thickness, in mm, of the side plating of non-effective superstructures is not to be less than the greater of the following values:

~~$t = 1.21s\sqrt{kp_{SI}} + t_C$~~ $t = 1.21s\sqrt{kp_{SI}} + 1.5$

$$t = 0.8\sqrt{kL}$$

## 4.2 Deck plating of non-effective superstructures

### 4.2.1

The gross thickness, in mm, of deck plating of non-effective superstructures is not to be less than the greater of the following values:

~~$t = 1.21s\sqrt{kp_D} + t_C$~~ $t = 1.21s\sqrt{kp_D} + 1.5$

$$t = (5.5 + 0,02L)\sqrt{k}$$

where $L$ is not to be taken greater than 200 m.

**4.2.2**

Where additional superstructures are arranged on non-effective superstructures located on the freeboard deck, the gross thickness required by [4.2.1] may be reduced by 10%.

**4.2.3**

Where plated decks are protected by sheathing, the gross thickness of the deck plating according to [4.2.1] and [4.2.2] may be reduced by ~~$t_C$~~ 1.5mm. However, such deck plating is not to be less than 5 mm.

Where a sheathing other than wood is used, attention is to be paid that the sheathing does not affect the steel. The sheathing is to be effectively fitted to the deck.

## 4.5 Decks of short deckhouses

### 4.5.1 Plating

The thickness, in mm, of weather deck of short deckhouses and is not to be less than:

~~$t = 8s\sqrt{k} + t_C$~~ $$t = 8s\sqrt{k} + 1.5$$

For weather decks of short deckhouses protected by sheathing and for decks within deckhouses, the gross thickness may be reduced by ~~$t_C$~~ 1.5mm. However, such deck plating is not to be less than 5 mm.

# 5. Superstructure end bulkheads and deckhouse walls

## 5.3 Scantlings

### 5.3.2 Plate thickness

The gross thickness of the plating, in mm, is not to be less than the greater of the values obtained from the following formulae:

~~$t = 0.9\,s\sqrt{kp_A} + t_C$~~ $$t = 0.9\,s\sqrt{kp_A} + 1.5$$

$$t_{min} = \left(5.0 + \frac{L_2}{100}\right)\sqrt{k}$$ , for the lowest tier

$$t_{min} = \left(4.0 + \frac{L_2}{100}\right)\sqrt{k}$$ , for the upper tiers, without being less than 5.0 mm.

# Common Structural Rules for Bulk Carriers, July 2008

# Technical Background for Rule Change Notice No.1-7 (Corrosion Additions)

# Technical Background for Changes Regarding Corrosion Additions:

## 1. Reason for the Rule Change

### 1.1 Note (3) in Table 1 of Ch 3, Sec 3:

The corrosion additions for structural members located within 3m below the top of the tank are enhanced considering the high temperature effect where the tank top is exposed.
Moreover, in the upper part of the bilge hopper tank not connected to the topside tank, the corrosion additions of structural members in such locations are enhanced considering the possible effect due to flushing in an air and water mixture environment as specified in KC ID 206.

Hence, the note (3) of Table 1 of the Rules is provided so that the enhanced corrosion addition is applicable to the structural members in the upper part of the bilge hopper tank.

However, this effect was not evaluated by the statistical thickness measurement data.

In order to evaluate this effect, the corrosion diminutions of the structural members in the upper part and other parts of the bilge hopper tank not connected to the topside tank are re-examined using the statistical data which is used for setting up the corrosion additions specified in CSRs.

In the statistical data, 6 ships from among 108 ships have bilge hopper tanks not connected to the topside tank. The difference of thickness diminution between the structural members in the upper and lower parts of the bilge hopper tank is given in Table 1.

Table 1 Difference of thickness diminution of structural members in bilge hopper tank
.

| | Average (mm) | 95 percentile value (mm) |
|---|---|---|
| | (Upper) – (Lower) | (Upper) – (Lower) |
| A (21-years) | -0.14 | -0.9 |
| B (16-years) | -0.20 | -0.8 |
| C (8-years) | 0.10 | 0.1 |
| C (16-years) | 0.00 | 0.0 |
| D (12-years) | -0.04 | -0.4 |
| E (11-years) | -0.07 | -0.4 |
| F (9-years) | 0.00 | -0.1 |

The results in Table 1 show that the thickness diminution of structural members in the upper part of the bilge hopper tank is rather small compared to those in the lower part.
Therefore, the note (3) of Table 1 of the Rules should be revised according to this result.

### 1.2 Ch 9, Sec 4

According to the requirements in Ch 3, Sec 2, [2.1.1] and Ch 9, Sec 4, [1.2.1], the scantlings of structural members in superstructures and deckhouses are gross. However, corrosion additions based on the net scantling approach specified in Ch 3, Sec 1, [2.2] are referred in “Symbols” and required thickness formula. This was not the intention of these requirements which come from GL rules.

## 2. Summary of the Rule Change

### 2.1 Note (3) in Table 1 of Ch 3, Sec 3

The structural members located within 3m below the top of the tank where the tank top is exposed to the weather deck is applicable to the enhanced corrosion additions specified in Table 1 of the Rules.

### 2.2 Ch 9, Sec 4

In all required thickness formulae, “tc” is changed to the absolute value, i.e., 1.5mm. In addition, the word “thickness” is changed to “gross thickness” for clarification.

## 3. Impact on scantlings

### 3.1 Note (3) in Table 1 of Ch 3, Sec 3

As the corrosion additions on one side of structural members within 3m below the top of the bilge hopper tank is changed to 1.2mm from 1.7mm, thicknesses of side shell and sloping plate and scantlings of longitudinals and transverses within 3m of the bilge hopper tank are reduced accordingly.

### 3.2 Ch 9, Sec 4

The gross thicknesses in superstructures and deckhouses are reduced by 0.5mm.

# Common Structural Rules for Bulk Carriers, July 2008

# Rule Change Notice No.1-8 (Corrugated Bulkhead)

Notes: (1) These Rule Changes enter into force on 1 July 2009.

For technical background for Rule Changes in this present document, reference is made to separate document Technical Background for Rule Change Notice No.1-8.

# CHAPTER 3 STRUCTURAL DESIGN PRINCIPLES

## Section 6 STRUCTURAL ARRANGEMENT PRINCIPLES

## 6. Double bottom

### 6.4 Floors

#### 6.4.2 Floors in way of transverse bulkheads

Where transverse bulkhead is provided with lower stool, solid floors are to be fitted in line with both sides of lower stool. Where transverse bulkhead is not provided with lower stool, solid floors are to be fitted in line with both flanges of the vertically corrugated transverse bulkhead or in line of plane transverse bulkhead.

~~The net thickness and material properties of the supporting floors and pipe tunnel beams are to be not less than those required for the bulkhead plating or, when a stool is fitted, of the stool side plating.~~

## 10. Bulkhead structure

### 10.4 Corrugated bulkheads

#### 10.4.2 Construction

The main dimensions $a$, $R$, $c$, $d$, $t$, $\varphi$and $s_C$ of corrugated bulkheads are defined in Fig 28.

The bending radius is not to be less than the following values, in mm:

$R = 3.0t$

where :

$t$ : As-built thickness, in mm, of the corrugated plate.

The corrugation angle $\varphi$ shown in Fig 28 is to be not less than 55°.

~~The thickness of the lower part of corrugations is to be maintained for a distance from the inner bottom (if no lower stool is fitted) or the top of the lower stool not less than $0.15\ell_C$.~~

~~The thickness of the middle part of corrugations is to be maintained for a distance from the deck (if no upper stool is fitted) or the bottom of the upper stool not greater than $0.3\ell_C$.~~

~~The section modulus of the corrugations in the remaining upper part of the bulkhead is to be not less than 75% of that required for the middle part, corrected for different minimum yield stresses.~~

When welds in a direction parallel to the bend axis are provided in the zone of the bend, the welding procedures are to be submitted to the Society for approval.

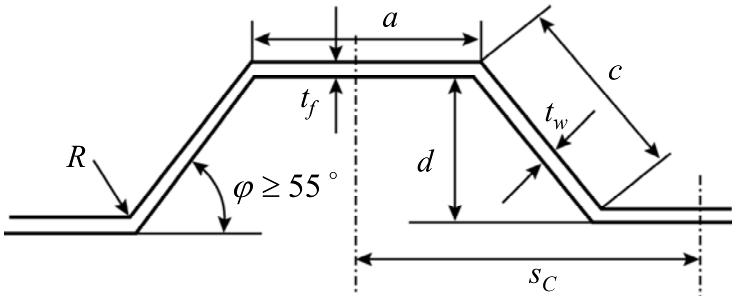



**Figure 28: Dimensions of a corrugated bulkhead**

### 10.4.5 Structural arrangements

The strength continuity of corrugated bulkheads is to be ensured at the ends of corrugations.

Where corrugated bulkheads are cut in way of primary supporting members, attention is to be paid to ensure correct alignment of corrugations on each side of the primary member.

Where vertically corrugated transverse bulkheads or longitudinal bulkheads are welded on the inner bottom plate, floors or girders are to be fitted in way of flanges of corrugations, respectively~~ and the net thickness and materials of floors and girders are to be not less than those adjacent corrugation face plate~~.

In general, the first vertical corrugation connected to the boundary structures is to have a width not smaller than typical width of corrugation flange.

~~Where stools are fitted at the lower part of transverse bulkheads, the net thickness of adjacent floors is to be not less than that of the stool plating.~~

### 10.4.6 Bulkhead stools

Plate diaphragms or web frames are to be fitted in bottom stools in way of the double bottom longitudinal girders or plate floors, as the case may be.

Brackets or deep webs are to be fitted to connect the upper stool to the deck transverse or hatch end beams, as the case may be.

~~The continuity of the corrugated bulkhead with the stool plating is to be adequately ensured. In particular, upper strake of the lower stool is to be of the same net thickness and yield stress as those of the lower strake of the bulkhead.~~

### 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.

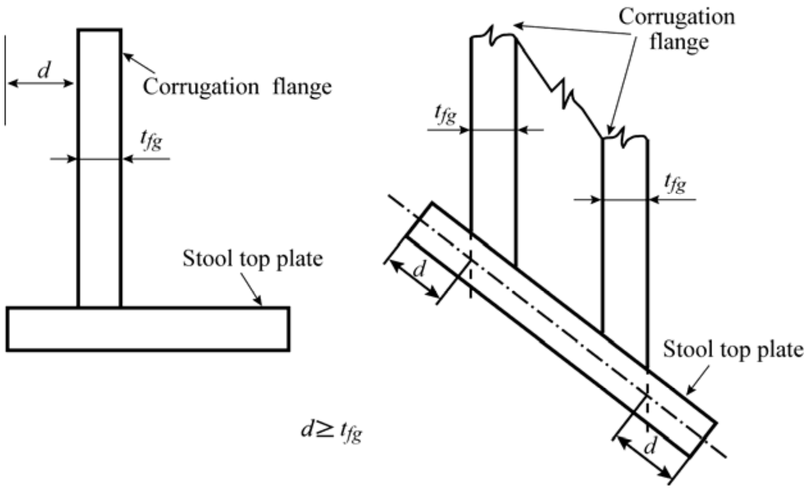



**Figure 30: Permitted distance, *d*, from the edge of the stool top plate to the surface of the corrugation flange**

### 10.4.8 Upper stool

The upper stool, when fitted, is to have a height in general between two and three times the depth of corrugations. Rectangular stools are to have a height in general equal to twice the depth of corrugations, measured from the deck level and at the hatch side girder.

The upper stool of transverse bulkhead is to be properly supported by deck girders or deep brackets between the adjacent hatch end beams.

The width of the upper stool bottom plate is generally to be the same as that of the lower stool top plate. The stool top of non-rectangular stools is to have a width not less than twice the depth of corrugations.

~~The thickness and material of the stool bottom plate are to be the same as those of the bulkhead plating below. The thickness of the lower portion of stool side plating is to be not less than 80% of that required for the upper part of the bulkhead plating where the same material is used.~~

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

The stool is to be fitted with diaphragms in line with and effectively attached to longitudinal deck girders extending to the hatch end coaming girders or transverse deck primary supporting members as the case may be, for effective support of the corrugated bulkhead.

Scallops in the brackets and diaphragms in way of the connection to the stool bottom plate are to be avoided.

### 10.4.9 Alignment

At deck, if no upper stool is fitted, two transverse or longitudinal reinforced beams as the case may be, are to be fitted in line with the corrugation flanges.

At bottom, if no lower stool is fitted, the corrugation flanges are to be in line with the supporting floors or girders.

The weld of corrugations and floors or girders to the inner bottom plating are to be full penetration ones. The thickness and material properties of the supporting floors or girders are to be not less than those of the corrugation flanges. Moreover,

Tthe cut-outs for connections of the inner bottom longitudinals to double bottom floors are to be closed by collar plates. The supporting floors or girders are to be connected to each other by suitably designed shear plates.

Stool side plating is to be aligned with the corrugation flanges. Lower stool side vertical stiffeners and their brackets in the stool are to be aligned with the inner bottom structures as longitudinals or similar, to provide appropriate load transmission between these stiffening members.

Lower stool side plating is not to be knuckled anywhere between the inner bottom plating and the stool top plate.

### 10.4.13 Section modulus at the lower end of corrugations

(void)

a) The section modulus at the lower end of corrugations (Fig 31 to Fig 35) is to be calculated with the compression flange having an effective flange width $b_{ef}$ not larger than that indicated in [10.4.10].

b) Webs not supported by local brackets

Except in case c), if the corrugation webs are not supported by local brackets below the stool top plate (or below the inner bottom) in the lower part, the section modulus of the corrugations is to be calculated considering the corrugation webs 30% effective.

c) Effective shedder plates

Provided that effective shedder plates, as defined in [10.4.11], are fitted (see Figs 31 and 32), when calculating the section modulus of corrugations at the lower end (cross sections 1 in Figs 31 and 32), the area of flange plates may be increased by the value obtained, in $cm^2$, from the following formula:

$$I_{SH} = 2.5a\sqrt{t_f t_{SH}}$$

without being taken greater than $2.5at_f$,

where:

$a$ : Width, in m, of the corrugation flange (see Fig 28)

$t_{SH}$ : Net shedder plate thickness, in mm

$t_f$ : Net flange thickness, in mm.

d) Effective gusset plates

Provided that effective gusset plates, as defined in [10.4.12], are fitted (see Figs 33 to 35), when calculating the section modulus of corrugations at the lower end (cross-sections 1 in Figs 33 to 35), the area of flange plates may be increased by the value obtained, in $cm^2$, from the following formula:

$$I_G = 7h_G t_f$$

where:

$h_G$ : Height, in m, of gusset plates (see Figs 33 to 35), to be taken not greater than $(10/7)S_{GU}$

$S_{GU}$ : Width, in m, of gusset plates

$t_f$ : Net flange thickness, in mm

e) Sloping stool top plate

If the corrugation webs are welded to a sloping stool top plate which has an angle not less than 45° with the horizontal plane, the section modulus of the corrugations may be calculated considering the corrugation webs fully effective. For angles less than 45°, the effectiveness of the web may be obtained by linear interpolation between 30% for 0° and 100% for 45°.

Where effective gusset plates are fitted, when calculating the section modulus of corrugations the area of flange plates may be increased as specified in d) above. No credit may be given to shedder plates only.

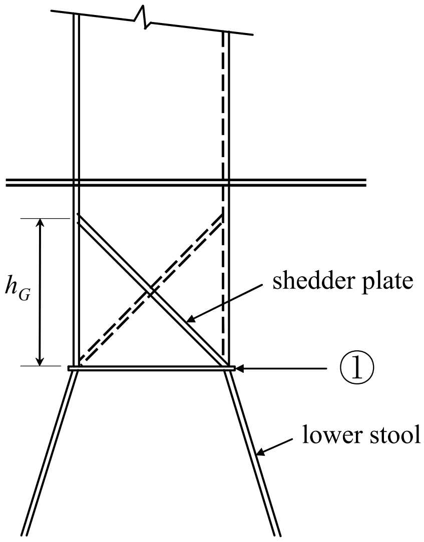



**Figure 31: Symmetrical shedder plates (void)**

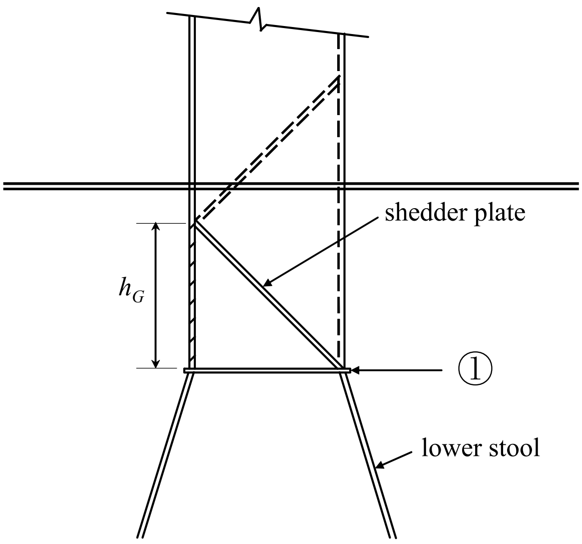



**Figure 32: Asymmetrical shedder plates (void)**

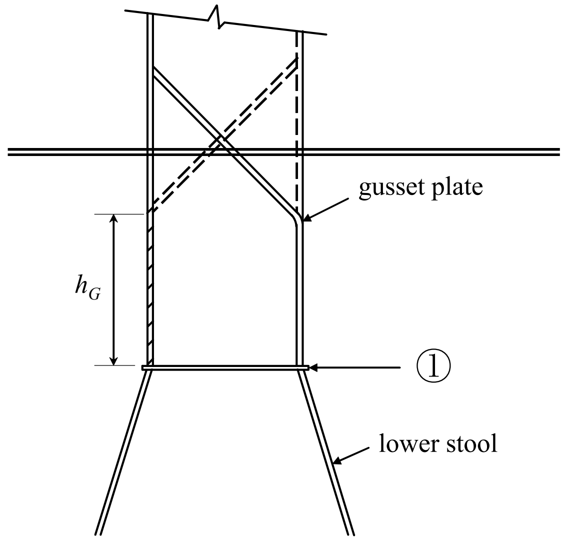



**Figure 33: ~~Symmetrical gusset/shedder plates~~ (void)**

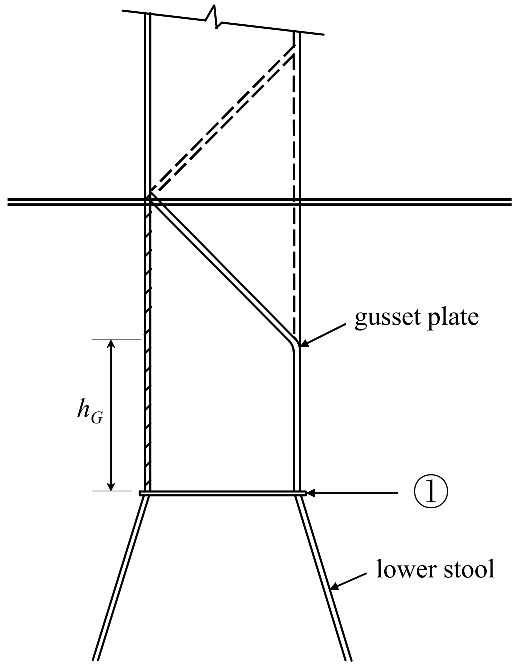



**Figure 34: ~~Asymmetrical gusset/shedder plates~~ (void)**

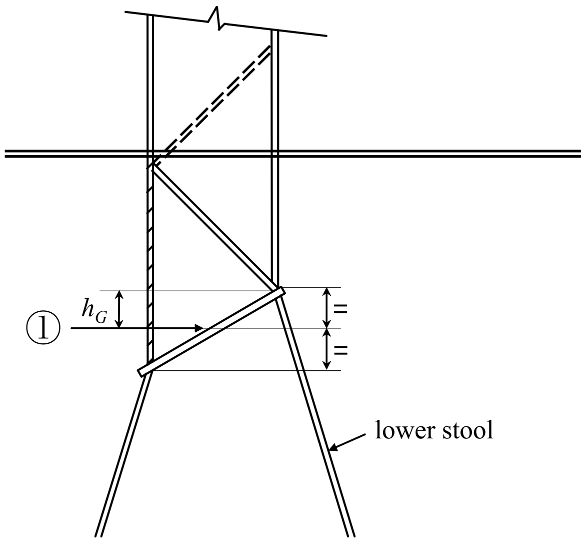



**Figure 35: ~~Asymmetrical gusset/shedder plates~~ (void)**

### 10.4.14 ~~Section modulus at sections other than the lower end of corrugations~~

(void)

~~The section modulus is to be calculated with the corrugation webs considered effective and the compression flange having an effective flange width, *bef*, not larger than that obtained in [10.4.10].~~

### 10.4.15 ~~Shear area~~

(void)

~~The shear area is to be reduced in order to account for possible non-perpendicularity between the corrugation webs and flanges. In general, the reduced shear area may be obtained by multiplying the web sectional area by (sin φ), φ being the angle between the web and the flange (see Fig 28).~~

# CHAPTER 6 HULL SCANTLING

## Section 1 PLATING

## 3. Strength check of plating subjected to lateral pressure

### 3.2 Plating thickness

#### 3.2.3 Net thickness of ~~the~~ corrugation~~s~~ of transverse vertically corrugated watertight bulkheads separating cargo holds for flooded conditions

The net plate thickness $t$, in mm, of transverse vertically corrugated watertight bulkheads separating cargo holds is to be not less than that obtained from the following formula:

$$t = 14.9 s \sqrt{\frac{1.05 p}{R_{eH}}}$$

$p$ : Resultant pressure, in kN/m$^2$, as defined in Ch 4, Sec 6, [3.3.7]

$s$ : plate width, in m, to be taken equal to the width of the corrugation flange or web, whichever is greater.

For built-up corrugation bulkheads, when the thicknesses of the flange and web are different:

- the net thickness of the narrower plating is to be not less than that obtained, in mm, from the following formula:

$$t_N = 14.9 s \sqrt{\frac{1.05 p}{R_{eH}}}$$

s : plate width, in m, of the narrower plating

- the net thickness of the wider plating is not to be less than the greater of those obtained, in mm, from the following formulae:

$$t_W = 14.9 s \sqrt{\frac{1.05 p}{R_{eH}}}$$

$$t_W = \sqrt{\frac{462 s^2 p}{R_{eH}} - t_{NP}^2}$$

where:

$t_{NP}$ : Actual net thickness of the narrower plating, in mm, to be not taken greater than:

$$t_{NP} = 14.9 s \sqrt{\frac{1.05 p}{R_{eH}}}$$

$s$ : plate width, in m, to be taken equal to the width of the corrugation flange or web, whichever is greater.

The net thickness of the lower part of corrugations is to be maintained for a distance from the inner bottom (if no lower stool is fitted) or the top of the lower stool not less than $0.15\ell_C$, where $\ell_C$ is the span of the corrugations, in m, to be obtained according to Ch 3, Sec 6, [10.4.4]. The net thickness is also to comply with the requirements in [3.2.1], Sec 2, [3.6.1 & 3.6.2], and Sec 3, [6].

The net thickness of the middle part of corrugations is to be maintained for a distance from the deck (if no upper stool is fitted) or the bottom of the upper stool not greater than $0.3\ell_C$. The net thickness is also to comply with the requirements in [3.2.1] and Sec 2, [3.6.1& 3.6.2].

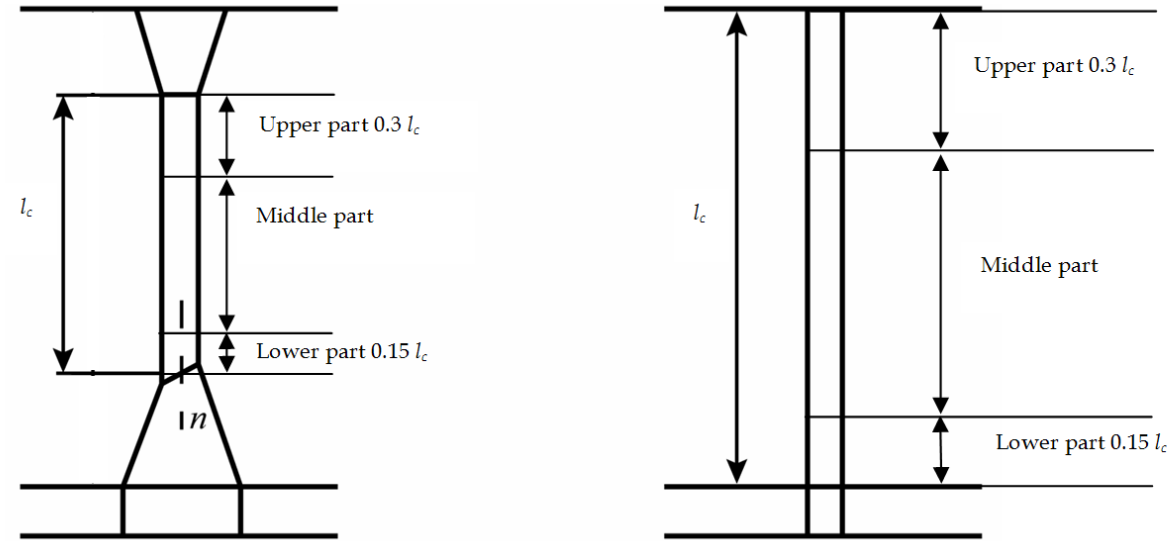



**Figure 5: Parts of Corrugation**

### 3.2.3 bis1 Net thickness of lower stool and upper stool

The net thickness and material of the stool top plate of lower stool are to be not less than those for the corrugated bulkhead plating above required by [3.2.3].

The net thickness and material of the upper portion of vertical or sloping stool side plating of lower stool within the depth equal to the corrugation flange width from the stool top are to be not less than the flange plate at the lower end of the corrugation required by [3.2.3], as applicable, whichever is the greater.

The net thickness and material of the stool bottom plate of upper stool are to be the same as those of the bulkhead plating below required by [3.2.3], as applicable, whichever is the greater.

The net thickness of the lower portion of stool side plating is to be not less than 80% of the upper part of the bulkhead plating required by [3.2.3], as applicable, whichever is the greater, where the same material is used.

The net thicknesses of lower stool and upper stool are to be not less than those required by [3.2.1], [3.2.2] and [3.2.4].

### 3.2.3 bis2 Net thickness of supporting floors of corrugated bulkhead

The net thickness and material of the supporting floors and pipe tunnel beams of corrugated bulkhead, when no stool is fitted, are to be not less than those of the corrugation flanges required by [3.2.3]

When a lower stool is fitted, the net thickness of supporting floors are to be not less than that of the stool side plating required by the first sentence of [3.2.2].

### 3.2.4 Testing conditions

The plating of compartments or structures as defined in Ch 4, Sec 6, [4] is to be checked in testing conditions. To this end, its net thickness is to be not less than the value obtained, in mm, from the following formula:

$$t = 15.8 c_a c_r s \sqrt{\frac{p_T}{1.05 R_Y}}$$

# Section 2 ORDINARY STIFFENERS

## 2. General requirements

### 2.1 ~~Corrugated bulkhead~~ (void)

**~~2.1.1~~**

(void)

~~Unless otherwise specified, the net section modulus and the net shear sectional area of a corrugation are to be not less than those obtained for an ordinary stiffener with $s$ equal $s_C$, as defined in Fig 2.~~

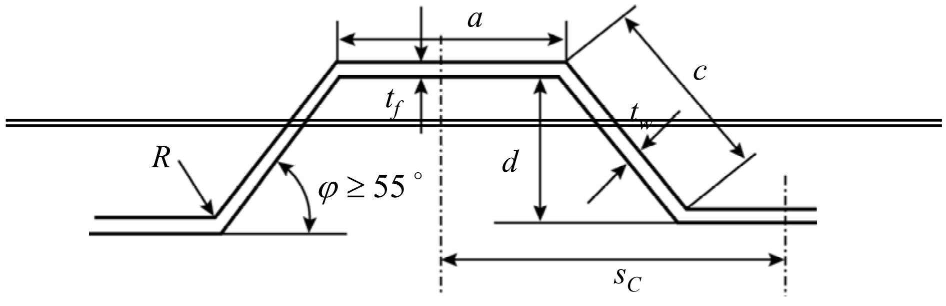



**Figure 2: ~~Corrugated bulkhead~~ (void)**

## 3. Yielding check

### 3.2 Strength criteria for single span ordinary stiffeners other than side frames of single side bulk carriers

#### 3.2.4 Net section modulus of corrugated bulkhead of ballast hold for ships having a length *L* less than 150m

The net section modulus $w$, in $cm^3$, of corrugated bulkhead of ballast hold for ships having a length $L$ less than 150m subjected to lateral pressure are to be not less than the values obtained from the following formula:

$$w = K \frac{(p_S + p_W) s_C \ell^2}{m \lambda_S R_Y} 10^3$$

where:

$K$ : Coefficient given in Tab 4 and 5, according to the type of end connection. When $d_H < 2.5 d_0$ , both section modulus per half pitch of corrugated bulkhead and section modulus of lower stool at inner bottom are to be calculated.

$s_C$ : Half pitch length, in m, of the corrugation, defined in ~~[2.1.1]~~ Ch 3, Sec 6, Fig 28

$\ell$ : Length, in m, between the supports, as indicated in Fig 6

$\lambda_S$ : Coefficient defined in Tab 3.

The effective width of the corrugation flange in compression is to be considered according to Ch3, Sec 6, [10.4.10] when the net section modulus of corrugated bulkhead is calculated.

**Table 4: Values of *K*, in case $d_H \geq 2.5 d_0$**

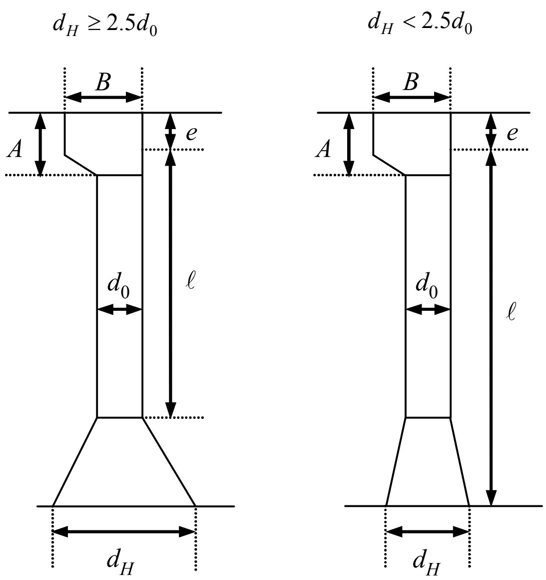
| ~~Lower end~~ | ~~Upper end~~ | | |
|---|---|---|---|
| | ~~Supported by girders~~ | ~~Welded directly to deck~~ | ~~Welded to stool efficiently supported by ship structure~~ |
| ~~Supported by girders or welded directly to decks or inner bottoms~~ | ~~0.83~~ | ~~1.25~~ | ~~1.25~~ |
| ~~Welded to stool efficiently supported by ship structure~~ | ~~1.25~~ | ~~1.00~~ | ~~0.83~~ |

| Upper end support | | |
|---|---|---|
| Supported by girders | Welded directly to deck | Welded to stool efficiently supported by ship structure |
| 1.25 | 1.00 | 0.83 |

**Table 5: Values of *K*, in case $d_H < 2.5 d_0$**

| ~~Upper end support~~ | ~~Supported by girders~~ | ~~Connected to deck~~ | ~~Connected to stool~~ |
|---|---|---|---|
| ~~Section modulus of corrugated bulkhead~~ | ~~0.83~~ | ~~0.71~~ | ~~0.65~~ |
| ~~Section modulus of stool at bottom~~ | ~~0.83~~ | ~~1.25~~ | ~~1.13~~ |

| Section modulus of | Upper end support | | |
|---|---|---|---|
| | Supported by girders | Connected to Deck | Connected to stool |
| Corrugated bulkhead | 0.83 | 0.71 | 0.65 |
| Stool at bottom | 0.83 | 1.25 | 1.13 |




$$e = A(1 - d_0 / 2B)$$

**Figure 6: Measurement of ℓ**

### 3.2.6 ~~Bending capacity and shear capacity of the corrugations of transverse vertically corrugated watertight bulkheads separating cargo holds for flooded conditions~~ (void)

~~The bending capacity and the shear capacity of the corrugations of watertight bulkheads between separating cargo holds are to comply with the following formulae:~~

$$0.5W_{LE} + W_M \geq \frac{M}{0.95R_{eH}}10^3$$

$$\tau \leq \frac{R_{eH}}{2}$$

~~where:~~

~~$M$ : Bending moment in a corrugation, to be obtained, in kN.m, from the following formula:~~

$M = F\ell_C / 8$

~~$F$ : Resultant force, in kN, to be calculated according to Ch 4, Sec 6, [3.3.7]~~

~~$\ell_C$ : Span of the corrugations, in m, to be obtained according to Ch 3, Sec 6, [10.4.4]~~

~~$W_{LE}$ : Net section modulus, in cm$^3$, of one half pitch corrugation, to be calculated at the lower end of the corrugations according to Ch 3, Sec 6, [10.4.13], without being taken greater than the value obtained from the following formula:~~

$$W_{LE,M} = W_G + \left(\frac{Q\,h_G - 0.5h_G^2\,s_C\,p_G}{R_{eH}}\right)10^3$$

~~$W_G$ : Net section modulus, in cm3, of one half pitch corrugation, to be calculated in way of the upper end of shedder or gusset plates, as applicable, according to Ch 3, Sec 6, [10.4.1413]~~

~~$Q$ : Shear force in a corrugation, to be obtained, in kN, from the following formula:~~

$Q = 0.8F$

~~$h_G$ : Height, in m, of shedders or gusset plates, as applicable (see Ch 3, Sec 6, Fig 31 to Fig 35)~~

~~$p_G$ : Resultant pressure, in kN/m2, to be calculated in way of the middle of the shedders or gusset plates, as applicable, according to Ch 4, Sec 6, [3.3.7]~~

~~$s_C$ : Spacing of the corrugations, in m, to be taken according to Fig 2~~

~~$W_M$ : Net section modulus, in cm$^3$, of one half pitch corrugation, to be calculated at the mid-span of corrugations according to Ch 3, Sec 6, [10.4.14], without being taken greater than 1.15$W_{LE}$~~

~~$\tau$ : Shear stress in the corrugation, in N/mm2, to be obtained from the following formula:~~

$$\tau = 10\frac{Q}{A_{sh}}$$

~~$Ash$ : Shear area, in cm$^2$, calculated according to Ch 3, Sec 6, [10.4.15].~~

### 3.2.7 Net section modulus and net shear sectional area of single span ordinary stiffeners under testing conditions

The net section modulus $w$, in cm$^3$, and the net shear sectional area $A_{sh}$, in cm$^2$, of single span ordinary stiffeners subjected to testing are to be not less than the values obtained from the following formulae:

$$w = \frac{p_T s \ell^2}{1.05 m R_Y}10^3$$

$$A_{sh} = \frac{5 p_T s \ell}{1.05\tau_a \sin\phi}$$

where:

φ : Angle, in deg, defined in [3.2.3].

## 3.6 Scantlings of transverse vertically corrugated watertight bulkheads separating cargo holds for flooded conditions

### 3.6.1 Bending capacity and shear capacity of the corrugations of transverse vertically corrugated watertight bulkheads separating cargo holds

The bending capacity and the shear capacity of the corrugations of watertight bulkheads between separating cargo holds are to comply with the following formulae:

$$0.5W_{LE} + W_M \geq \frac{M}{0.95R_{eH}} 10^3$$

$$\tau \leq \frac{R_{eH}}{2}$$

where:

$M$ : Bending moment in a corrugation, to be obtained, in kN.m, from the following formula:

$$M = F\ell_C / 8$$

$F$ : Resultant force, in kN, to be calculated according to Ch 4, Sec 6, [3.3.7]

$\ell_C$ : Span of the corrugations, in m, to be obtained according to [3.6.2]

$W_{LE}$ : Net section modulus, in cm$^3$, of one half pitch corrugation, to be calculated at the lower end of the corrugations according to [3.6.2], without being taken greater than the value obtained from the following formula:

$$W_{LE,M} = W_G + \left( \frac{Q\,h_G - 0.5h_G^2\,s_C\,p_G}{R_{eH}} \right) 10^3$$

$W_G$ : Net section modulus, in cm$^3$, of one half pitch corrugation, to be calculated in way of the upper end of shedder or gusset plates, as applicable, according to [3.6.2]

$Q$ : Shear force at the lower end of a corrugation, to be obtained, in kN, from the following formula:

$$Q = 0.8F$$

$h_G$ : Height, in m, of shedders or gusset plates, as applicable (see Fig 11 to Fig 15)

$p_G$ : Resultant pressure, in kN/m$^2$, to be calculated in way of the middle of the shedders or gusset plates, as applicable, according to Ch 4, Sec 6, [3.3.7]

$s_C$ : Spacing of the corrugations, in m, to be taken according to Ch 3, Sec 6, Fig 28

$W_M$ : Net section modulus, in cm$^3$, of one half pitch corrugation, to be calculated at the mid-span of corrugations according to [3.6.2] without being taken greater than $1.15W_{LE}$

τ : Shear stress in the corrugation, in N/mm$^2$, to be obtained from the following formula:

$$\tau = 10\frac{Q}{A_{sh}}$$

$A_{sh}$ : Shear area, in cm$^2$, calculated according to the followings.

The shear area is to be reduced in order to account for possible non-perpendicular between the corrugation webs and flanges. In general, the reduced shear area may be obtained by multiplying the web sectional area by (sin φ), φ being the angle between the web and the flange (see Ch 3, Sec 6, Fig 28).

The actual net section modulus of corrugations is to be calculated according to [3.6.2].

The net section modulus of the corrugations upper part of the bulkhead, as defined in Sec 1, Fig 5, is to be not less than 75% of that of the middle part complying with this requirement and Sec 1, [3.2.1], corrected for different minimum yield stresses.

### 3.6.2 Net Section modulus at the lower end of corrugations

a) The net section modulus at the lower end of corrugations (Fig 11 to Fig 15) is to be calculated with the compression flange having an effective flange width $b_{ef}$ not larger than that indicated in Ch 3, Sec 6, [10.4.10]

b) Webs not supported by local brackets

Except in case e), if the corrugation webs are not supported by local brackets below the stool top plate (or below the inner bottom) in the lower part, the section modulus of the corrugations is to be calculated considering the corrugation webs 30% effective.

c) Effective shedder plates

Provided that effective shedder plates, as defined in Ch 3, Sec 6, [10.4.11] are fitted (see Fig 11 and Fig 12), when calculating the section modulus of corrugations at the lower end (cross sections 1 in Fig 11 and Fig 12), the net area of flange plates may be increased by the value obtained, in cm$^2$, from the following formula:

$I_{SH} = 2.5a\sqrt{t_f t_{SH}}$ without being taken greater than $2.5at_f$.

where:

$a$ : Width, in m, of the corrugation flange (see Ch 3, Sec 6, Fig 28)

$t_{SH}$ : Net shedder plate thickness, in mm

$t_f$ : Net flange thickness, in mm.

d) Effective gusset plates

Provided that effective gusset plates, as defined in Ch 3, Sec 6, [10.4.12], are fitted (see Fig 13 to Fig 15), when calculating the net section modulus of corrugations at the lower end (cross-sections 1 in Fig 13 to Fig 15), the area of flange plates may be increased by the value obtained, in cm$^2$, from the following formula:

$I_G = 7h_G t_f$

where:

$h_G$ : Height, in m, of gusset plates (see Fig 13 to Fig 15), to be taken not greater than $(10/7)S_{GU}$

$S_{GU}$ : Width, in m, of gusset plates

$t_f$ : Net flange thickness, in mm

e) Sloping stool top plate

If the corrugation webs are welded to a sloping stool top plate which has an angle not less than 45° with the horizontal plane, the section modulus of the corrugations may be calculated considering the corrugation webs fully effective. For angles less than 45°, the effectiveness of the web may be obtained by linear interpolation between 30% for 0° and 100% for 45°.

Where effective gusset plates are fitted, when calculating the net section modulus of corrugations the net area of flange plates may be increased as specified in d) above. No credit may be given to shedder plates only.

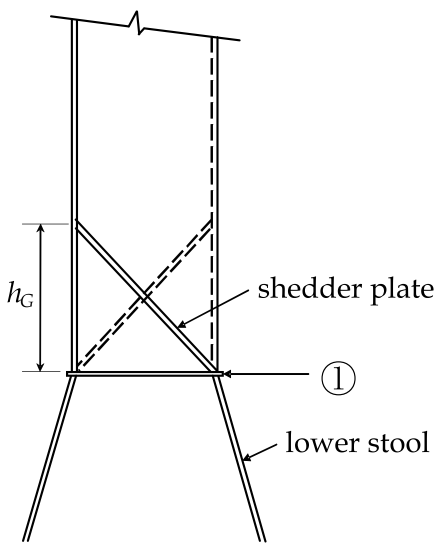



**Figure 11: Symmetrical shedder plates**

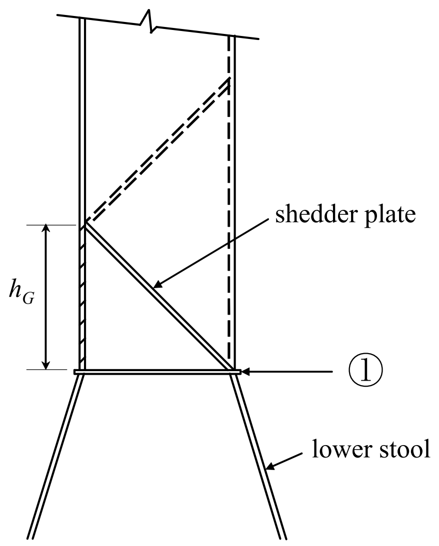



**Figure 12: Asymmetrical shedder plates**

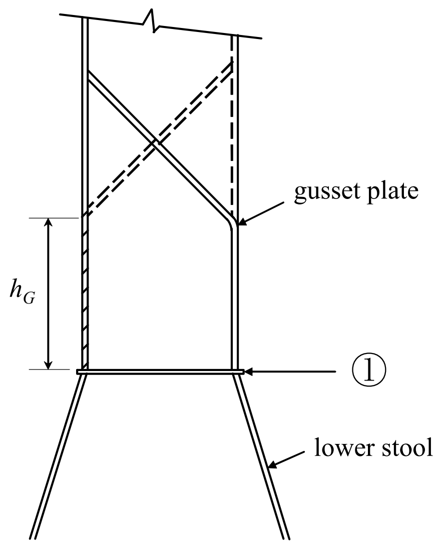



**Figure 13: Symmetrical gusset/shedder plates**

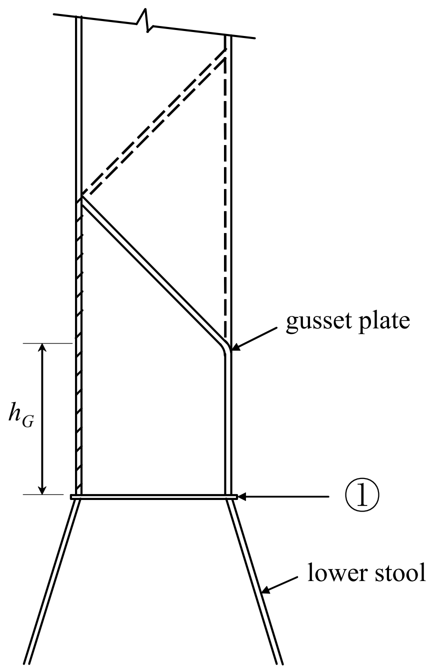



**Figure 14: Asymmetrical gusset/shedder plates**

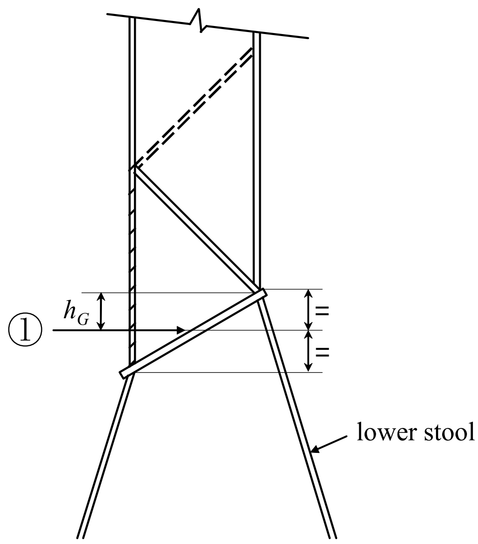



**Figure 15: Asymmetrical gusset/shedder plates**

### 3.6.3 Stiffeners in lower stool and upper stool

The net section modulus of stiffeners in lower stool and upper stool is to be greater of the values obtained from the following formula or required by [3.2.5].

$$w = \frac{ps\ell^2}{16\alpha\lambda_s R_Y} 10^3$$

Where,

$p$ : Pressure, in kN/m$^2$, as defined in Ch 4 Sec 6, [3.3.7]

$\alpha$ and $\lambda_s$ : defined in [3.2.5]

# Section 3 BUCKLING & ULTIMATE STRENGTH OF ORDINARY STIFFENERS AND STIFFENED PANELS

## 6. Transverse vertically corrugated watertight bulkhead in flooded condition

### 6.1 General

#### 6.1.1 Shear buckling check of the bulkhead corrugation webs

The shear stress $\tau$, calculated according to Ch 6, Sec 2, [3.6.1 ~~3.2.6~~], is to comply with the following formula:

$\tau \le \tau_C$

where:

$\tau_C$ : Critical shear buckling stress to be obtained, in N/mm$^2$, from the following formulae:

$$\tau_C = \tau_E \qquad \text{for } \tau_E \le \frac{R_{eH}}{2\sqrt{3}}$$

$$\tau_C = \frac{R_{eH}}{\sqrt{3}}\left(1 - \frac{R_{eH}}{4\sqrt{3}\,\tau_E}\right) \qquad \text{for } \tau_E > \frac{R_{eH}}{2\sqrt{3}}$$

$\tau_E$ : Euler shear buckling stress to be obtained, in N/mm$^2$, from the following formula:

$$\tau_E = 0.9 k_t E\left(\frac{t_w}{10^3 c}\right)^2$$

$k_t$ : Coefficient, to be taken equal to 6.34

$t_W$ : Net thickness, in mm, of the corrugation webs

$c$ : Width, in m of the corrugation webs (see Ch 3, Sec 6, Fig 28 ~~Ch 6, Sec 2, Fig 2~~).

# Common Structural Rules for Bulk Carriers, July 2008

# Technical Background for Rule Change Notice No.1-8 (Corrugated Bulkhead)

# Technical Background for the Changes regarding Corrugated Bulkhead:

## 1. Reason for the Rule Change:

There are paragraphs in Ch 3, Sec 6, [10.4] and Ch 6, Sec 1 & 2 where requirements are specified to transverse vertically corrugated watertight bulkheads separating cargo holds. However, there are obscure scantling requirements in their application.

It is due to that;

- the scantling requirements are included in both chapters which incurs confusion to the user, and
- the application of the requirements is not clearly identified especially for flooded condition although it was the original intention that IACS UR S18 requirements were to be incorporated explicitly.

The rule change is prepared in order to resolve this issue by;

- shifting the scantling requirements in Ch 3, Sec 6, [10.4] to the appropriate paragraphs in Ch 6, Sec 2, and
- collecting together the scantling requirements for flooded conditions in the new paragraph to be in line with IACS UR S18 requirements, and
- only requirements to structural arrangement being remained in Ch 3, Sec 6, [10.4], and
- clarifying the cross reference of the related paragraphs.

The answers or interpretations in KC IDs 332, 354, 450 and 580 are taken into consideration for preparation of this rule change.

In addition, the thickness requirement in Ch 3, Sec 6, [6.4.2] is shifted to Ch 6, Sec 1.

## 2. Summary of Rule Change

### 2.1 Ch 3, Sec 6, [6.4.2] and Ch 6, Sec 1, [3.2.3 bis2]

The thickness requirement in Ch 3, Sec 6, [6.4.2] is shifted to Ch 6, Sec 1, [3.2.3 bis2] with partly modification.

### 2.2 Ch 3 Sec 6, [10.4.2] "Construction" and Ch 6 Sec 1 [3.2.3]

The scantling requirements in Ch 3, Sec 6, [10.4.2] are deleted and shifted to Ch 6, Sec 1, [3.2.3]. Further in Ch 6, Sec 1, [3.2.3], taking account of the answer in KC ID 332,

- "net" scantling basis is clarified, and
- the definition of $\lambda_c$ is added,
- it is clarified that the net thickness of lowest part of corrugation is to comply with the requirements in [3.2.1], Ch 6, Sec 2, [3.6.1] & [3.6.2] and Ch 6, Sec 3, [6], and,
- it is clarified that the net thickness of middle part of corrugation is to comply with the requirements in [3.2.1], Ch 6 and Sec 2, [3.6.1 & 3.6.2]

### 2.3 Ch 3, Sec 6, [10.4.5], [10.4.6] and [10.4.7], Ch 6, Sec 1, [3.2.3 bis1] and [3.2.4]

The scantling requirements in Ch 3, Sec 6, [10.4.5], [10.4.6] and [10.4.7] are deleted and shifted to Ch 6, Sec 1, [3.2.3 bis1], and "net" scantling basis is clarified and in line with the answer in KC ID 450 the shifted rule text is modified.

Taking account of the answer in KC ID 332, it is clarified that the required corrugation flange net plate thickness is according to [3.2.3] or [3.2.4].

**2.4 Ch 3, Sec 6, [10.4.8] Upper stool and Ch 6, Sec 1, [3.2.3 bis1]**

The scantling requirements are deleted and shifted to Ch 6, Sec 1 [3.2.3 bis1] and "net" scantling basis is clarified.

Taking account of the answer in KC ID 332, it is clarified that the bulkhead plating below the upper stool bottom plating and upper part of the bulkhead plating are according to [3.2.3] or [3.2.4].

**2.5 Ch 3, Sec 6, [10.4.9] Alignment and Ch 6, Sec 1, [3.2.3 bis2]**

The scantling requirements in Ch 3, Sec 6, [10.4.9] are deleted and shifted to Ch 6, Sec 1, [3.2.3 bis2], considering the consistency with the requirement in Ch 3, Sec 6, [6.4.2] and "net" scantling basis is clarified.

**2.6 Ch 3, Sec 6, [10.4.13] Section modulus at the lower end of corrugations and Ch 6, Sec 2, [3.6.2]**

The requirement in Ch 3, Sec 6, [10.4.13] is deleted and shifted to the new paragraph Ch 6, Sec 2, [3.6.2] since it is only related to the scantling requirements for flooded condition. Further in the new paragraph figure nos. are corrected from "31 thru 35" to "11 thru 15" accordingly and the cross references in the text are modified.

**2.7 Ch 3, Sec 6, [10.4.14] Section modulus at sections other than the lower end of corrugations and Ch 3, Sec 6, [10.4.15] Shear area**

The requirement in Ch 3, Sec 6, [10.4.14] is deleted and shifted to the new paragraph Ch 6, Sec 2, [3.6.2] (a).

The requirement in Ch 3, Sec 6, [10.4.15] is deleted and shifted to the new paragraph Ch 6, Sec 2, [3.6.1].

**2.8 Ch 6, Sec 2, [2.1.1]**

Figure 2 is only applicable when section modulus of corrugated bulkhead is investigated according to Ch 6, Sec 2, [3.2.4]. Figure 2 is same as Ch 3, Sec 6, and Figure 28. In order to avoid user's misinterpretation Ch 6, Sec 2, [2.1.1] is deleted together with Figure 2.

**2.9 Ch 6, Sec 2, [3.2.4], Tables 4 and 5**

The definition of the effective width of the corrugation flange is added and Tables 4 and 5 are clarified.

**2.10 Ch 6, Sec 2, [3.2.6], Bending capacity and shear capacity of the corrugations of transverse vertically corrugated watertight bulkheads separating cargo holds for flooded conditions and [3.6]**

This paragraph is deleted and shifted to the new paragraph Ch 6, Sec 2, [3.6.2] so that all requirements related to flooded condition are unified together in the new paragraph Ch 6, Sec 2, [3.6] and the paragraph Ch 6, Sec 2, [3.6] is newly provided so that the UR S18 requirements can be clearly collected and identified therein. In addition, for determining the net section modulus of stiffeners in lower stool and upper stool, as it is necessary to consider the pressure specified in Ch 4, Sec 6, [3.3.7] which comes from IACS UR S18, the new paragraph [3.6.3] is added.

**2.11 Ch 6, Sec 3, [6.1.1]**

The reference is changed, according to the modification of Ch 6, Sec 2.

## 3. Impact on Scantling

Since the subject revisions to the text are:
a) the clarification of the text in line with the original intention, or
b) the clarification of the texts.
For a) it is not necessary to perform impact study.
For b) it is not possible to perform impact study because the basis is not identified clearly.

# Common Structural Rules for Bulk Carriers, July 2008

# Rule Change Notice No.1-9 (Main Engine Foundation)

Notes: (1) These Rule Changes enter into force on 1 July 2009.

For technical background for Rule Changes in this present document, reference is made to separate document Technical Background for Rule Change Notice No.1-9.

# CHAPTER 9 OTHER STRUCTURES

## Section 3 MACHINERY SPACE

### 7. Main machinery seating

#### 7.2 Minimum scantlings

**7.2.1**

The net scantlings of the structural elements in way of the internal combustion engine seatings are to be obtained from the formulae in Tab 2. However, the net cross-sectional area of each bedplate of the seatings may be determined by the engine manufacturers, provided the information regarding permissible foundation stiffness considering the engine characteristics and engine room arrangement, etc..

**Table 2: Minimum scantlings of the structural elements in way of machinery seatings**

| Scantling minimum value | Scantling minimum value |
|---|---|
| Net cross-sectional area, in cm$^2$, of each bedplate of the seatings | $40 + 70 \frac{P}{n_r L_E}$ |
| Bedplate net thickness, in mm | Bedplates supported by two or more girders: $\sqrt{240 + 175 \frac{P}{n_r L_E}}$<br>Bedplates supported by one girder: $5 + \sqrt{240 + 175 \frac{P}{n_r L_E}}$ |
| Total web net thickness, in mm, of girders fitted in way of machinery seatings | Bedplates supported by two or more girders: $\sqrt{320 + 215 \frac{P}{n_r L_E}}$<br>Bedplates supported by one girder: $\sqrt{95 + 65 \frac{P}{n_r L_E}}$ |
| Web net thickness, in mm, of floors fitted in way of machinery seatings | $\sqrt{55 + 40 \frac{P}{n_r L_E}}$ |

# Common Structural Rules for Bulk Carriers, July 2008

# Technical Background for Rule Change Notice No.1-9 (Main Engine Foundation)

# Technical Background for the Changes Regarding Main Engine Foundations

## 1. Reason for the Rule Change in Ch 9, Sec 3, [7.2]

PT1 was requested to make an interpretation for the usage of Table 2 of the Rule (KC-ID 413). The scantling according this table leads to very large scantlings, especially the net cross-sectional area of engine seatings. This was not the intention of these requirements. However, the scantling formula except for cross-sectional area of engine seatings specified in Table 2 of the Rules are considered reasonable according to the investigation results of existing BCs as given in Figure 1 to Figure 4.

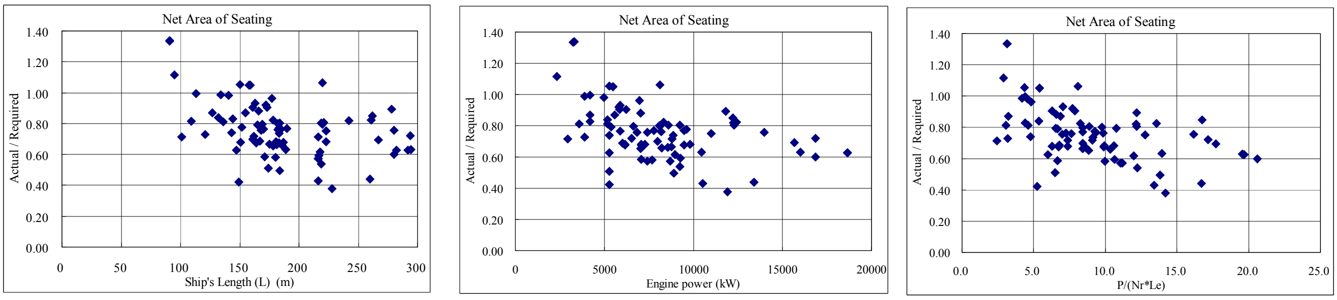



Fig.1 Cross-sectional area of engine seating

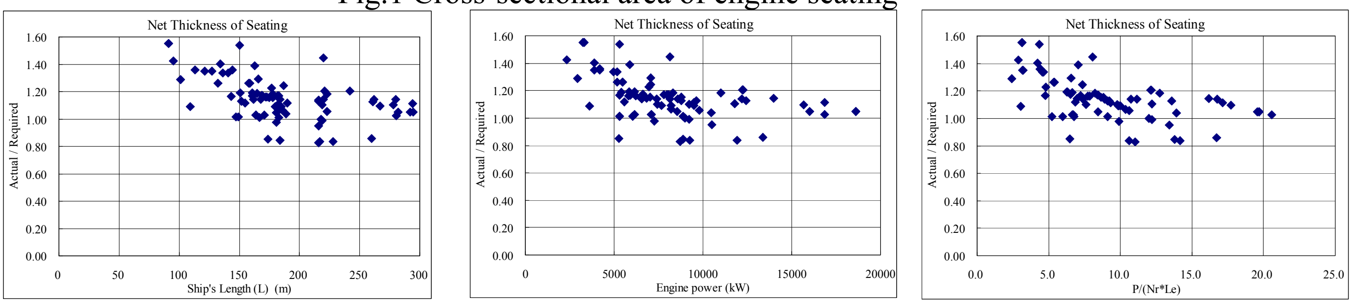



Fig.2 Net thickness of engine seating

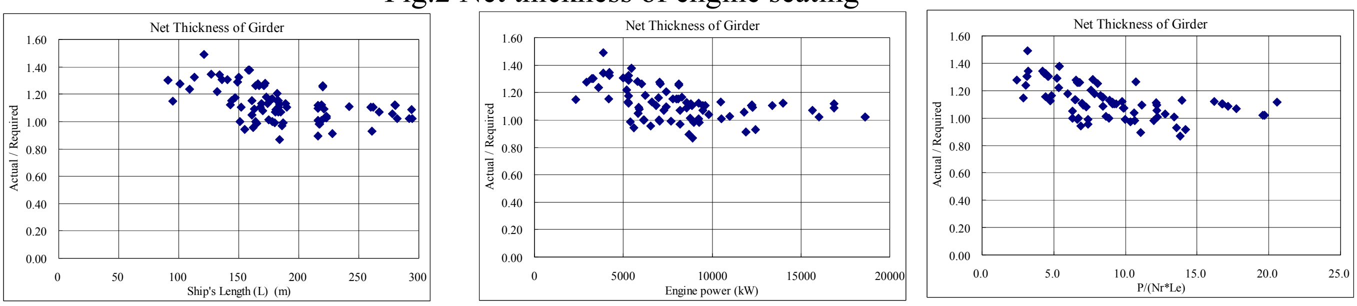



Fig.3 Total net thickness of girders

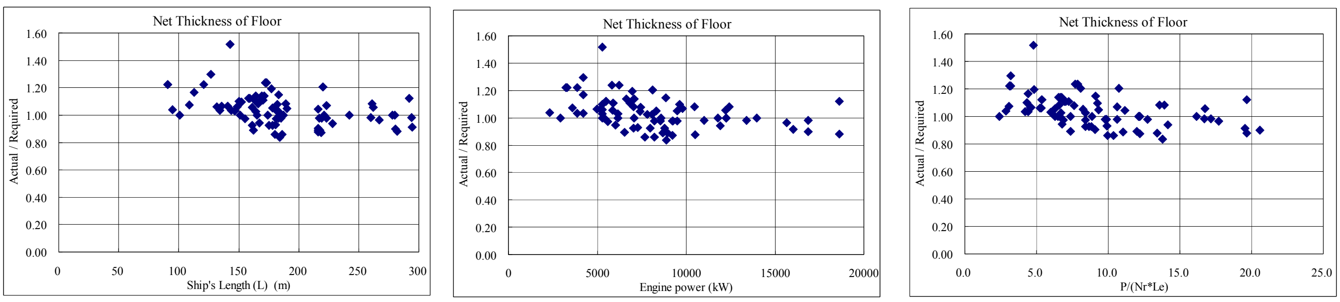



Fig.4 Net thickness of floors

From these results, it is necessary to clarify the dealing with the formula for cross-sectional area of engine seatings.
In this regard, we considered that it is possible to deal with the drawings supplied by the engine manufactures with information regarding permissible foundation stiffness considering the engine characteristics and engine room arrangement, etc..

## 2. Summary of the Rule Change

The scantling of the combustion engine foundation is generally determined by not only the results of the calculations or experiments for the required foundation stiffness, derived by the engine manufacturer but also the engine room arrangements. It is not the intention of the CSR for bulk carrier to establish requirements for the combustion engine foundation, which are more severe than the requirements from the engine manufacturer.
The following examples give an overview of the scantling impact

Therefore, we propose to add the following sentence after the present text of Ch 9, Sec 3, [7.2.1]

<Quote>
However, the net cross-sectional area of each bedplate of the seatings may be determined by the engine manufacturers, provided the information regarding permissible foundation stiffness considering the engine characteristics and engine room arrangement, etc..
<Unquote>

## 3. Effects and impact on scantling due to this definition

The following table gives an overview of the scantling impact regarding the cross-sectional area of engine seatings.

| Ship size | | Handy <150m | Handy <150m | Handymax | Handymax | Panamax | Panamax | Capesize |
|---|---|---|---|---|---|---|---|---|
| Max. cont. rating P | [kW] | 4980 | 3883 | 8890 | 7280 | 9230 | 8973 | 16860 |
| Number of revolution $n_r$ | [1/min] | 170 | 210 | 116 | 108 | 106 | 104 | 91 |
| Effective length $L_E$ | [m] | 6,40 | 4,40 | 6,08 | 6,80 | 6,52 | 7,20 | 9,00 |
| Actual bedplate cross section area | [cm²] | 355 | 331 | 498 | 500 | 484 | 543 | 889 |
| Required cross section area | [cm²] | 360 | 334 | 923 | 734 | 976 | 879 | 1481 |
| Required / Actual cross section area | | **1,02** | **1,01** | **1,85** | **1,47** | **2,02** | **1,62** | **1,67** |