Common Structural Rules for Bulk Carriers, January 2006

Background Document

CHAPTER 6 – HULL SCANTLINGS

NOTE:

- This TB is published to improve the transparency of CSRs and increase the understanding of CSRs in the industry.
- The content of the TB is not to be considered as requirements.
- This TB cannot be used to avoid any requirements in CSRs, and in cases where this TB deviates from the Rules, the Rules have precedence.
- This TB provides the background for the first version (January 2006) of the CSRs, and is not subject to maintenance.

IACS
INTERNATIONAL ASSOCIATION OF CLASSIFICATION SOCIETIES LTD.

Enquiries should be addressed to the Permanent Secretary,
International Association of Classification Societies Ltd,
36 Broadway
London, SW1H 0BH
Telephone: +44 (0)20 7976 0660
Fax: +44 (0)20 7808 1100
Email: PERMSEC@IACS.ORG.UK

TABLE OF CONTENTS:

SECTION 1 – PLATING

1. GENERAL

1.1 Application

1.1.1

1.1.1.a This Section applies for the strength check of plating subjected to lateral pressure and, for plating contributing to the longitudinal strength, to in-plane hull girder normal stress.

1.2 Net thicknesses

1.2.1

1.2.1.a This requirement specifies that all thicknesses are determined in net value, and specify how to obtain the gross thickness.

1.2.2

1.2.2.a The applicability of net scantling approach to platings is specified.

1.3 Pressure combination scantlings

1.3.1 Elements of the outer shell

1.3.1.a The way to combine the loads to be considered is specified.

1.3.2 Elements other than those of the outer shell

1.3.2.a The way to combine the loads to be considered is specified.

1.4 Elementary plate panel

1.4.1

1.4.1.a The definition of what is an Elementary Plate Panel is indicated.

1.5 Load calculation point

1.5.1

1.5.1.a The determination of the point at which pressures and stresses are calculated is specified, depending on the type of framing.

2. GENERAL REQUIREMENTS

2.1 Corrugated bulkhead

2.1.1

2.1.1.a The parameters for the determination of the thickness of a corrugated bulkhead as Elementary Plate Panel are specified.

2.2 Minimum net thicknesses

2.2.1

2.2.1.a This requirement specifies minimum net thickness, adapted from BV Rules for Steel Ships (Ch 7, Sec 1).

2.3 Bilge plating

2.3.1

2.3.1.a This requirement is based on 2.3.1 of Part B, Chapter 7, Section 1 of BV Rules for Steel Ships.

2.3.2

2.3.2.a This requirement is based on 2.3.2 of Part B, Chapter 7, Section 1 of BV Rules for Steel Ships.

2.3.3

2.3.3.a This requirement is based on 2.3.3 of Part B, Chapter 7, Section 1 of BV Rules for Steel Ships.

2.4 Keel plating

2.4.1

2.4.1.a This requirement specifies the thickness of the keel in respect to the thickness of the adjacent bottom plating.

2.5 Sheerstrake

2.5.1 Welded sheerstrake

2.5.1.a This requirement is based on 2.5.1 of Part B, Chapter 7, Section 1 of BV Rules for Steel Ships.

2.5.2 Rounded sheerstrake

2.5.2.a This requirement is based on 2.5.2 of Part B, Chapter 7, Section 1 of BV Rules for Steel Ships.

2.5.3 Net thickness of the sheerstrake in way of breaks of long superstructures

2.5.3.a This requirement is based on 2.5.3 of Part B, Chapter 7, Section 1 of BV Rules for Steel Ships.

2.5.4 Net thickness of the sheerstrake in way of breaks of short superstructures

2.5.4.a This requirement is based on 2.5.4 of Part B, Chapter 7, Section 1 of BV Rules for Steel Ships.

2.6 Stringer plate

2.6.1 General

2.6.1.a This requirement is based on 2.6.1 of Part B, Chapter 7, Section 1 of BV Rules for Steel Ships.

2.6.2 Net thickness of the stringer plate in way of breaks of long superstructures

2.6.2.a This requirement is based on 2.6.2 of Part B, Chapter 7, Section 1 of BV Rules for Steel Ships.

2.6.3 Net thickness of the stringer plate in way of breaks of short superstructures

2.6.3.a This requirement is based on 2.6.3 of Part B, Chapter 7, Section 1 of BV Rules for Steel Ships.

2.7 Inner bottom loaded by steel coils on a wooden support

2.7.1 General

2.7.1.a This requirement is based on NK Rules.

2.7.2 Inner bottom plating

2.7.2.a This requirement is based on NK Rules.

2.7.3 Hopper sloping plate and inner hull plating

2.7.3.a This requirement is based on NK Rules.

2.7.4

2.7.4.a This requirement is based on NK Rules.

3. STRENGTH CHECK OF PLATING SUBJECTED TO LATERAL PRESSURE

3.1 Load model

3.1.1 General

3.1.1.a The loads to be considered are specified in 3.1.2 to 3.1.4. The basic concepts considered related to loads are static loads and wave loads corresponding to 8 load cases, induced by the sea and various type of cargoes. The loads in flooded (i.e. damaged) condition and testing condition are also considered.

3.1.2 Lateral pressure in intact conditions

3.1.2.a The lateral pressures (i.e. the local pressure applied normally to the plating) in intact condition are specified. They are static and wave loads, induced by the sea or by the various type of cargoes.

3.1.3 Lateral pressure in flooded conditions

3.1.3.a The lateral pressure in the specific case of flooded condition is specified and refers to Ch 4, Sec 6.

3.1.4 Lateral pressure in testing conditions

3.1.4.a The lateral pressure in testing condition are specified and refers to Ch 4, Sec 6. The draught T_1 at which the testing is carried out may be taken into account, if known. These lateral pressures apply to the platings subjected to testing, as defined in Ch 11, Sec 3.

3.1.5 Normal stresses

3.1.5.a This requirement specifies the normal stress to be considered for the strength check of plating contributing to the hull girder longitudinal strength. It is defined for the 8 load cases, and is taken as the maximum value between sagging and hogging conditions.

3.2 Plating thickness

3.2.1 Intact conditions

3.2.1.a This requirement specifies the thickness required under intact condition. It is to be noted that the formula is in line with CSR for Oil Tankers.

3.2.2 Net thickness under flooded conditions excluding corrugations of transverse vertically corrugated bulkhead separating cargo holds

3.2.2.a This requirement specifies the thickness required under flooded condition for plating which constitutes the boundary of compartments not intended to carry liquids (excluding bottom plating and side shell plating), and excluding corrugations of transverse vertically corrugated bulkhead separating cargo holds, which is covered under 3.2.3.

3.2.3 Net thickness of the corrugations of transverse vertically corrugated watertight bulkheads separating cargo holds for flooded conditions

3.2.3.a This requirement specifies the thickness required under flooded condition for plating of transverse vertically corrugated watertight bulkheads separating cargo holds. This regulation is in accordance with IACS UR S18 (S18.4.7).

3.2.4 Testing conditions

3.2.4.a This requirement specifies the thickness required under testing condition for platings subjected to testing.

SECTION 2 – ORDINARY STIFFENERS

1. GENERAL

1.1 Application

1.1.1

1.1.1.a This Section applies for the yielding check of ordinary stiffeners subjected to lateral pressure and, for ordinary stiffeners contributing to the hull girder longitudinal strength, to hull girder normal stresses.

1.2 Net scantlings

1.2.1

1.2.1.a The applicability of net scantling approach to ordinary stiffeners is specified.

1.3 Pressure combination scantlings

1.3.1 Elements of the outer shell

1.3.1.a The way to combine the loads to be considered is specified.

1.3.2 Elements other than those of the outer shell

1.3.2.a The way to combine the loads to be considered is specified.

1.4 Load calculation point

1.4.1 Horizontal stiffeners

1.4.1.a The determination of the point at which pressures and stresses are calculated, in case of horizontal stiffeners, is specified.

1.4.2 Vertical stiffeners

1.4.2.a The determination of the point at which pressures and stresses are calculated, in case of vertical stiffeners, is specified.

2. GENERAL REQUIREMENTS

2.1 Corrugated bulkhead

2.1.1

2.1.1.a The parameters for the determination of the section modulus of corrugation of a corrugated bulkhead, if any, are specified.

2.2 Minimum net thicknesses of webs of ordinary stiffeners

2.2.1 Ordinary stiffeners other than side frames of single side bulk carriers

2.2.1.a This requirement specifies minimum net thickness of web, based on the ones indicated in CSR for Oil Tankers. In addition, some ratio between web thickness of ordinary stiffener and thickness of attached plating is specified to allow an easy weldability.

2.2.2 Side frames of single side bulk carriers

2.2.2.a This requirement is based on requirement S12.5 of the draft text of IACS UR S12 Rev.4 agreed at the WP/S meeting of 8-10 April 2003.

2.3 Net dimensions of ordinary stiffeners

2.3.1 Flat bar

2.3.1.a This requirement covers a buckling check of a flat bar. It is based on 1.4.1 of Part B, Chapter 7, Section 2 of BV Rules for Steel Ships.

2.3.2 T-section

2.3.2.a This requirement covers a buckling check of a T-section. It is based on 1.4.2 of Part B, Chapter 7, Section 2 of BV Rules for Steel Ships.

2.3.3 Angle

2.3.3.a This requirement covers a buckling check of an angle profile. It is based on 1.4.3 of Part B, Chapter 7, Section 2 of BV Rules for Steel Ships.

2.4 Struts connecting ordinary stiffeners

2.4.1

2.4.1.a This requirement applies to the scantlings of struts , as defined in Ch 3, Sec 6, [4.2.3]. It is based on 2.3.1 of Part B, Chapter 7, Section 2 of BV Rules for Steel Ships.

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

2.5.1 General

2.5.1.a This requirement is based on NK Rules.

2.5.2 Ordinary stiffeners located on inner bottom plating

2.5.2.a This requirement is based on NK Rules.

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

2.5.3.a This requirement is based on NK Rules.

2.5.4

2.5.4.a This requirement is based on NK Rules.

2.6 Deck ordinary stiffeners in way of launching appliances used for survival craft or rescue boat

2.6.1

2.6.1.a This requirement is based on 2.3.1 of Part B, Chapter 7, Section 2 of BV Rules for Steel Ships.

2.6.2

2.6.2.a This requirement is based on 2.3.2 of Part B, Chapter 7, Section 2 of BV Rules for Steel Ships.

2.6.3

2.6.3.a This requirement is based on 2.3.3 of Part B, Chapter 7, Section 2 of BV Rules for Steel Ships.

3. YIELDING CHECK

3.1 Load model

3.1.1 General

3.1.1.a The loads to be considered are specified in 3.1.2 to 3.1.4. The basic concepts considered related to loads are static loads and wave loads corresponding to 8 load cases, induced by the sea and various type of cargoes. The loads in flooded (i.e. damaged) condition and testing condition are also considered.

3.1.2 Lateral pressure in intact conditions

3.1.2.a The lateral pressures (i.e. the local pressure applied normally to the attached plating) in intact condition are specified. They are static and wave loads, induced by the sea or by the various type of cargoes.

3.1.3 Lateral pressure in flooded conditions

3.1.3.a The lateral pressure in the specific case of flooded condition is specified and refers to Ch 4, Sec 6.

3.1.4 Lateral pressure in testing conditions

3.1.4.a The lateral pressure in testing condition are specified and refers to Ch 4, Sec 6. The draught T_1 at which the testing is carried out may be taken into account, if known. These lateral pressures apply to the ordinary stiffeners subjected to testing, as defined in Ch 11, Sec 3.

3.1.5 Normal stresses

3.1.5.a This requirement specifies the normal stress to be considered for the strength check of ordinary stiffeners contributing to the hull girder longitudinal strength. It is defined for the 8 load cases, and is taken as the maximum value between sagging and hogging conditions.

3.2 Strength criteria for single span ordinary stiffeners other than side frames of single side bulk carriers

3.2.1 Boundary conditions

3.2.1.a The scantlings of ordinary stiffeners in 3.2 to 3.5 are indicated for ordinary stiffeners considered as being clamped at both ends, except otherwise specified. The yielding check for other boundary conditions is not covered.

3.2.2 Groups of equal ordinary stiffeners

3.2.2.a This requirement indicates a practical criteria to check scantlings of ordinary stiffeners gathered in group having the same actual scantlings.

3.2.3 Net section modulus and net shear sectional area of single span ordinary stiffeners under intact conditions

3.2.3.a This requirement indicates section modulus and shear area of ordinary stiffeners and it is based on elastic design under lateral pressures in intact conditions.

3.2.4 Net section modulus of corrugated bulkhead of ballast hold for ships having a length less than 150m

3.2.4.a This requirement applies to corrugated bulkhead of ballast hold for ships having a length less than 150m. It indicates the section modulus of corrugation and it is based on NK Rules.

3.2.5 Net section modulus and net shear sectional area of single span ordinary stiffeners under flooded conditions excluding corrugations of transverse vertically corrugated bulkhead separating cargo holds

3.2.5.a This requirement indicates section modulus and shear area of ordinary stiffeners and it is based on elastic design under lateral pressures in flooded conditions.

3.2.6 Bending capacity and shear capacity of the corrugations of transverse vertically corrugated watertight bulkheads separating cargo holds for flooded conditions

3.2.6.a This requirement specifies the bending capacity and the shear capacity of corrugations of transverse vertically corrugated watertight bulkheads separating cargo holds under flooded conditions. This requirement is in accordance with IACS UR S18 (S18.4.2).

3.2.7 Net section modulus and net shear sectional area of single span ordinary stiffeners under testing conditions

3.2.7.a This requirement indicates section modulus and shear area of ordinary stiffeners and it is based on elastic design under lateral pressures in testing conditions.

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

3.3.1.a This requirement is based on requirement S12.4.1 of the draft text of IACS UR S12 Rev.4 agreed at the WP/S meeting of 8-10 April 2003.

This draft text consider the net section modulus and the minimum net web thickness under the following forms:

- Net section modulus : $Z = C_3 \frac{m_m \; P_{frame} \; h}{\sigma_F}$
- Net web thickness : $t_w = \frac{1000 \; C_s \; P_{frame}}{d_b \; \sin\phi \; \tau_a} \cdot \frac{h - 2h_B}{h}$

These formulae have been then expressed in terms of symbols specific to CSR for bulk carriers:

- Net section modulus : $w = 1.125\alpha_m \frac{(p_S + p_W) s \ell^2}{m \lambda_S R_Y} 10^3$
- Net shear sectional area : $A_{sh} = 1.1\alpha_S \frac{5(p_S + p_W) s \ell}{\tau_a \sin\phi} \left(\frac{\ell - 2\ell_B}{\ell} \right)$

The technical background is given below:

The shear force at the lower end of the side frame span is obtained, by assuming that the sum of the still water and wave pressures is uniform along the span. It is also assumed that the percentage of total lateral force on the frame that is carried by the lower end support is equal to:

- 60%, in general,
- 66%, for the side frames of holds specified to be empty in ships assigned with the BC-A notation, as defined in UR S25. This greater value is due to the effect of the hopper tank rotation induced by the sea pressure on the double bottom, not counterbalanced by any internal cargo (see below).

The shear force at section b) is assumed to be equal to that at section a) multiplied by a factor. The factor is equal to the frame span "h" minus twice the length of the lower bracket divided by "h" (it is assumed here that the upper and the lower brackets have the same length).

The minimum net web thickness of the side frame is evaluated at the section b), considering the angle of the inclination of the web to the shell plating.

The bending moment acting on the side frame is obtained by multiplying the total lateral force on the frame by the frame span and by coefficients "mm", that gives the factor of the maximum bending moment along the side frame span.

The "mm" values depend on the loading condition of the hold to which the frame under consideration belongs. Finite element calculations have shown that the maximum bending moment for the side frames of ore holds is at the mid-span; for empty holds the maximum bending moment is at the lower end.

On the basis of finite element calculations, "mm" values are assumed to be 70 for BC-A ships, as defined in UR S25, and 60 for other cases; the value of 70 for the loaded holds of BC-A ships is equivalent to the bending moment of the frame assumed simply supported inside the brackets.

For the empty holds of BC-A ships, an higher values of the coefficient "mm" has been included considering that in non-homogeneous loading conditions (i.e. at the maximum draft) the sea pressure acting on the double bottom is not counterbalanced by internal cargo. This induces significant rotation of the hopper tanks and hence of the side frame lower ends, that increases the bending moment at the lower end.

The required net section modulus of the side frame is evaluated in the elastic domain; a reduction of 20 per cent, incorporated using coefficient C3 equal to 0,83, was included in the formula for the required modulus to permit some plastic behaviour under extreme loads.

3.3.2 Supplementary strength requirements

3.3.2.a This requirement is based on requirement S12.4.2 of the draft text of IACS UR S12 Rev.4 agreed at the WP/S meeting of 8-10 April 2003,as follows:

Service record of bulk carriers and other type of ships reports that vertical crack occurs on side shell plating along the line of collision bulkhead. In case where brackets are fitted on side shell between collision bulkhead and a hold frame abaft the bulkhead, those brackets crack or side shell plating cracks along the hold frame abaft the brackets fitted.

It is considered that deformation of hold frame due to repeated wave load induces bending of side shell plating between collision bulkhead and the hold frame thereafter and this bending of side shell plating induces fatigue crack on side shell plating along the line of collision bulkhead. Cracks of brackets or of side shell plating abaft brackets are considered to occur for the same reason.

A formula to require a moment of inertia of hold frame is specified to control the deformation of the frame within 3/1000*(frame space) at its mid span where a sea pressure force, P_{frame}, acts on the side shell plating.

3.3.3 Lower bracket of side frame

3.3.3.a This requirement is based on requirements S12.6 and S12.8 of the draft text of IACS UR S12 Rev.4 agreed at the WP/S meeting of 8-10 April 2003,as follows:

First, the relevant requirements in UR S12 Rev. 3 have been written in terms of the net scantlings, considering a corrosion of 25 %. This corrosion is consistent with the corrosion additions considered for the frame webs.

Secondly, limit values for the web depth to thickness ratio are introduced for lower brackets, in addition to those already specified in UR S12 Rev.3, which are valid for the side frames.

The limits for the web depth to thickness ratio of lower brackets take into account that, in order to comply with the requirements for the section modulus of the brackets in S12.6, the web depth increases more in the lower bracket than the shear force, with respect to the corresponding value at the top of the lower bracket. As a consequence, the shear stresses in the lower bracket are lower than in the span (the highest shear stress values occur at the top of the lower bracket).

When calculating the web depth to the thickness ratio, the web depth of the 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.

The thickness $t_{d/t}$, which satisfies the web dept to thickness ratio, can be reduced to $t'_{d/t} = \sqrt[3]{{t_{d/t}}^2 t_w}$ for the frames immediately abaft the collision bulkheads, which are often oversized for the purpose of providing a smooth stiffness transition between the fore peak structure and the hold side structures. For these frames, when the required minimum net web thickness t_W is such that the side frame web works in the elastic domain, the formula for $t'_{d/t}$ accounts for the fact that the working shear stress is lower than the admissible one.

The formula for $t'_{d/t}$ is derived as reported in the following:

The relationship between critical shear stresses and the web plate thickness is given by the formula (1)

$$\tau_{cr} = K \frac{\pi^2 E}{12(1-\upsilon^2)}\left(\frac{t}{b}\right)^2 = S_f \tau_a \qquad (1)$$

where:

t = $t_{d/t}$, web thickness satisfying the required shear buckling criteria corresponding to the assumed allowable shear stress τ_a with safety factor.

τ_a = allowable shear stress (= 0,5 σ_y)

S_f = safety factor

In case where working shear stress τ_{work} is less than the allowable shear stress τ_a the corresponding critical shear stress τ_{cr}', while maintaining the same safety factor, is given by

$$\tau_{cr}' = K \frac{\pi^2 E}{12(1-\upsilon^2)}\left(\frac{t'_{d/t}}{b}\right)^2 = S_f \tau_{work} \qquad (2)$$

where, $t'_{d/t}$ is the web plate thickness giving the critical shear stress τ_{cr}'

On the other hand, the working shear stresses τ_{work} is given by formula (3)

$$\tau_{work} = \frac{t_w}{t'_{d/t}} \tau_a \qquad (3)$$

where, t_W is as given in S12.4.1 or in S12.5, whichever is the greater.

The following equation is obtained by substituting τ_{work} in formula (2) by that of formula (3):

$$K \frac{\pi^2 E}{12(1-\upsilon^2)}\left(\frac{t'_{d/t}}{b}\right)^2 = S_f \frac{t_w}{t'_{d/t}} \tau_a = S_f \tau_a \frac{t_w}{t'_{d/t}} \qquad (4)$$

Combining equations (1) and (4) give the following relationship between $t_{d/t}$ and $t'_{d/t}$:

$$\left(\frac{t'_{d/t}}{b}\right)^2 = \frac{t_w}{t'_{d/t}}\left(\frac{t_{d/t}}{b}\right)^2 \qquad (5)$$

Equation (5) gives $t'_{d/t}$ as follows:

$$t'_{d/t} = \sqrt[3]{t_{d/t}^2 t_w} \qquad (6)$$

$t'_{d/t}$ given by the formula (6) gives the web thickness for side frames and lower brackets satisfying the shear buckling criteria corresponding to the working shear stresses, where $t_{d/t}$ is greater than t_w.

The formula for $t'_{d/t}$ is based on the formulation of the elastic shear buckling stress, which is valid for shear stress lower than $\frac{1}{2 \cdot \sqrt{3}} \cdot \sigma_F$, that is 0,29 of the material yielding. As t_W is based on the admissible shear stress equal to 0,5 of the material yielding, when the thickness $t_{d/t}$ is greater than 0,5/0,29 of t_W, that is 1,73 t_w, the side frame web works in the elastic domain and $t'_{d/t}$ will be obtained by the following formula:

$$t'_{d/t} = \sqrt[3]{t_{d/t}^{\,2} t_w}$$

Furthermore, in the requirements for asymmetrically flanged frames the higher strength steel k factor has been removed, as the same UR S12 allows such frames to be adopted only if made in normal strength steel.

3.3.4 Upper bracket of side frame

3.3.4.a This requirement is based on requirements S12.6 of the draft text of IACS UR S12 Rev.4 agreed at the WP/S meeting of 8-10 April 2003: the relevant requirements in UR S12 Rev. 3 have been written in terms of the net scantlings, considering a corrosion of 25 %. This corrosion is consistent with the corrosion additions considered for the frame webs.

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

3.4.1

3.4.1.a This requirement is based on requirements S12.7 of the draft text of IACS UR S12 Rev.4 agreed at the WP/S meeting of 8-10 April 2003.

This draft text consider the relation ship between net section modulus and distances under the following form:

- $$\sum_n (Z_i \cdot a_i) \geq \frac{1000\, C_t\, P_{frame}\, h\, \ell_1^2}{16\, s\, \sigma_F}$$

This formula have been then expressed in terms of symbols specific to CSR for bulk carriers:

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

The technical background is given below:

The section modulus of the longitudinals is required to have sufficient bending strength to support the end fixing moment of the side frame about the intersection point of the sloping bulkhead and the side shell.

The end fixing moment of the side frame is that induced by the external sea pressure acting on the side frame (end brackets excluded) and the deflection and rotation of the end support due to the loading on the hopper and the double bottom.

The sea pressure loading on the end brackets is not included because the sea pressure loading on this and on the connecting structure of the hopper and topside tank are assumed to cancel.

The end fixing moment, M_{ef}, in Nm, of the side frame about the intersection point of the sloping bulkhead and the side shell in Nm is given as:

$$M_{ef} = 1000 \cdot P_{frame} \cdot h \cdot C_m + h_B \cdot 1000 \cdot P_{frame} \cdot C_s \cdot \frac{h - 2h_B}{h}$$

where:

C_m is the bending moment coefficient at the lower end or at the upper end of the side frame;

C_s is the fraction of the total sea pressure force, which is carried by the lower end or the upper end of the side frame.

The end fixing moment, M_{ef}, gives rise to the line loads, q_{ef}, in N/m, on the longitudinals of the side shell and sloping bulkhead, that support the lower and upper connecting brackets, given as:

$$q_{ef} = \frac{M_{ef}}{s\ a} = \frac{1000\ P_{frame}\ h}{s\ \ a}\left(C_m + \frac{h_B}{h} \cdot \frac{h - 2h_B}{h}\ C_s\right)$$

The line load, q_{ef}, gives rise to the plastic bending moments, M_c, in Nm, in the longitudinals, that support the lower and upper connecting brackets, given as:

$$M_c = \frac{q_{ef}\ \ell_l^2}{16} = \frac{1000\ P_{frame}\ h\ \ell_l^2}{16\ \ s\ \ a}\left(C_m + \frac{h_B}{h} \cdot \frac{h - 2h_B}{h}\ C_s\right)$$

Hence, assuming an allowable stress equal to yield, the section modulus requirement for a connected side or sloping bulkhead longitudinal in cm³ becomes:

$$Z = \frac{M_c}{\sigma_F} = \frac{1000\ P_{frame}\ h\ \ell_l^2}{16\ \ s\ \ a\ \sigma_F}\left(C_m + \frac{h_B}{h} \cdot \frac{h - 2h_B}{h}\ C_s\right)$$

The above expression assumes a single connected longitudinal. For more than one connected longitudinal, the plastic bending moment M_c is to be supported by the sum of the connected longitudinals and the requirement becomes:

$$\sum_n \left(Z_i \cdot a_i\right) = \frac{1000\ P_{frame}\ h\ \ell_l^2}{16\ \ s\ \ \sigma_F}\left(C_m + \frac{h_B}{h} \cdot \frac{h - 2h_B}{h}\ C_s\right)$$

The above expression, assuming $C_T = \left(C_m + \frac{h_B}{h} \cdot \frac{h - 2h_B}{h}\ C_s\right)$, becomes:

$$\sum_n \left(Z_i \cdot a_i\right) = \frac{1000\ P_{frame}\ h\ \ell_l^2}{16\ \ s\ \ \sigma_F} C_T$$

On the basis of the finite element calculations, C_m is assumed equal to 0,07 for the lower end and 0,02 for the upper end.

For a lower bracket length of 0,125 the side frame span, considering the value for C_S equal to 0,66, as defined in S12.4.1, the term $\frac{h_B}{h} \cdot \frac{h - 2h_B}{h} C_s$ is, conservatively assumed equal to 0,08 for the lower brackets; hence C_T is assumed equal to 0,15 for the longitudinal stiffeners supporting the lower connecting brackets.

Assuming that the shear force supported by the upper end is 2/3 of that supported by the lower end, the term $\frac{h_B}{h} \cdot \frac{h - 2h_B}{h} C_s$ is, conservatively equal to 0,05 for the upper brackets, hence C_T is assumed equal to 0,075 for the longitudinal stiffeners supporting the upper connecting brackets.

3.4.2

3.4.2.a This requirement is based on requirements S12.7 of the draft text of IACS UR S12 Rev.4 agreed at the WP/S meeting of 8-10 April 2003: this draft text consider a specified requirement to ensure that the brackets have a sufficient net connection area to the longitudinals supporting the brackets. This net connection area A_i of the bracket to the i-th longitudinal stiffener supporting the bracket is given under the following form:

- $A_i = 0,4\, Z_i\, s\, k_{bkt} / (\ell_i^2\, k_{long,i})$

This formula have been then expressed in terms of symbols specific to CSR for bulk carriers:

- $A_i = 0.4 \frac{w_i s}{\ell_i^2} \frac{k_{bkt}}{k_{lg,i}}$

3.5 Strength criteria for multi-span ordinary stiffeners

3.5.1 Checking criteria

3.5.1.a This requirement indicates the admissible normal and shear stresses to consider in intact, flooded or testing condition for the check of stresses in a multi-span ordinary stiffener.

3.5.2 Multi-span ordinary stiffeners

3.5.2.a This requirement specifies the parameters to take into account for the determination of normal and shear stresses in a multi-span ordinary stiffener.

4. WEB STIFFENERS OF PRIMARY SUPPORTING MEMBERS

4.1 Net scantlings

4.1.1

4.1.1.a This requirement is based on 4.7.2 of Part B, Chapter 4, Section 3 of BV Rules for Steel Ships.

4.1.2

4.1.2.a This requirement is based on 4.7.3 of Part B, Chapter 4, Section 3 of BV Rules for Steel Ships.

4.1.3 Connection ends of web stiffeners

4.1.3.a This requirement is based on NK Rules.

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

1. GENERAL

1.1

1.1.1

1.1.1.a The buckling strength requirements are based on the DIN-standard 18800, "Structural steelwork, Part 1 to 4" [DIN] amended in 1990 which is based on the ultimate strength concept. Part 2 contains "Analysis of safety against buckling of linear members and frames" and Part 3 "Analysis of safety against buckling of plates". Comments are given in "Beuth – Kommentare Stahlbauten, 1. Auflage 1993, J. Lindner, J. Scheer, H. Schmidt" [LIN]. The calculation procedures are based on experimental and analytical buckling and ultimate strength data.

In order to improve the practical application the calculation procedure has been simplified in some areas and has been adapted to specific conditions of hull structures of ships as described in "Background Information for Users of the New Requirements of Germanischer Lloyd for Proof of Buckling Strength, 1997" [BCK]. The main difference of the CSR-Buckling procedure to the procedure used at Germanischer Lloyd is the net thickness concept. Therefore the following adjustments were necessary:

- Adjustment of safety factors
- Change of formula for degree of fixation of torsional buckling check

The buckling check is valid for structures which comply with IACS Rec. 47 [I47] or recognized national shipbuilding quality standards.

To afford a complete overview about the background of the buckling and ultimate strength concept used in CSR for Bulk Carriers, reference is made to the following literature:

[DIN]DIN 18800, "Structural steelwork", Part 1 to 4, Beuth Verlag, Berlin, 1993

[LIN] J. Lindner, J. Scheer, H. Schmidt, „Beuth – Kommentare Stahlbauten", 1993

[BCK]M. Böckenhauer, H.-J. Schulte, "Background Information for Users of the New Requirements of Germanischer Lloyd for Proof of Buckling Strength", Germanischer Lloyd, Hamburg, 1997

[BLE] Bleich, "Buckling strength of metal structures", Mc Graw-Hill Book Complex, New York, Toronto, London, 1952

[I47] IACS Recommendation No.47 "Shipbuilding and Repair Quality Standard", 2006

1.1.2

1.1.2.a It is considered that for this topic, no information in addition to that shown in the CSR for Bulk Carriers , is necessary to explain the background.

1.1.3

1.1.3.a It is considered that for this topic, no information in addition to that shown in the CSR for Bulk Carriers , is necessary to explain the background.

2. APPLICATION

2.1 Load model for hull transverse section analysis

2.1.1 General

2.1.1.a It is considered that for this topic, no information in addition to that shown in the CSR for Bulk Carriers , is necessary to explain the background.

2.1.2 Normal stress σ_n

2.1.2.a It is considered that for this topic, no information in addition to that shown in the CSR for Bulk Carriers , is necessary to explain the background.

2.1.3 Shear stress

2.1.3.a It is considered that for this topic, no information in addition to that shown in the CSR for Bulk Carriers , is necessary to explain the background.

2.1.4 Lateral pressure

2.1.4.a It is considered that for this topic, no information in addition to that shown in the CSR for Bulk Carriers, is necessary to explain the background.

2.2 Application

2.2.1

2.2.1.a The application of the buckling and ultimate strength criterion is described in App1 of Ch06 Sec03 of the CSR for Bulk Carriers.

3. BUCKLING CRITERIA OF ELEMENTARY PLATE PANELS

3.1 Plates

3.1.1 General

3.1.1.a Taking into account that the maximum values of the normal stresses resulting from global bending of the hull and the maximum value of shear stress resulting from hull girder shear forces are not acting simultaneously a stress combination is defined.

3.1.1.b The ratio between normal and shear stress is based on GL-Rules and the long-term experience of Germanischer Lloyd applying the buckling assessment.

3.1.2 Verification of elementary plate panel in a transverse section analysis

3.1.2.a The verification criteria given in this section are a simplification of the general criterion (interaction formulation) given in [3.2.4] taking into account normal stresses in ships longitudinal direction and shear stresses. The criteria are formulated with respect to framing system (longitudinally or transverse framed plating). For the determination of e_3, κ_y is to be taken equal to 1 in case of longitudinally stiffened plating and κ_x is to be taken equal to 1 in case of transversely stiffened plating.

3.2 Verification of elementary plate panel within FEM analysis

3.2.1 General

3.2.1.a It is considered that for this topic, no information in addition to that shown in the CSR for Bulk Carriers, is necessary to explain the background.

3.2.2 Stresses

3.2.2.a It is considered that for this topic, no information in addition to that shown in the CSR for Bulk Carriers, is necessary to explain the background.

3.2.3 Poisson effect

3.2.3.a The membrane stresses σ_x and σ_y are either resulting from a calculation based on simple beam theory or from a FE analysis. In the latter case, the stress share due to the suppression of transverse contraction (Poisson-effect) is already included in the result, while this is not the case for the simple beam theory. In order to bring the results to a comparable level, the FE stresses are to be transformed to beam stresses as described in the rules. The stress correction has to be carried out after the summation of stresses due to global and local loads. Furthermore both of the stress components (longitudinal and transverse) are to be compressive stresses. Reference is made to [BCK].

3.2.3.b Results obtained with the CSR buckling strength checks are based on stresses resulting from calculations using simple beam theory (e.g. conventional longitudinal strength calculations). If the results are instead to be based on stresses resulting from a finite element calculation, then the stress share due to the Poisson effect is already included in the result. This is not the case if the simple beam method is applied. In order to bring the results of both calculation procedures to a comparable level, the stresses obtained from a calculation procedure which already incorporates the Poisson effect may be reduced. One reason for this procedure is that the load carrying capacity of a plate field with the Poisson effect (longitudinal edges non-displaceable in the plate level) is at least equal or greater than the capacity of a plate field with longitudinal edges which can freely move. Shear stresses have no effect on the reduction of the finite element stresses, but they must of course be included in the subsequent buckling strength assessment.

It should be noted that the stress reduction is a 'may' condition, i.e. it should not be applied when the smaller compressive stress is less than 0.3 times the larger since an unrestrained elongation at the unloaded plate edge does not produce a stress acting in the direction of the loaded plate edge. Accordingly, if both σ_x^* and σ_y^* are compressive stresses, then the reduced stresses σ_x and σ_y as input data for a buckling strength calculation are derived as follows:

$$\sigma_x{}^* = \sigma_x + \nu\sigma_y \quad \rightarrow \quad \sigma_x = \sigma_x{}^* - \nu\sigma_y \quad \rightarrow \quad \sigma_x = \frac{\sigma_x{}^* - \nu\sigma_y{}^*}{1-\nu^2} \qquad \text{(Eq. 1)}$$

where $\sigma_y^* \geq 0.3\ \sigma_x^*$. If $\sigma_y^* < 0.3\ \sigma_x^*$, then $\sigma_y = 0$ and $\sigma_x = \sigma_x^*$.

and

$$\sigma_y{}^* = \sigma_y + \nu\sigma_x \quad \rightarrow \quad \sigma_y = \sigma_y{}^* - \nu\sigma_x \quad \rightarrow \quad \sigma_y = \frac{\sigma_y{}^* - \nu\sigma_x{}^*}{1-\nu^2} \qquad \text{(Eq. 2)}$$

where $\sigma_x^* \geq 0.3\ \sigma_y^*$. If $\sigma_x^* < 0.3\ \sigma_y^*$, then $\sigma_x = 0$ and $\sigma_y = \sigma_y^*$.

Finally, since it cannot be guaranteed that both stress components are always acting simultaneously (e.g. if they develop from separate loads), stresses containing the Poisson effect are not permitted to exceed the ultimate strength of the plate under a uniaxial stress (i.e. $\sigma_x^* \leq \kappa_x R_{eH}$ and $\sigma_y^* \leq \kappa_y R_{eH}$).

3.2.3.c Example: Elementary plate panel (EPP) with uniform stresses (τ = 0 N/mm²) – Figure 1.

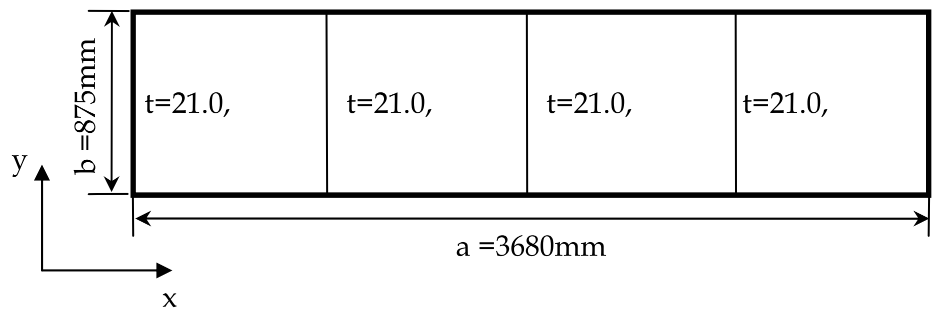


Figure 1

Boundary correction factor F_1 = 1.00. Load correction factor $c_1 = (1-F_1/\alpha) \geq 0$. Safety factor S = 1.0.

To illustrate the relationship between stress combinations with and without the Poisson effect, Figure 2 shows the capacity curve of stress combinations which include the Poisson effect (upper curve) and the capacity curve of those which exclude it (lower curve - κ_x = 0.979, κ_y = 0.462). Stress combinations from the upper curve would generally come from finite element analyses and the stress combinations from the lower curve would be those used in the buckling strength assessment. As can be seen, the capacity curve of stress combinations which include the Poisson effect (upper curve) is divided into four segments. The first segment is that in which $\sigma_x \leq 0.3\ \sigma_y$ and so $\sigma_x = 0$ and $\sigma_y = \sigma_y^*$. Similarly, the fourth segment is that in which $\sigma_y \leq 0.3\ \sigma_x$ and so $\sigma_y = 0$ and $\sigma_x = \sigma_x^*$. In the second segment, stresses containing the Poisson effect are limited by the ultimate strength of the plate under a uniaxial stress in the y-direction (i.e. $\sigma_y^* \leq \kappa_y R_{eH}$). Finally, in the third segment the relationship between stress combinations with and without the Poisson effect are as described in Eq. 1 and Eq. 2.

3.2.3.d In the examples which follow, it is assumed that the stated stresses already include the foregoing correction for Poisson effect.

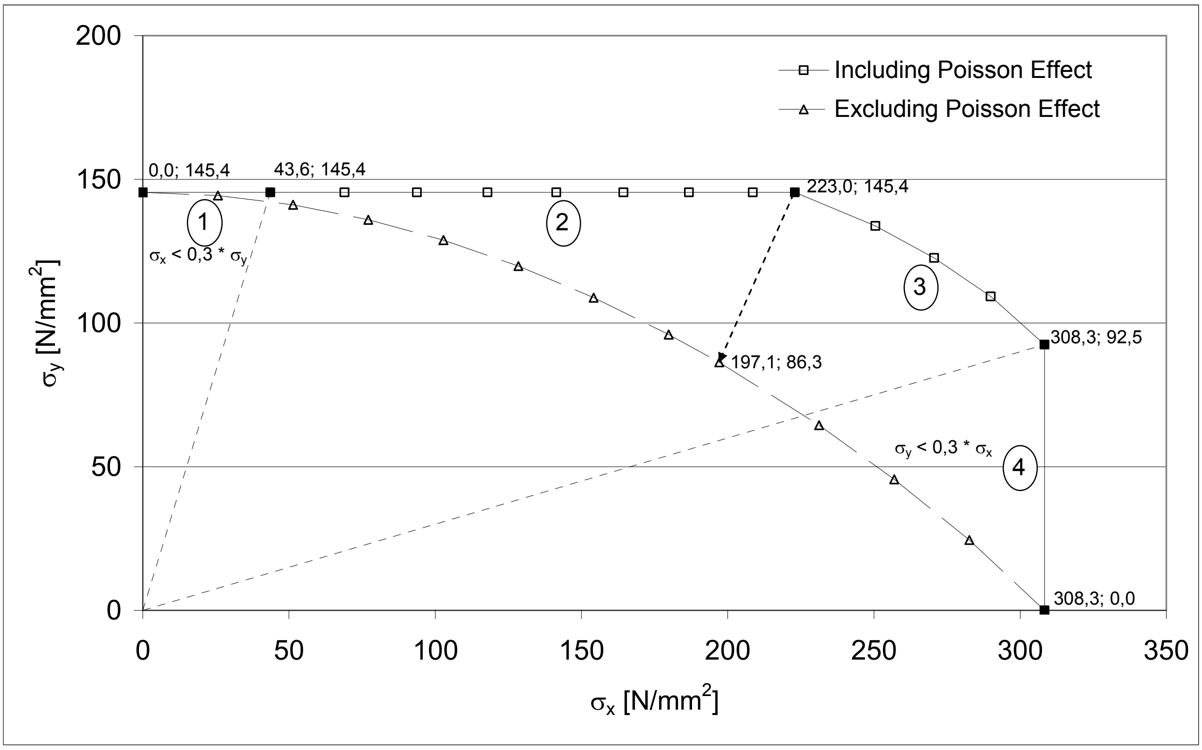


Figure 2

3.2.4 Checking Criteria

3.2.4.a The CSR buckling strength checks of elementary plate fields require proof of sufficient ultimate strength capacity. The checks require proof for membrane stresses acting in the x- and y-direction and for shear stresses acting in the x-y plane. Lateral loads may be neglected in the buckling strength check. The capacity of elementary plate panels subjected to lateral loads is regulated by separate strength criteria in other sections of the CSR.

The proof of single plate fields for stresses acting in the x- and y-direction and for shear stresses acting in the xy-plane has to satisfy the following interaction condition considering the net thickness.

$$\left(\frac{|\sigma_x|S}{\kappa_x R_{eH}}\right)^{e1}+\left(\frac{|\sigma_y|S}{\kappa_y R_{eH}}\right)^{e2}-B\left(\frac{\sigma_x\sigma_y S^2}{R_{eH}^2}\right)+\left(\frac{|\tau|S\sqrt{3}}{\kappa_\tau R_{eH}}\right)^{e3}\le 1.0$$

The symbols in the above condition have the following meaning:

σ_x, σ_y = membrane stresses in the x- or y-direction (compression is positive) [N/mm²]

τ = shear stress in the x-y plane of the plate field [N/mm²]

S = safety factor

R_{eH} = minimum yield stress of the material [N/mm²]

κ_x, κ_y, κ_t	=	reduction factors which, in principal, depend on the reference degree of slenderness
e_1, e_2, e_3, B	=	functions of the reduction factors κ_x, κ_y and κ_t

3.2.4.b Each individual term of the above interaction condition shall not be greater than 1,0. In accordance with DIN 18800 lateral loads are neglected. The strength of plane plate fields subjected to lateral loads is regulated by other sections of the CSR for Bulk Carriers.

3.2.4.c The interaction condition exemplarily is illustrated for a quadratic plate field for different effective widths of platings.

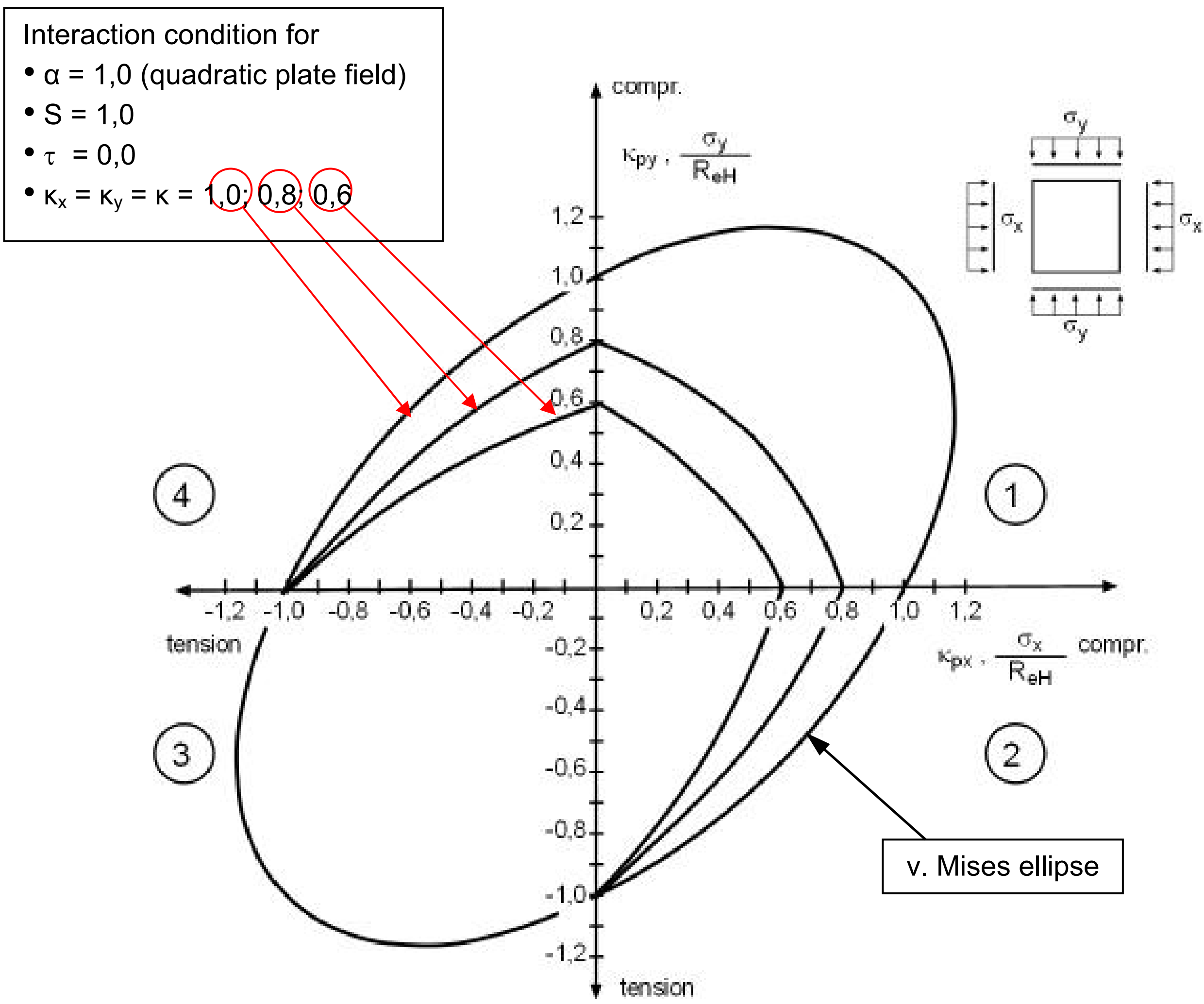


Figure 3: Interaction condition of a quadratic plate field for different effective widths

3.2.4.d For a fully effective width, i.e. a stocky plate with κ=1,0 the interaction condition results in the von Mises ellipse.

3.2.4.e For wide plate fields a large part of the plate field behaves like a single beam (column buckling) which reduces the load bearing capacity of the plate field. This effect is included in the formulations for wide plate fields.

3.2.4.f According to the DIN 18800 the interaction condition applies to single plate fields and to partial and total plate fields. In the GL-Rules this condition is only used for single plate fields.

3.2.4.g An analysis of the interaction condition indicated that the results in the 2nd and 4th sector, indicated in Figure 3 (σ_x or σ_y is a tension stress), are very conservative. If the interaction condition of the DIN 18800 should be incorporated into the CSR for Bulk Carrier in principle and should remain valid in all sectors, only the 3rd term could be modified. Therefore the κ_p-values for σ_x and σ_y in this term are set to 1.0 for the sectors 2, 3 and 4. This implies that in the CSR for Bulk Carrier the factor B is set to 1.0 in these three sectors.

3.2.4.h The reference degree of slenderness results from the degree of slenderness of the plate field $\lambda_p = \pi\sqrt{\frac{E}{K \cdot \sigma_e}}$ and from the degree of slenderness related to the yield stress $\lambda_a = \pi\sqrt{\frac{E}{R_{eH}}}$ as follows:

$$\lambda = \frac{\lambda_p}{\lambda_a} = \sqrt{\frac{R_{eH}}{K \cdot \sigma_e}},$$

3.3 Webs and Flanges

3.3.1

3.3.1.a It is considered that for this topic, no information in addition to that shown in the CSR for Bulk Carriers, is necessary to explain the background.

4. BUCKLING CRITERIA OF PARTIAL AND TOTAL PANELS

4.1 Longitudinal and transverse stiffeners

4.1.1

4.1.1.a It is considered that for this topic, no information in addition to that shown in the CSR for Bulk Carriers, is necessary to explain the background.

4.2 Ultimate strength in lateral buckling mode

4.2.1 Checking Criteria

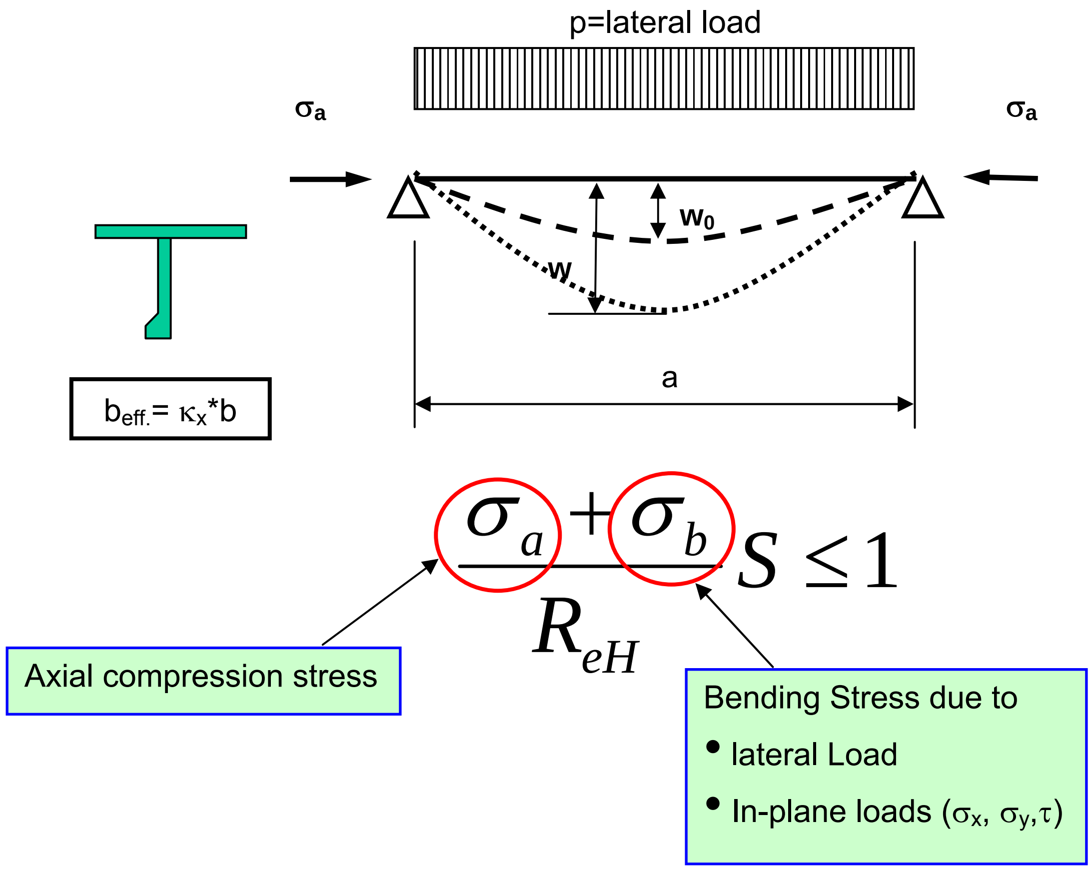
4.2.1.a In addition to the buckling analysis for single plate fields stiffeners must have sufficient strength against lateral and torsional buckling.

4.2.1.b Proof of sufficient safety against lateral buckling is made by applying 2nd order theory. Thereby the following loads are to be considered:

- Compressive stresses in stiffener direction
- Compressive stresses perpendicular to the stiffener direction
- Shear stresses in the plate plane
- External lateral loads
- Calculated loads resulting from pre-deformations are considered in accordance with the buckling curve b of DIN 18800, Part 2 [DIN]. These are valid, until the structure complies with IACS Rec. 47 (Shipbuilding and Repair Quality Standard) or recognized national shipbuilding standards.

4.2.1.c According to DIN 18800, Part 2 [DIN] it is assumed that the in-plane stresses σ_x, σ_y and τ_{xy} with regard to the pre-deformation are applied by equivalent lateral loads to obtain correct bending stresses in the stiffener. Here the cross section values of stiffener with attached plating are determined using the effective width of 2nd order.

4.2.1.d The sum of the axial compression stress and the resultant bending stresses of all load components is checked with a required safety factor against yield stress. The following figure illustrates the procedure.



$$\frac{\sigma_a + \sigma_b}{R_{eH}} S \leq 1$$

Figure 4: Lateral Buckling, check against a required safety factor to yield stress

4.2.2 Evaluation of the bending stress σ_b

4.2.2.a The calculation of the bending stress σ_b is in detail described in [BCK]. Initial deflections are considered in accordance with the buckling curve b of DIN 18800 Part 2 [DIN].

4.2.3 Equivalent criteria for longitudinal and transverse ordinary stiffeners not subjected to lateral pressure

4.2.3.a The formulas to check the strength of stiffeners not subjected to lateral pressure are taken from GL-Rules. The formulations are based on 2nd Order Theory considering imperfections and are checked against the yield strength applying an appropriate safety factor.

4.3 Torsional buckling

4.3.1 Longitudinal stiffeners

4.3.1.a Stiffeners subjected to compressive stresses are to be examined for their ability to resist torsional buckling. The basic condition is: $\frac{\sigma_x \cdot S}{\kappa_\tau \cdot R_{eH}} \leq 1.0$

4.3.1.b The calculation procedure of the reduction factor κ_τ follows the buckling curve a of DIN 18800, Part 2 [DIN].

4.3.1.c The reference degree of slenderness uses the critical torsional buckling stress σ_{KiT} derived by Bleich, "Buckling Strength of Metal Structures" [BLE].

4.3.2 Transverse stiffeners

4.3.2.a It is considered that for this topic, no information in addition to that shown in the CSR for Bulk Carriers, is necessary to explain the background.

5. EFFECTIVE WIDTH OF ATTACHED PLATING

5.1 Ordinary stiffeners

5.1.1

5.1.1.a Two different approaches were used for the determination of the effective width of the attached plating for ordinary stiffeners. The minimum value determined for the two approaches have to be used for further calculations. The first approach multiplies the reduction factor κ_x or κ_y with the distance between the stiffeners a or b for longitudinal or transverse stiffeners respectively. The reduction factor for this approach is based on the plate buckling assessment for elementary plate panels. For the second approach (shear lag effect) a reduction factor κ_s is multiplied with the distance between the stiffeners s. The calculation of the reduction factor κ_s is dependent of an effective length of the stiffener l_{eff} (dependent from supporting conditions or moment distribution along the length of the stiffener). The calculation gives results similar to table 6 of CSR CH06, Sec03 [5.2] with the assumption, that ordinary stiffeners are loaded by uniformly distributed loads (equivalent to e_{m1} of table 6).

5.2 Primary supporting members

5.2.1

5.2.1.a In difference to the beam theory the normal stress in wide plate flanges of beams is not uniformly distributed in reality. To simplify the calculations acc. to the beam theory an effective width is obtained such that the resulting force of the stresses acting on the real plate flange is equal to the force of the uniformly distributed normal stresses acting on the plate flange of the effective width.

5.2.1.b The effective width is dependent of the moment distribution alongside the girder, resulting from boundary conditions and the applied forces as well as of the ratio between the length of the girder and the width of the supported plating (shear lag effect).

5.2.1.c Based on a plane stress state, effective width can be calculated for varying ratios between the length of the girder and the supported width and the moment distribution caused by boundary conditions and applied loads. Results for such calculations are given in table 6 of CSR Ch06 Sec03 [5.2] with respect to uniformly distributed loads and single loads.

6. TRANSVERSE VERTICALLY CORRUGATED WATERTIGHT BULKHEAD IN FLOODED CONDITIONS

6.1 General

6.1.1 Shear buckling check of bulkhead corrugation webs

6.1.1.a The proof of the shear buckling strength of bulkhead corrugation webs follows the method of IACS UR S18.

SECTION 4 – PRIMARY SUPPORTING MEMBERS

1. GENERAL

1.1 Application

1.1.1

1.1.1.a Primary supporting members are assessed by direct strength calculation for ships of length 150 m and greater, except for double bottom strength in the flooded condition incorporating IACS UR S20. For primary supporting members in ships of length below 150 m, strength formulae are specified with the focus on shear strength.

1.2 Primary supporting members for ships less than 150 m in length (L)

1.2.1

1.2.1.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

1.2.2

1.2.2.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

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

1.3.1

1.3.1.a It is considered that for this topic, no information in addition to that shown in the Rules, is necessary to explain the background.

1.4 Net scantlings

1.4.1

1.4.1.a Half the corrosion addition is considered in direct strength calculation, but in the rule formulae, 100% of the corrosion addition is considered because primary supporting members are assessed locally.

1.5 Minimum net thickness of webs of primary supporting members

1.5.1

1.5.1.a Net thickness was taken as $0.6\sqrt{L}$ considering empirical values.

2. SCANTLING OF PRIMARY SUPPORTING MEMBERS FOR SHIPS OF LESS THAN 150 M IN LENGTH (L)

2.1 Load model

2.1.1 General

2.1.1.a The same regulation as for plating in Section 1, Chapter 6 has been set.

2.1.2 Lateral pressure in intact conditions

2.1.2.a The same regulation as for plating in Section 1, Chapter 6 has been set.

2.1.3 Elements of the outer shell

2.1.3.a The same regulation as for plating in Section 1, Chapter 6 has been set.

2.1.4 Elements other than those of the outer shell

2.1.4.a The same regulation as for plating in Section 1, Chapter 6 has been set.

2.1.5 Normal stresses

2.1.5.a The same regulation as for plating in Section 1, Chapter 6 has been set.

2.2 Center girders and side girders

2.2.1 Net web thickness

2.2.1.a This regulation is based on NK Rules.

2.3 Floors

2.3.1 Net web thickness

2.3.1.a This regulation is based on NK Rules.

2.4 Stringer of double side structure

2.4.1 Net web thickness

2.4.1.a This regulation is based on NK Rules.

2.5 Transverse web in double side structure

2.5.1 Net web thickness

2.5.1.a This regulation is based on NK Rules.

2.6 Primary supporting member in bilge hopper tanks and topside tanks and other structures

2.6.1 Load calculation point

2.6.1.a The same regulation as for plating in 1.4.1, Section 2, Chapter 6 has been set.

2.6.2 Boundary conditions

2.6.2.a

2.6.3 Net section modulus, net shear sectional area and web thickness under intact conditions

2.6.3.a

3. ADDITIONAL REQUIREMENTS FOR PRIMARY SUPPORTING MEMBERS OF BC-A AND BC-B SHIPS

3.1 Evaluation of double bottom capacity and allowable hold loading in flooded conditions

3.1.1 Shear capacity of the double bottom

3.1.1.a This regulation is in accordance with IACS UR S20.

3.1.2 Floor shear strength

3.1.2.a This regulation is in accordance with IACS UR S20.

3.1.3 Girder shear strength

3.1.3.a This regulation is in accordance with IACS UR S20.

3.1.4 Allowable hold loading

3.1.4.a This regulation is in accordance with IACS UR S20.

4. PILLARS

4.1 Buckling of pillars subjected to compressive axial load

4.1.1 General

4.1.1.a Compressive stress acting in pillars is required to be less than the critical column buckling stress.

4.1.2 Critical column buckling stress of pillars

4.1.2.a This requirement is based on the BV Rules.

APPENDIX 1 – BUCKLING & ULTIMATE STRENGTH

"The Appendix 1 shows the sample applications of Chapter 6 Section 3. Therefore, it is considered that for this topic, no information in addition to that shown in the CSR for Bulk Carriers, is necessary to explain the background.