

**S21**

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## Evaluation of Scantlings of Hatch Covers and Hatch Coamings of Cargo Holds of Bulk Carriers, Ore Carriers and Combination Carriers

### S21.1 Application and definitions

These requirements apply to all bulk carriers, ore carriers and combination carriers, as defined in UR Z11, and are for all cargo hatch covers and hatch forward and side coamings on exposed decks in position 1, as defined in ILLC.

Rev. 3 of this UR applies to ships contracted for construction on or after 1 January 2004.

This UR does not apply to CSR Bulk Carriers.

The strength requirements are applicable to hatch covers and hatch coamings of stiffened plate construction. The secondary stiffeners and primary supporting members of the hatch covers are to be continuous over the breadth and length of the hatch covers, as far as practical. When this is impractical, sniped end connections are not to be used and appropriate arrangements are to be adopted to provide sufficient load carrying capacity.

The spacing of primary supporting members parallel to the direction of secondary stiffeners is not to exceed 1/3 of the span of primary supporting members.

The secondary stiffeners of the hatch coamings are to be continuous over the breadth and length of the hatch coamings.

These requirements are in addition to the requirements of the ILLC.

The net minimum scantlings of hatch covers are to fulfil the strength criteria given in:

- S21.3.3, for plating,
- S21.3.4, for secondary stiffeners,
- S21.3.5 for primary supporting members,

the critical buckling stress check in S21.3.6 and the rigidity criteria given in S21.3.7, adopting the load model given in S21.2.

The net minimum scantlings of hatch coamings are to fulfil the strength criteria given in:

- S21.4.2, for plating,
- S21.4.3, for secondary stiffeners,
- S21.4.4, for coaming stays,

adopting the load model given in S21.4.1.

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#### Note:

1. The "contracted for construction" date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of "contract for construction", refer to IACS Procedural Requirement (PR) No. 29.

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The net thicknesses,  $t_{net}$ , are the member thicknesses necessary to obtain the minimum net scantlings required by S21.3 and S21.4.

The required gross thicknesses are obtained by adding the corrosion additions,  $t_s$ , given in S21.6, to  $t_{net}$ .

Material for the hatch covers and coamings is to be steel according to the requirements for ship's hull.

### S21.2 Hatch cover load model

The pressure  $p$ , in  $\text{kN/m}^2$ , on the hatch covers panels is given by:

For ships of 100 m in length and above

$$p = 34.3 + \frac{p_{FP} - 34.3}{0.25} \left( 0.25 - \frac{x}{L} \right) \geq 34.3, \text{ for hatchways located at the freeboard deck}$$

where:

$$p_{FP} = \text{pressure at the forward perpendicular} \\ = 49.1 + (L-100)a$$

$$a = 0.0726 \text{ for type B freeboard ships} \\ 0.356 \text{ for ships with reduced freeboard}$$

$L$  = Freeboard length, in m, as defined in Regulation 3 of Annex I to the 1966 Load Line Convention as modified by the Protocol of 1988, to be taken not greater than 340 m

$x$  = distance, in m, of the mid length of the hatch cover under examination from the forward end of  $L$

Where a position 1 hatchway is located at least one superstructure standard height higher than the freeboard deck, the pressure  $p$  may be  $34.3 \text{ kN/m}^2$ .

For ships less than 100 m in length

$$p = 15.8 + \frac{L}{3} \left( 1 - \frac{5}{3} \cdot \frac{x}{L} \right) - 3.6 \frac{x}{L} \geq 0.195L + 14.9, \text{ for hatchways located at the freeboard deck}$$

Where two or more panels are connected by hinges, each individual panel is to be considered separately.

### S21.3 Hatch cover strength criteria

#### S21.3.1 Allowable stress checks

The normal and shear stresses  $\sigma$  and  $\tau$  in the hatch cover structures are not to exceed the allowable values,  $\sigma_a$  and  $\tau_a$ , in  $\text{N/mm}^2$ , given by:

$$\sigma_a = 0.8\sigma_F$$

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$$\tau_a = 0.46\sigma_F$$

$\sigma_F$  being the minimum upper yield stress, in N/mm<sup>2</sup>, of the material.

The normal stress in compression of the attached flange of primary supporting members is not to exceed 0.8 times the critical buckling stress of the structure according to the buckling check as given in S21.3.6.

The stresses in hatch covers that are designed as a grillage of longitudinal and transverse primary supporting members are to be determined by a grillage or a FE analysis.

When a beam or a grillage analysis is used, the secondary stiffeners are not to be included in the attached flange area of the primary members.

When calculating the stresses  $\sigma$  and  $\tau$ , the net scantlings are to be used.

### S21.3.2 Effective cross-sectional area of panel flanges for primary supporting members

The effective flange area  $A_f$ , in cm<sup>2</sup>, of the attached plating, to be considered for the yielding and buckling checks of primary supporting members, when calculated by means of a beam or grillage model, is obtained as the sum of the effective flange areas of each side of the girder web as appropriate:

$$A_F = \sum_{nf} (10b_{ef}t)$$

where:

$nf$  = 2 if attached plate flange extends on both sides of girder web  
= 1 if attached plate flange extends on one side of girder web only

$t$  = net thickness of considered attached plate, in mm

$b_{ef}$  = effective breadth, in m, of attached plate flange on each side of girder web  
=  $b_p$ , but not to be taken greater than  $0.165\ell$

$b_p$  = half distance, in m, between the considered primary supporting member and the adjacent one

$\ell$  = span, in m, of primary supporting members

### S21.3.3 Local net plate thickness

The local net plate thickness  $t$ , in mm, of the hatch cover top plating is not to be less than:

$$t = F_p 15.8s \sqrt{\frac{p}{0.95\sigma_F}}$$

but to be not less than 1% of the spacing of the stiffener or 6 mm if that be greater.

where:

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- $F_p$  = factor for combined membrane and bending response  
 = 1.50 in general  
 = 1.90  $\sigma/\sigma_a$ , for  $\sigma/\sigma_a \geq 0.8$ , for the attached plate flange of primary supporting members
- $s$  = stiffener spacing, in m
- $p$  = pressure, in  $\text{kN/m}^2$ , as defined in S21.2
- $\sigma$  = as defined in S21.3.5
- $\sigma_a$  = as defined in S21.3.1.

### S21.3.4 Net scantlings of secondary stiffeners

The required minimum section modulus,  $Z$ , in  $\text{cm}^3$ , of secondary stiffeners of the hatch cover top plate, based on stiffener net member thickness, are given by:

$$Z = \frac{1000 \ell^2 s p}{12 \sigma_a}$$

where:

- $\ell$  = secondary stiffener span, in m, to be taken as the spacing, in m, of primary supporting members or the distance between a primary supporting member and the edge support, as applicable. When brackets are fitted at both ends of all secondary stiffener spans, the secondary stiffener span may be reduced by an amount equal to 2/3 of the minimum brackets arm length, but not greater than 10% of the gross span, for each bracket.
- $s$  = secondary stiffener spacing, in m
- $p$  = pressure, in  $\text{kN/m}^2$ , as defined in S21.2
- $\sigma_a$  = as defined in S21.3.1.

The net section modulus of the secondary stiffeners is to be determined based on an attached plate width assumed equal to the stiffener spacing.

### S21.3.5 Net scantlings of primary supporting members

The section modulus and web thickness of primary supporting members, based on member net thickness, are to be such that the normal stress  $\sigma$  in both flanges and the shear stress  $\tau$ , in the web, do not exceed the allowable values  $\sigma_a$  and  $\tau_a$ , respectively, defined in S21.3.1.

The breadth of the primary supporting member flange is to be not less than 40% of their depth for laterally unsupported spans greater than 3.0 m. Tripping brackets attached to the flange may be considered as a lateral support for primary supporting members.

The flange outstand is not to exceed 15 times the flange thickness.

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### S21.3.6 Critical buckling stress check

#### S21.3.6.1 Hatch cover plating

The compressive stress  $\sigma$  in the hatch cover plate panels, induced by the bending of primary supporting members parallel to the direction of secondary stiffeners, is not to exceed 0.8 times the critical buckling stress  $\sigma_{C1}$ , to be evaluated as defined below:

$$\begin{aligned}\sigma_{C1} &= \sigma_{E1} && \text{when } \sigma_{E1} \leq \frac{\sigma_F}{2} \\ &= \sigma_F \left[ 1 - \frac{\sigma_F}{4\sigma_{E1}} \right] && \text{when } \sigma_{E1} > \frac{\sigma_F}{2}\end{aligned}$$

where:

$\sigma_F$  = minimum upper yield stress, in N/mm<sup>2</sup>, of the material

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

E = modulus of elasticity, in N/mm<sup>2</sup>  
= 2.06 x 10<sup>5</sup> for steel

t = net thickness, in mm, of plate panel

s = spacing, in m, of secondary stiffeners

The mean compressive stress  $\sigma$  in each of the hatch cover plate panels, induced by the bending of primary supporting members perpendicular to the direction of secondary stiffeners, is not to exceed 0.8 times the critical buckling stress  $\sigma_{C2}$ , to be evaluated as defined below:

$$\begin{aligned}\sigma_{C2} &= \sigma_{E2} && \text{when } \sigma_{E2} \leq \frac{\sigma_F}{2} \\ &= \sigma_F \left[ 1 - \frac{\sigma_F}{4\sigma_{E2}} \right] && \text{when } \sigma_{E2} > \frac{\sigma_F}{2}\end{aligned}$$

where:

$\sigma_F$  = minimum upper yield stress, in N/mm<sup>2</sup>, of the material

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

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

E = modulus of elasticity, in N/mm<sup>2</sup>  
= 2.06 x 10<sup>5</sup> for steel

## S21 (cont)

- $t$  = net thickness, in mm, of plate panel  
 $s_s$  = length, in m, of the shorter side of the plate panel  
 $l_s$  = length, in m, of the longer side of the plate panel  
 $\psi$  = ratio between smallest and largest compressive stress  
 $c$  = 1.3 when plating is stiffened by primary supporting members  
 $c$  = 1.21 when plating is stiffened by secondary stiffeners of angle or T type  
 $c$  = 1.1 when plating is stiffened by secondary stiffeners of bulb type  
 $c$  = 1.05 when plating is stiffened by flat bar

The biaxial compressive stress in the hatch cover panels, when calculated by means of FEM shell element model, is to be in accordance with each classification society's rule as deemed equivalent to the above criteria.

### S21.3.6.2 Hatch cover secondary stiffeners

The compressive stress  $\sigma$  in the top flange of secondary stiffeners, induced by the bending of primary supporting members parallel to the direction of secondary stiffeners, is not to exceed 0.8 times the critical buckling stress  $\sigma_{CS}$ , to be evaluated as defined below:

$$\sigma_{CS} = \sigma_{ES} \quad \text{when } \sigma_{ES} \leq \frac{\sigma_F}{2}$$

$$= \sigma_F \left[ 1 - \frac{\sigma_F}{4\sigma_{ES}} \right] \quad \text{when } \sigma_{ES} > \frac{\sigma_F}{2}$$

where:

$\sigma_F$  = minimum upper yield stress, in N/mm<sup>2</sup>, of the material

$\sigma_{ES}$  = ideal elastic buckling stress, in N/mm<sup>2</sup>, of the secondary stiffener,  
= minimum between  $\sigma_{E3}$  and  $\sigma_{E4}$

$$\sigma_{E3} = \frac{0.001E I_a}{A \ell^2}$$

$E$  = modulus of elasticity, in N/mm<sup>2</sup>  
= 2.06 x 10<sup>5</sup> for steel

$I_a$  = moment of inertia, in cm<sup>4</sup>, of the secondary stiffener, including a top flange equal to the spacing of secondary stiffeners

$A$  = cross-sectional area, in cm<sup>2</sup>, of the secondary stiffener, including a top flange equal to the spacing of secondary stiffeners

$\ell$  = span, in m, of the secondary stiffener

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$$\sigma_{E4} = \frac{\pi^2 E I_w}{10^4 I_p \ell^2} \left( m^2 + \frac{K}{m^2} \right) + 0.385 E \frac{I_t}{I_p}$$

$$K = \frac{C \ell^4}{\pi^4 E I_w} 10^6$$

m = number of half waves, given by the following table:

	$0 < K < 4$	$4 < K < 36$	$36 < K < 144$	$(m-1)^2 m^2 < K \leq m^2 (m+1)^2$
m	1	2	3	m

$I_w$  = sectorial moment of inertia, in  $\text{cm}^6$ , of the secondary stiffener about its connection with the plating

$$= \frac{h_w^3 t_w^3}{36} 10^{-6} \quad \text{for flat bar secondary stiffeners}$$

$$= \frac{t_f b_f^3 h_w^2}{12} 10^{-6} \quad \text{for "Tee" secondary stiffeners}$$

$$= \frac{b_f^3 h_w^2}{12(b_f + h_w)^2} \left[ t_f (b_f^2 + 2b_f h_w + 4h_w^2) + 3t_w b_f h_w \right] 10^{-6} \quad \text{for angles and bulb secondary stiffeners}$$

$I_p$  = polar moment of inertia, in  $\text{cm}^4$ , of the secondary stiffener about its connection with the plating

$$= \frac{h_w^3 t_w}{3} 10^{-4} \quad \text{for flat bar secondary stiffeners}$$

$$= \left( \frac{h_w^3 t_w}{3} + h_w^2 b_f t_f \right) 10^{-4} \quad \text{for flanged secondary stiffeners}$$

$I_t$  = St Venant's moment of inertia, in  $\text{cm}^4$ , of the secondary stiffener without top flange

$$= \frac{h_w t_w^3}{3} 10^{-4} \quad \text{for flat bar secondary stiffeners}$$

$$= \frac{1}{3} \left[ h_w t_w^3 + b_f t_f^3 \left( 1 - 0.63 \frac{t_f}{b_f} \right) \right] 10^{-4} \quad \text{for flanged secondary stiffeners}$$

$h_w, t_w$  = height and net thickness, in mm, of the secondary stiffener, respectively

$b_f, t_f$  = width and net thickness, in mm, of the secondary stiffener bottom flange, respectively

s = spacing, in m, of secondary stiffeners

$$C = \text{spring stiffness exerted by the hatch cover top plating} = \frac{k_p E t_p^3}{3s \left( 1 + \frac{1.33 k_p h_w t_p^3}{1000 s t_w^3} \right)} 10^{-3}$$

## S21 (cont)

$k_p = 1 - \eta_p$  to be taken not less than zero;  
for flanged secondary stiffeners,  $k_p$  need not be taken less than 0.1

$$\eta_p = \frac{\sigma}{\sigma_{E1}}$$

$\sigma$  = as defined in S21.3.5

$\sigma_{E1}$  = as defined in S21.3.6.1

$t_p$  = net thickness, in mm, of the hatch cover plate panel.

For flat bar secondary stiffeners and buckling stiffeners, the ratio  $h/t_w$  is to be not greater than  $15k^{0.5}$ , where:

$h, t_w$  = height and net thickness of the stiffener, respectively

$$k = 235/\sigma_F$$

$\sigma_F$  = minimum upper yield stress, in  $N/mm^2$ , of the material.

### S21.3.6.3 Web panels of hatch cover primary supporting members

This check is to be carried out for the web panels of primary supporting members, formed by web stiffeners or by the crossing with other primary supporting members, the face plate (or the bottom cover plate) or the attached top cover plate.

The shear stress  $\tau$  in the hatch cover primary supporting members web panels is not to exceed 0.8 times the critical buckling stress  $\tau_C$ , to be evaluated as defined below:

$$\begin{aligned} \tau_C &= \tau_E && \text{when } \tau_E \leq \frac{\tau_F}{2} \\ &= \tau_F \left[ 1 - \tau_F / (4\tau_E) \right] && \text{when } \tau_E > \frac{\tau_F}{2} \end{aligned}$$

where:

$\sigma_F$  = minimum upper yield stress, in  $N/mm^2$ , of the material

$$\tau_F = \sigma_F / \sqrt{3}$$

$$\tau_E = 0.9k_t E \left[ \frac{t_{pr,n}}{1000d} \right]^2$$

$E$  = modulus of elasticity, in  $N/mm^2$   
=  $2.06 \times 10^5$  for steel

$t_{pr,n}$  = net thickness, in mm, of primary supporting member

$$k_t = 5.35 + 4.0 / (a / d)^2$$



## S21 (cont)

- a = greater dimension, in m, of web panel of primary supporting member  
 d = smaller dimension, in m, of web panel of primary supporting member

For primary supporting members parallel to the direction of secondary stiffeners, the actual dimensions of the panels are to be considered.

For primary supporting members perpendicular to the direction of secondary stiffeners or for hatch covers built without secondary stiffeners, a presumed square panel of dimension d is to be taken for the determination of the stress  $\tau_C$ . In such a case, the average shear stress  $\tau$  between the values calculated at the ends of this panel is to be considered.

### S21.3.7 Deflection limit and connections between hatch cover panels

Load bearing connections between the hatch cover panels are to be fitted with the purpose of restricting the relative vertical displacements.

The vertical deflection of primary supporting members is to be not more than  $0.0056\ell$ , where  $\ell$  is the greatest span of primary supporting members.

### S21.4 Hatch coamings and local details

#### S21.4.1 Load model

The pressure  $p_{\text{coam}}$ , in  $\text{kN/m}^2$ , on the No. 1 forward transverse hatch coaming is given by:

$$p_{\text{coam}} = 220, \text{ when a forecastle is fitted in accordance with UR S28} \\ = 290 \text{ in the other cases}$$

The pressure  $p_{\text{coam}}$ , in  $\text{kN/m}^2$ , on the other coamings is given by:

$$p_{\text{coam}} = 220$$

#### S21.4.2 Local net plate thickness

The local net plate thickness  $t$ , in mm, of the hatch coaming plating is given by:

$$t = 14.9s \sqrt{\frac{p_{\text{coam}}}{\sigma_{a,\text{coam}}} S_{\text{coam}}}$$

where:

s = secondary stiffener spacing, in m

$p_{\text{coam}}$  = pressure, in  $\text{kN/m}^2$ , as defined in S21.4.1

$S_{\text{coam}}$  = safety factor to be taken equal to 1.15

$\sigma_{a,\text{coam}} = 0.95 \sigma_F$

The local net plate thickness is to be not less than 9.5 mm.

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### S21.4.3 Net scantlings of longitudinal and transverse secondary stiffeners

The required section modulus  $Z$ , in  $\text{cm}^3$ , of the longitudinal or transverse secondary stiffeners of the hatch coamings, based on net member thickness, is given by:

$$Z = \frac{1000 S_{\text{coam}} \ell^2 s p_{\text{coam}}}{m c_p \sigma_{\text{a,coam}}}$$

where:

$m$  = 16 in general  
= 12 for the end spans of stiffeners sniped at the coaming corners

$S_{\text{coam}}$  = safety factor to be taken equal to 1.15

$\ell$  = span, in m, of secondary stiffeners

$s$  = spacing, in m, of secondary stiffeners

$p_{\text{coam}}$  = pressure in  $\text{kN/m}^2$  as defined in S21.4.1

$c_p$  = ratio of the plastic section modulus to the elastic section modulus of the secondary stiffeners with an attached plate breadth, in mm, equal to  $40t$ , where  $t$  is the plate net thickness  
= 1.16 in the absence of more precise evaluation

$\sigma_{\text{a,coam}} = 0.95 \sigma_F$

### S21.4.4 Net scantlings of coaming stays

The required minimum section modulus,  $Z$ , in  $\text{cm}^3$ , and web thickness,  $t_w$ , in mm of coamings stays designed as beams with flange connected to the deck or sniped and fitted with a bracket (see Figures 1 and 2) at their connection with the deck, based on member net thickness, are given by:

$$Z = \frac{1000 H_C^2 s p_{\text{coam}}}{2 \sigma_{\text{a,coam}}}$$

$$t_w = \frac{1000 H_C s p_{\text{coam}}}{h \tau_{\text{a,coam}}}$$

$H_C$  = stay height, in m

$s$  = stay spacing, in m

$h$  = stay depth, in mm, at the connection with the deck

$p_{\text{coam}}$  = pressure, in  $\text{kN/m}^2$ , as defined in S21.4.1

$\sigma_{\text{a,coam}} = 0.95 \sigma_F$

$T_{\text{a,coam}} = 0.5 \sigma_F$

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For calculating the section modulus of coaming stays, their face plate area is to be taken into account only when it is welded with full penetration welds to the deck plating and adequate underdeck structure is fitted to support the stresses transmitted by it.

For other designs of coaming stays, such as, for examples, those shown in Figures 3 and 4, the stress levels in S21.3.1 apply and are to be checked at the highest stressed locations.

### S21.4.5 Local details

The design of local details is to comply with the Society requirement for the purpose of transferring the pressures on the hatch covers to the hatch coamings and, through them, to the deck structures below. Hatch coamings and supporting structures are to be adequately stiffened to accommodate the loading from hatch covers, in longitudinal, transverse and vertical directions.

Underdeck structures are to be checked against the load transmitted by the stays, adopting the same allowable stresses specified in S21.4.4.

Unless otherwise stated, weld connections and materials are to be dimensioned and selected in accordance with the Society requirements.

Double continuous welding is to be adopted for the connections of stay webs with deck plating and the weld throat is to be not less than  $0.44 t_w$ , where  $t_w$  is the gross thickness of the stay web.

Toes of stay webs are to be connected to the deck plating with deep penetration double bevel welds extending over a distance not less than 15% of the stay width.

### S21.5 Closing arrangements

#### S21.5.1 Securing devices

The strength of securing devices is to comply with the following requirements:

Panel hatch covers are to be secured by appropriate devices (bolts, wedges or similar) suitably spaced alongside the coamings and between cover elements.

Arrangement and spacing are to be determined with due attention to the effectiveness for weather-tightness, depending upon the type and the size of the hatch cover, as well as on the stiffness of the cover edges between the securing devices.

The net sectional area of each securing device is not to be less than:

$$A = 1.4 a / f \text{ (cm}^2\text{)}$$

where:

$a$  = spacing in m of securing devices, not being taken less than 2 m

$f$  =  $(\sigma_Y / 235)^e$

$\sigma_Y$  = specified minimum upper yield stress in  $\text{N/mm}^2$  of the steel used for fabrication, not to be taken greater than 70% of the ultimate tensile strength.

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$$e = 0.75 \text{ for } \sigma_Y > 235$$

$$= 1.0 \text{ for } \sigma_Y \leq 235$$

Rods or bolts are to have a net diameter not less than 19 mm for hatchways exceeding 5 m<sup>2</sup> in area.

Between cover and coaming and at cross-joints, a packing line pressure sufficient to obtain weathertightness is to be maintained by the securing devices.

For packing line pressures exceeding 5 N/mm, the cross section area is to be increased in direct proportion. The packing line pressure is to be specified.

The cover edge stiffness is to be sufficient to maintain adequate sealing pressure between securing devices. The moment of inertia,  $I$ , of edge elements is not to be less than:

$$I = 6pa^4 \text{ (cm}^4\text{)}$$

$p$  = packing line pressure in N/mm, minimum 5 N/mm.

$a$  = spacing in m of securing devices.

Securing devices are to be of reliable construction and securely attached to the hatchway coamings, decks or covers. Individual securing devices on each cover are to have approximately the same stiffness characteristics.

Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

Where hydraulic cleating is adopted, a positive means is to be provided to ensure that it remains mechanically locked in the closed position in the event of failure of the hydraulic system.

### S21.5.2 Stoppers

Hatch covers are to be effectively secured, by means of stoppers, against the transverse forces arising from a pressure of 175 kN/m<sup>2</sup>.

With the exclusion of No.1 hatch cover, hatch covers are to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 175 kN/m<sup>2</sup>.

No. 1 hatch cover is to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 230 kN/m<sup>2</sup>.

This pressure may be reduced to 175 kN/m<sup>2</sup> when a forecastle is fitted in accordance with UR S28.

The equivalent stress:

- i. in stoppers and their supporting structures, and
- ii. calculated in the throat of the stopper welds

is not to exceed the allowable value of 0.8  $\sigma_Y$ .

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(cont)**S21.5.3 Materials and welding**

Stoppers or securing devices are to be manufactured of materials, including welding electrodes, meeting relevant IACS requirements.

**S21.6 Corrosion addition and steel renewal****S21.6.1 Hatch covers**

For all the structure (plating and secondary stiffeners) of single skin hatch covers, the corrosion addition  $t_s$  is to be 2.0 mm.

For double skin hatch covers, the corrosion addition is to be:

- 2.0 mm for the top and bottom plating
- 1.5 mm for the internal structures.

For single skin hatch covers and for the plating of double skin hatch covers, steel renewal is required where the gauged thickness is less than  $t_{net} + 0.5$  mm. Where the gauged thickness is within the range  $t_{net} + 0.5$  mm and  $t_{net} + 1.0$  mm, coating (applied in accordance with the coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal. Coating is to be maintained in GOOD condition, as defined in UR Z10.2.1.2.

For the internal structure of double skin hatch covers, thickness gauging is required when plating renewal is to be carried out or when this is deemed necessary, at the discretion of the Society Surveyor, on the basis of the plating corrosion or deformation condition. In these cases, steel renewal for the internal structures is required where the gauged thickness is less than  $t_{net}$ .

**S21.6.2 Hatch coamings**

For the structure of hatch coamings and coaming stays, the corrosion addition  $t_s$  is to be 1.5 mm.

Steel renewal is required where the gauged thickness is less than  $t_{net} + 0.5$  mm. Where the gauged thickness is within the range  $t_{net} + 0.5$  mm and  $t_{net} + 1.0$  mm, coating (applied in accordance with the coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal. Coating is to be maintained in GOOD condition, as defined in UR Z10.2.1.2.

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Figure 1

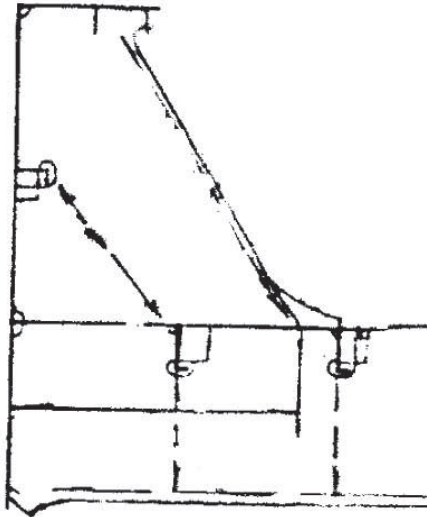


Figure 2

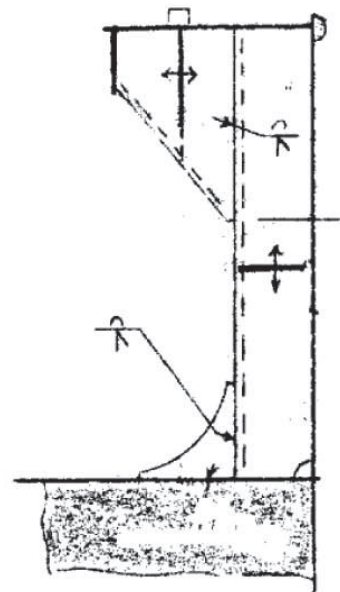


Figure 3

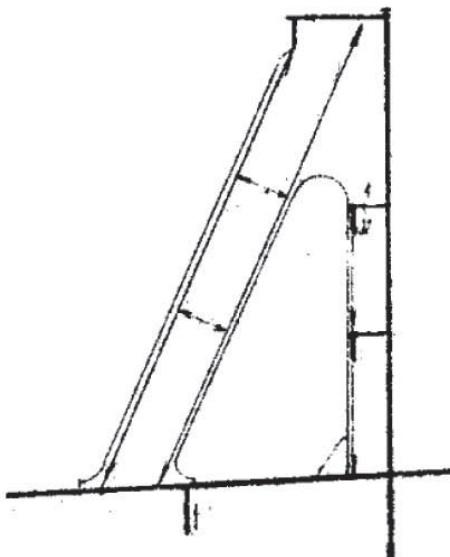
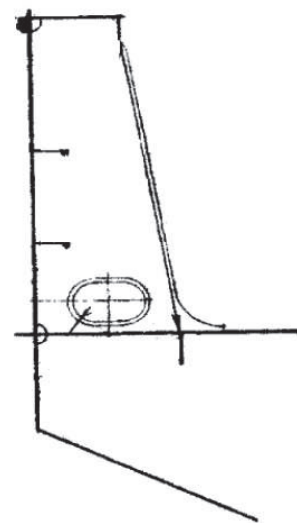


Figure 4



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**S21A**

(May  
2011)  
(Corr.1  
Oct  
2011)

**Requirements  
concerning  
STRENGTH OF SHIPS**

**S21A**

**Evaluation of Scantlings of Hatch Covers and Hatch  
Coamings and Closing Arrangements of Cargo Holds  
of Ships**

**S21A**  
(cont)**1 Application and definitions****1.1 Application**

These requirements apply to all ships except bulk carriers, ore carriers and combination carriers, as defined in UR Z11, and are for all cargo hatch covers and coamings on exposed decks.

The strength requirements are applicable to hatch covers and hatch coamings of stiffened plate construction and its closing arrangements.

This UR is applicable to hatch covers and coamings made of steel. In case of alternative materials and innovative designs the approval is subject to the individual class society.

This UR does not apply to portable covers secured weathertight by tarpaulins and battening devices, or pontoon covers, as defined in ICLL Regulation 15.

This UR applies for ships contracted for construction on or after **1 July 2012**. These requirements are in addition to the requirements of the ICLL.

The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to IACS Procedural Requirement (PR) No. 29.

**1.2 Definitions**

ICLL Where ICLL is referred to in the text, this is to be taken as the International Convention on Load Lines , 1966 as amended by the 1988 protocol, as amended in 2003.

**1.2.1 Hatch cover types****• Single skin cover**

A hatch cover made of steel or equivalent material that is designed to comply with ICLL Regulation 16. The cover has continuous top and side plating, but is open underneath with the stiffening structure exposed. The cover is weathertight and fitted with gaskets and clamping devices unless such fittings are specifically excluded.

**• Double skin cover**

A hatch cover as above but with continuous bottom plating such that all the stiffening structure and internals are protected from the environment.

**• Pontoon type cover**

A special type of portable cover, secured weathertight by tarpaulins and battening devices. Such covers are to be designed in accordance with ICLL Regulation 15 and are not covered by this UR.



## S21A

(cont)

### Clarification note:

Modern hatch cover designs of lift-away-covers are in many cases called pontoon covers. This definition does not fit to the definition above. Modern lift-away hatch cover designs should belong to one of the two categories single skin covers or double skin cover.

### 1.2.2 Positions

The hatchways are classified according to their position as follows:

Position 1      Upon exposed freeboard and raised quarterdecks, and upon exposed superstructure decks situated forward of a point located a quarter of ship's length from forward perpendicular.

Position 2      Upon exposed superstructure decks situated abaft a quarter of the ship's length from the forward perpendicular and located at least one standard height of the superstructure above the freeboard deck.

Upon exposed superstructure decks situated forward of a point located a quarter of the ship's length from the forward perpendicular and located at least two standard height of the superstructure above the freeboard deck.

### 1.3 Material

Hatch covers and coamings are to be made of material in accordance with the definitions of UR S6. A material class I is to be applied for hatch covers.

### 1.4 General requirements

Primary supporting members and secondary stiffeners of hatch covers are to be continuous over the breadth and length of hatch covers, as far as practical. When this is impractical, sniped end connections are not to be used and appropriate arrangements are to be adopted to provide sufficient load carrying capacity.

The spacing of primary supporting members parallel to the direction of secondary stiffeners is not to exceed 1/3 of the span of primary supporting members. When strength calculation is carried out by FE analysis using plane strain or shell elements, this requirement can be waived.

Secondary stiffeners of hatch coamings are to be continuous over the breadth and length of hatch coamings.

### 1.5 Net scantling approach

Unless otherwise quoted, the thicknesses  $t$  of the following sections are net thicknesses.

The net thicknesses are the member thicknesses necessary to obtain the minimum net scantlings required by 3 and 5.

The required gross thicknesses are obtained by adding corrosion additions,  $t_s$ , given in Tab.9 in 7.1.

## S21A (cont)

Strength calculations using beam theory, grillage analysis or FEM are to be performed with net scantlings.

### 2 Hatch cover and coaming load model

Structural assessment of hatch covers and hatch coamings is to be carried out using the design loads, defined in this chapter.

#### Definitions

- L = length of ship, in m, as defined in UR S2
- $L_{LL}$  = length of ship, in m, as defined in ICLL Regulation 3
- x = longitudinal co-ordinate of mid point of assessed structural member measured from aft end of length L or  $L_{LL}$ , as applicable
- $T_{fb}$  = draught, in m, corresponding to the assigned summer load line
- $h_N$  = standard superstructure height in m  
 $= 1,05 + 0,01L_{LL}, 1,8 \leq h_N \leq 2,3$

#### 2.1 Vertical weather design load

The pressure  $p_H$ , in kN/m<sup>2</sup>, on the hatch cover panels is given by ICLL. This may be taken from Tab.1. The vertical weather design load needs not to be combined with cargo loads according to 2.3 and 2.4.

In Fig.1 the positions 1 and 2 are illustrated for an example ship.

Where an increased freeboard is assigned, the design load for hatch covers according to Tab.1 on the actual freeboard deck may be as required for a superstructure deck, provided the summer freeboard is such that the resulting draught will not be greater than that corresponding to the minimum freeboard calculated from an assumed freeboard deck situated at a distance at least equal to the standard superstructure height  $h_N$  below the actual freeboard deck, see Fig.2.

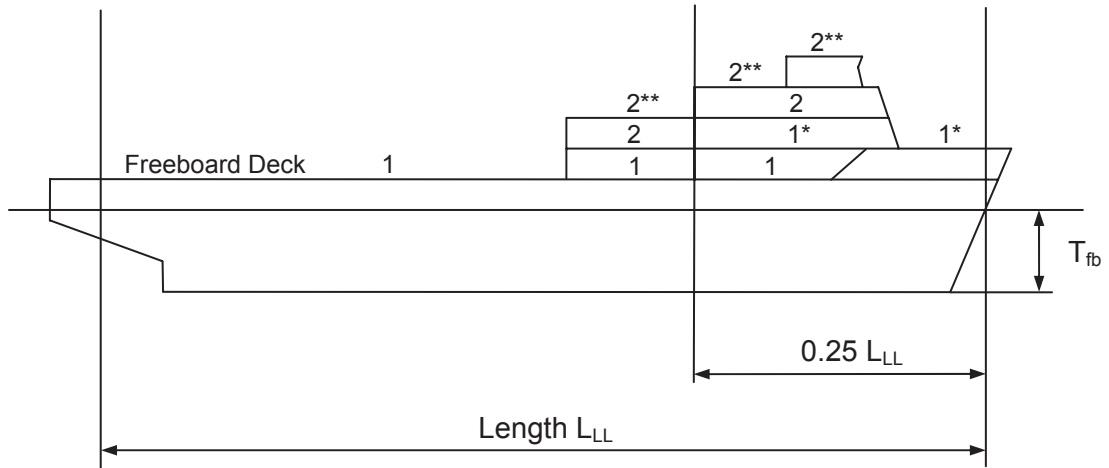
# S21A

(cont)

**Tab. 1 Design load  $p_H$  of weather deck hatches**

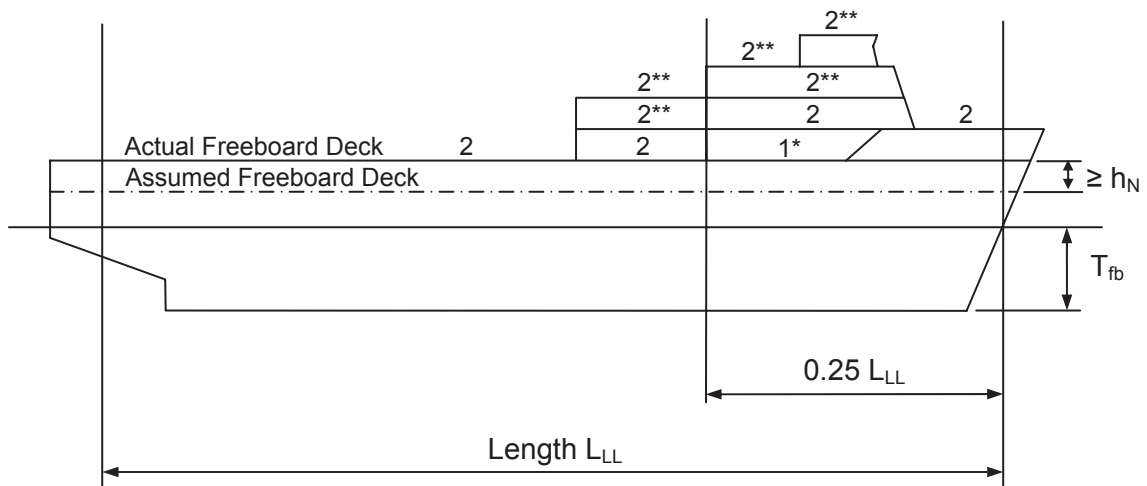
Position	Design load $p_H$ [kN/m <sup>2</sup> ]	
	$\frac{x}{L_{LL}} \leq 0,75$	$0,75 < \frac{x}{L_{LL}} \leq 1,0$
1	for $24 \text{ m} \leq L_{LL} \leq 100 \text{ m}$	
	$\frac{9,81}{76} \cdot (1,5 \cdot L_{LL} + 116)$	on freeboard deck
		$\frac{9,81}{76} \cdot \left[ (4,28 \cdot L_{LL} + 28) \cdot \frac{x}{L_{LL}} - 1,71 \cdot L_{LL} + 95 \right]$
		upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck
		$\frac{9,81}{76} \cdot (1,5 \cdot L_{LL} + 116)$
	for $L_{LL} > 100 \text{ m}$	
$9,81 \cdot 3,5$	on freeboard deck for type B ships according to ICLL	
	$9,81 \cdot \left[ (0,0296 \cdot L_1 + 3,04) \cdot \frac{x}{L_{LL}} - 0,0222 \cdot L_1 + 1,22 \right]$	
	on freeboard deck for ships with less freeboard than type B according to ICLL	
	$9,81 \cdot \left[ (0,1452 \cdot L_1 - 8,52) \cdot \frac{x}{L_{LL}} - 0,1089 \cdot L_1 + 9,89 \right]$	
	$L_1 = L_{LL}$ but not more than 340 m	
	upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck	
	$9,81 \cdot 3,5$	
2	for $24 \text{ m} \leq L_{LL} \leq 100 \text{ m}$	
	$\frac{9,81}{76} \cdot (1,1 \cdot L_{LL} + 87,6)$	
	for $L_{LL} > 100 \text{ m}$	
	$9,81 \cdot 2,6$	
	upon exposed superstructure decks located at least one superstructure standard height above the lowest Position 2 deck	$9,81 \cdot 2,1$

**S21A**  
(cont)



- \* reduced load upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck
- \*\* reduced load upon exposed superstructure decks of vessels with  $L_{LL} > 100$  m located at least one superstructure standard height above the lowest Position 2 deck

**Fig. 1 Positions 1 and 2**



- \* reduced load upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck
- \*\* reduced load upon exposed superstructure decks of vessels with  $L_{LL} > 100$  m located at least one superstructure standard height above the lowest Position 2 deck

**Fig. 2 Positions 1 and 2 for an increased freeboard**

## S21A (cont)

### 2.2 Horizontal weather design load

The horizontal weather design load, in kN/m<sup>2</sup>, for determining the scantlings of outer edge girders (skirt plates) of weather deck hatch covers and of hatch coamings is:

$$p_A = a \cdot c \cdot (b \cdot c_L \cdot f - z)$$

$$f = \frac{L}{25} + 4,1 \quad \text{for } L < 90 \text{ m}$$

$$= 10,75 - \left( \frac{300 - L}{100} \right)^{1,5} \quad \text{for } 90 \text{ m} \leq L < 300 \text{ m}$$

$$= 10,75 \quad \text{for } 300 \text{ m} \leq L < 350 \text{ m}$$

$$= 10,75 - \left( \frac{L - 350}{150} \right)^{1,5} \quad \text{for } 350 \text{ m} \leq L \leq 500 \text{ m}$$

$$c_L = \sqrt{\frac{L}{90}} \quad \text{for } L < 90 \text{ m}$$

$$= 1 \quad \text{for } L \geq 90 \text{ m}$$

$$a = 20 + \frac{L_1}{12} \quad \text{for unprotected front coamings and hatch cover skirt plates}$$

$$a = 10 + \frac{L_1}{12} \quad \text{for unprotected front coamings and hatch cover skirt plates, where the distance from the actual freeboard deck to the summer load line exceeds the minimum non-corrected tabular freeboard according to ICLL by at least one standard superstructure height } h_N$$

$$a = 5 + \frac{L_1}{15} \quad \text{for side and protected front coamings and hatch cover skirt plates}$$

$$a = 7 + \frac{L_1}{100} - 8 \cdot \frac{x'}{L} \quad \text{for aft ends of coamings and aft hatch cover skirt plates abaft amidships}$$

$$a = 5 + \frac{L_1}{100} - 4 \cdot \frac{x'}{L} \quad \text{for aft ends of coamings and aft hatch cover skirt plates forward of amidships}$$

$$L_1 = L, \text{ need not be taken greater than } 300 \text{ m}$$

$$b = 1,0 + \left( \frac{\frac{x'}{L} - 0,45}{C_B + 0,2} \right)^2 \quad \text{for } \frac{x'}{L} < 0,45$$

$$= 1,0 + 1,5 \cdot \left( \frac{\frac{x'}{L} - 0,45}{C_B + 0,2} \right)^2 \quad \text{for } \frac{x'}{L} \geq 0,45$$

$0,6 \leq C_B \leq 0,8$ , when determining scantlings of aft ends of coamings and aft hatch cover skirt plates forward of amidships,  $C_B$  need not be taken less than 0,8.

## S21A (cont)

$x'$  = distance in m between the transverse coaming or hatch cover skirt plate considered and aft end of the length  $L$ . When determining side coamings or side hatch cover skirt plates, the side is to be subdivided into parts of approximately equal length, not exceeding  $0,15 L$  each, and  $x'$  is to be taken as the distance between aft end of the length  $L$  and the centre of each part considered.

$z$  = vertical distance in m from the summer load line to the midpoint of stiffener span, or to the middle of the plate field

$$c = 0,3 + 0,7 \cdot \frac{b'}{B'}$$

$b'$  = breadth of coaming in m at the position considered

$B'$  = actual maximum breadth of ship in m on the exposed weather deck at the position considered.

$b'/B'$  is not to be taken less than 0,25.

The design load  $p_A$  is not to be taken less than the minimum values given in Tab.2.

**Tab. 2 Minimum design load  $p_{Amin}$**

L	$P_{Amin}$ in kN/m <sup>2</sup> for	
	unprotected fronts	elsewhere
$\leq 50$	30	15
$> 50$	$25 + \frac{L}{10}$	$12,5 + \frac{L}{20}$
$< 250$		
$\geq 250$	50	25

### 2.3 Cargo loads

#### 2.3.1 Distributed loads

The load on hatch covers due to cargo loads  $p_L$ , in kN/m<sup>2</sup>, resulting from heave and pitch is to be determined according to the following formula:

$$p_L = p_C (1 + a_v)$$

$p_C$  = uniform cargo load in kN/m<sup>2</sup>

$a_v$  = acceleration addition as follows:

## S21A

(cont)

$$a_v = F \cdot m$$

$$F = 0,11 \cdot \frac{v_0}{\sqrt{L}}$$

$$m = m_0 - 5(m_0 - 1) \frac{x}{L} \quad \text{for } 0 \leq \frac{x}{L} \leq 0,2$$

$$= 1,0 \quad \text{for } 0,2 < \frac{x}{L} \leq 0,7$$

$$= 1 + \frac{m_0 + 1}{0,3} \left[ \frac{x}{L} - 0,7 \right] \quad \text{for } 0,7 < \frac{x}{L} \leq 1,0$$

$$m_0 = 1,5 + F$$

$v_0$  = max. speed at summer load line draught,  $v_0$  is not to be taken less than  $\sqrt{L}$  in kn

### 2.3.2 Point loads

The loads due to single forces  $P$  in kN resulting from heave and pitch (e.g. in case of containers) are to be determined as follows:

$$P = P_s (1 + a_v)$$

$P_s$  = single force in kN

### 2.4 Container loads

Where containers are stowed on hatch covers the following loads in kN due to heave, pitch, and the ship's rolling motion are to be considered, see also Fig.3.

$$A_z = 9,81 \frac{M}{2} \cdot (1 + a_v) \cdot \left( 0,45 - 0,42 \frac{h_m}{b} \right)$$

$$B_z = 9,81 \frac{M}{2} \cdot (1 + a_v) \cdot \left( 0,45 + 0,42 \frac{h_m}{b} \right)$$

$$B_y = 2,4 \cdot M$$

$a_v$  = acceleration addition according to 2.3.1

$M$  = maximum designed mass of container stack in t

$h_m$  = designed height of centre of gravity of stack above hatch cover supports in m

$b$  = distance between foot points in m

$A_z, B_z$  = support forces in z-direction at the forward and aft stack corners

$B_y$  = support force in y-direction at the forward and aft stack corners

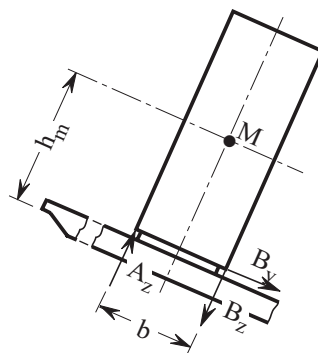
#### Note:

For  $M$  and  $h_m$  it is recommended to apply those values, which are used for the calculations of cargo securing (container lashing). If different assumptions are made for  $M$  and  $h_m$ , the designer has to verify that, in the calculation model, the hatch cover structure is not loaded less than by those values recommended.

## S21A (cont)

When strength of the hatch cover structure is assessed by FE analysis according to 3.5.2 using shell or plane strain elements,  $h_m$  may be taken as the designed height of centre of gravity of stack above the hatch cover top plate.

Values of  $M$  and  $h_m$  applied for the assessment of hatch cover strength are to be shown in the drawings of the hatch covers.



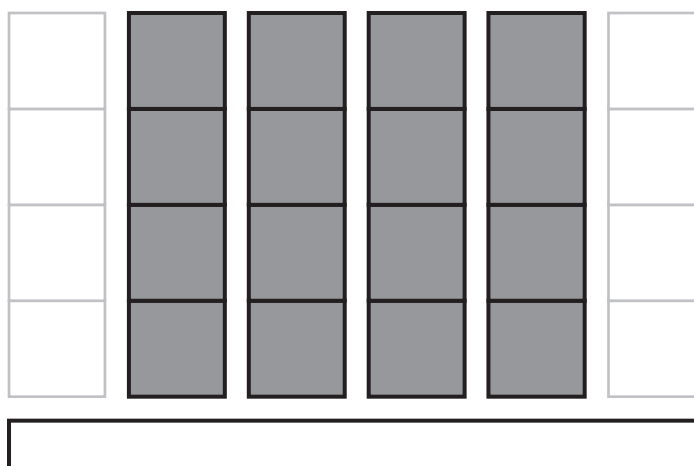
**Fig. 3 Forces due to container loads**

In case of container stacks secured to lashing bridges or carried in cell guides the forces acting on the hatch cover may be specially considered.

Alternatively, container loads may be applied based on accelerations calculated by an individual acceleration analysis for the used lashing system. The individual acceleration analysis shall be carried out by the individual classification society.

### 2.4.1 Load cases with partial loading

The load cases 2.3 and 2.4 are also to be considered for partial non homogeneous loading which may occur in practice, e.g. where specified container stack places are empty. The load case *partial loading of container hatch covers* can be evaluated using a simplified approach, where the hatch cover is loaded without the outermost stacks, see Fig.4.



**Fig. 4 Partial loading of a container hatch cover**



# S21A

(cont)

## 2.5 Loads due to elastic deformations of the ship's hull

Hatch covers, which in addition to the loads according to 2.1 to 2.4 are loaded in the ship's transverse direction by forces due to elastic deformations of the ship's hull, are to be designed such that the sum of stresses does not exceed the permissible values given in 3.1.1.

## 3 Hatch cover strength criteria

### 3.1 Permissible stresses and deflections

#### 3.1.1 Stresses

The equivalent stress  $\sigma_v$  in steel hatch cover structures related to the net thickness shall not exceed  $0,8 \cdot \sigma_F$ , where  $\sigma_F$  is the minimum yield stress, in  $\text{N/mm}^2$ , of the material. For design loads according to 2.2 to 2.5, the equivalent stress  $\sigma_v$  related to the net thickness shall not exceed  $0,9 \cdot \sigma_F$  when the stresses are assessed by means of FEM using plane stress or shell elements.

For steels with a minimum yield stress of more than  $355 \text{ N/mm}^2$ , the value of  $\sigma_F$  to be applied throughout this requirement is subject to the individual classification society but is not to be more than the minimum yield stress of the material.

For beam element calculations and grillage analysis, the equivalent stress may be taken as follows:

$$\sigma_v = \sqrt{\sigma^2 + 3\tau^2} \text{ in N/mm}^2$$

$\sigma$  = normal stress in  $\text{N/mm}^2$   
 $\tau$  = shear stress in  $\text{N/mm}^2$

For FEM calculations, the equivalent stress may be taken as follows:

$$\sigma_v = \sqrt{\sigma_x^2 - \sigma_x \cdot \sigma_y + \sigma_y^2 + 3\tau^2} \text{ in N/mm}^2$$

$\sigma_x$  = normal stress, in  $\text{N/mm}^2$ , in x-direction  
 $\sigma_y$  = normal stress, in  $\text{N/mm}^2$ , in y-direction  
 $\tau$  = shear stress, in  $\text{N/mm}^2$ , in the x-y plane

Indices x and y are coordinates of a two-dimensional Cartesian system in the plane of the considered structural element.

In case of FEM calculations using shell or plane strain elements, the stresses are to be read from the centre of the individual element. Where shell elements are used, the stresses are to be evaluated at the mid plane of the element.

Stress concentrations are to be assessed to the satisfaction of the individual classification society.

## S21A (cont)

### 3.1.2 Deflection

The vertical deflection of primary supporting members due to the vertical weather design load according to 2.1 is to be not more than  $0.0056 \cdot l_g$  where  $l_g$  is the greatest span of primary supporting members.

**Note:**

Where hatch covers are arranged for carrying containers and mixed stowage is allowed, i.e., a 40'-container stowed on top of two 20'-containers, particular attention should be paid to the deflections of hatch covers. Further the possible contact of deflected hatch covers with in hold cargo has to be observed.

### 3.2 Local net plate thickness

The local net plate thickness  $t$ , in mm, of the hatch cover top plating is not to be less than:

$$t = F_p \cdot 15,8 \cdot s \sqrt{\frac{p}{0,95 \cdot \sigma_F}}$$

and to be not less than 1% of the spacing of the stiffener or 6 mm if that be greater.

$F_p$  = factor for combined membrane and bending response  
= 1,5 in general

=  $1,9 \cdot \frac{\sigma}{\sigma_a}$ , for  $\frac{\sigma}{\sigma_a} \geq 0,8$  for the attached plate flange of primary supporting members

$s$  = stiffener spacing in m

$p$  = pressure  $p_H$  and  $p_L$ , in  $\text{kN/m}^2$ , as defined in 2.

$\sigma$  = normal stress, in  $\text{N/mm}^2$ , of hatch cover top plating

$\sigma_a$  =  $0,8 \cdot \sigma_F$  in  $\text{N/mm}^2$

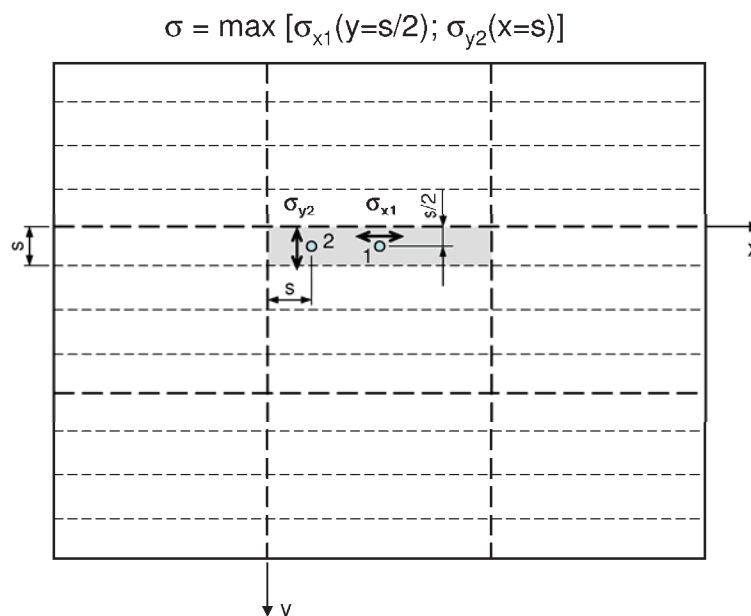
For flange plates under compression sufficient buckling strength according to 3.6 is to be demonstrated.

**Note:**

The normal stress  $\sigma$  of the hatch cover plating may be determined in a distance  $s$  from webs of adjacent primary supporting members perpendicular to secondary stiffeners and in a distance  $s/2$  from the web of an adjacent primary supporting member parallel to secondary stiffeners, refer to Fig.5. The greater of both stresses is to be taken. For the distribution of normal stress  $\sigma$  between two parallel girders, refer to 3.6.3.2.

## S21A

(cont)



**Fig. 5 Determination of normal stress of the hatch cover plating**

### 3.2.1 Local net plate thickness of hatch covers for wheel loading

The local net plate thickness of hatch covers for wheel loading have to be derived from the individual classification society's rules.

### 3.2.2 Lower plating of double skin hatch covers and box girders

The thickness to fulfill the strength requirements is to be obtained from the calculation according to 3.5 under consideration of permissible stresses according to 3.1.1.

The net thickness must not be less than the larger of the following values when the lower plating is taken into account as a strength member of the hatch cover:

$$t = 6,5 \cdot s \text{ in mm}$$

$$t_{\min} = 5 \text{ mm}$$

$s$  = stiffener spacing in m

When the lower plating is not considered as a strength member of the hatch cover, the thickness of the lower plating should be determined according to the individual class society's rules.

### 3.3 Net scantling of secondary stiffeners

The net section modulus  $Z$  and net shear area  $A_s$  of uniformly loaded hatch cover stiffeners constraint at both ends must not be less than:

$$Z = \frac{104}{\sigma_F} \cdot s \cdot l^2 \cdot p \text{ in cm}^3$$

$$A_s = \frac{10 \cdot s \cdot l \cdot p}{\sigma_F} \text{ in cm}^2$$

## S21A (cont)

- l = secondary stiffener span, in m, to be taken as the spacing, in m, of primary supporting members or the distance between a primary supporting member and the edge support, as applicable.
- s = secondary stiffener spacing in m
- p = pressure  $p_H$  and  $p_L$ , in  $\text{kN/m}^2$ , as defined in 2.

The net section modulus of the secondary stiffeners is to be determined based on an attached plate width assumed equal to the stiffener spacing.

For flat bar secondary stiffeners and buckling stiffeners, the ratio  $h/t_w$  is to be not greater than  $15 \cdot k^{0.5}$ , where:

- h = height of the stiffener  
 $t_w$  = net thickness of the stiffener  
 $k = 235/\sigma_F$

Stiffeners parallel to primary supporting members and arranged within the effective breadth according to 3.5.1 must be continuous at crossing primary supporting member and may be regarded for calculating the cross sectional properties of primary supporting members. It is to be verified that the combined stress of those stiffeners induced by the bending of primary supporting members and lateral pressures does not exceed the permissible stresses according to 3.1.1.

For hatch cover stiffeners under compression sufficient safety against lateral and torsional buckling according 3.6.3 is to be verified.

For hatch covers subject to wheel loading stiffener scantlings are to be determined by direct calculations under consideration of the permissible stresses according to 3.1.1 or are to be determined according to the individual class society's rules.

### 3.4 Net scantling of primary supporting members

#### 3.4.1 Primary supporting members

Scantlings of primary supporting members are obtained from calculations according to 3.5 under consideration of permissible stresses according to 3.1.1.

For all components of primary supporting members sufficient safety against buckling must be verified according to 3.6. For biaxial compressed flange plates this is to be verified within the effective widths according to 3.6.3.2.

The net thickness, in mm, of webs of primary supporting members shall not be less than:

$$t = 6,5 \cdot s \text{ in mm}$$

$$t_{\min} = 5 \text{ mm}$$

s = stiffener spacing in m

## S21A (cont)

### 3.4.2 Edge girders (Skirt plates)

Scantlings of edge girders are obtained from the calculations according to 3.5 under consideration of permissible stresses according to 3.1.1.

The net thickness, in mm, of the outer edge girders exposed to wash of sea shall not be less than the largest of the following values:

$$t = 15,8 \cdot s \cdot \sqrt{\frac{p_A}{0,95 \cdot \sigma_F}}$$

$$t = 8,5 \cdot s \text{ in mm}$$

$$t_{min} = 5 \text{ mm}$$

$p_A$  = horizontal pressure as defined in 2.2

$s$  = stiffener spacing in m

The stiffness of edge girders is to be sufficient to maintain adequate sealing pressure between securing devices. The moment of inertia, in  $\text{cm}^4$ , of edge girders is not to be less than:

$$I = 6 \cdot q \cdot s_{SD}^4$$

$q$  = packing line pressure in N/mm, minimum 5 N/mm

$s_{SD}$  = spacing, in m, of securing devices

### 3.5 Strength calculations

Strength calculation for hatch covers may be carried out by either, using beam theory, grillage analysis or FEM.

#### 3.5.1 Effective cross-sectional properties for calculation by beam theory or grillage analysis

Cross-sectional properties are to be determined considering the effective breadth. Cross sectional areas of secondary stiffeners parallel to the primary supporting member under consideration within the effective breadth can be included, refer Fig.7.

The effective breadth of plating  $e_m$  of primary supporting members is to be determined according to Tab.3, considering the type of loading. Special calculations may be required for determining the effective breadth of one-sided or non-symmetrical flanges.

The effective cross sectional area of plates is not to be less than the cross sectional area of the face plate.

For flange plates under compression with secondary stiffeners perpendicular to the web of the primary supporting member, the effective width is to be determined according to 3.6.3.2.

Tab. 3 Effective breadth  $e_m$  of plating of primary supporting members

$l/e$	0	1	2	3	4	5	6	7	$\geq 8$
$e_{m1}/e$	0	0.36	0.64	0.82	0.91	0.96	0.98	1.00	1.00
$e_{m2}/e$	0	0.20	0.37	0.52	0.65	0.75	0.84	0.89	0.90

$e_{m1}$  is to be applied where primary supporting members are loaded by uniformly distributed loads or else by not less than 6 equally spaced single loads  
 $e_{m2}$  is to be applied where primary supporting members are loaded by 3 or less single loads  
 Intermediate values may be obtained by direct interpolation.  
 $l$  length of zero-points of bending moment curve:  
 $l = l_0$  for simply supported primary supporting members  
 $l = 0,6 \cdot l_0$  for primary supporting members with both ends constraint, where  $l_0$  is the unsupported length of the primary supporting member  
 $e$  width of plating supported, measured from centre to centre of the adjacent unsupported fields

### 3.5.2 General requirements for FEM calculations

For strength calculations of hatch covers by means of finite elements, the cover geometry shall be idealized as realistically as possible. Element size must be appropriate to account for effective breadth. In no case element width shall be larger than stiffener spacing. In way of force transfer points and cutouts the mesh has to be refined where applicable. The ratio of element length to width shall not exceed 4.

The element height of webs of primary supporting member must not exceed one-third of the web height. Stiffeners, supporting plates against pressure loads, have to be included in the idealization. Buckling stiffeners may be disregarded for the stress calculation.

### 3.6 Buckling strength of hatch cover structures

For hatch cover structures sufficient buckling strength is to be demonstrated.

The buckling strength assessment of coaming parts is to be done according to the individual class society's rules.

#### Definitions

$a$  = length of the longer side of a single plate field in mm (x-direction)

$b$  = breadth of the shorter side of a single plate field in mm (y-direction)

$\alpha$  = aspect ratio of single plate field

$$= a / b$$

$n$  = number of single plate field breadths within the partial or total plate field

$t$  = net plate thickness in mm

$\sigma_x$  = membrane stress, in N/mm<sup>2</sup>, in x-direction

$\sigma_y$  = membrane stress, in N/mm<sup>2</sup>, in y-direction

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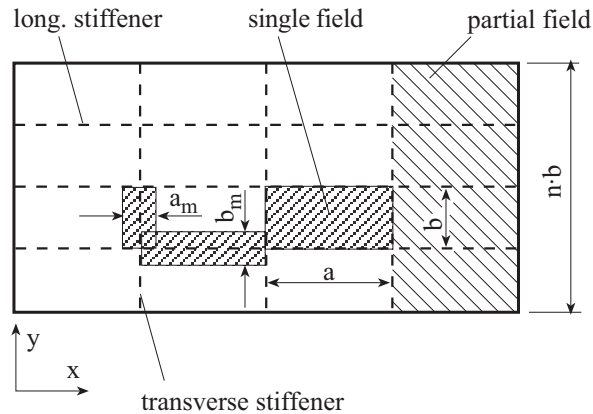
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$\tau$  = shear stress, in N/mm<sup>2</sup>, in the x-y plane

$E$  = modulus of elasticity, in N/mm<sup>2</sup>, of the material  
 = 2,06·10<sup>5</sup> N/mm<sup>2</sup> for steel

$\sigma_F$  = minimum yield stress, in N/mm<sup>2</sup>, of the material

Compressive and shear stresses are to be taken positive, tension stresses are to be taken negative.



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

**Fig. 6 General arrangement of panel**

**Note:**

If stresses in the x- and y-direction already contain the Poisson-effect (calculated using FEM), the following modified stress values may be used. Both stresses  $\sigma_x^*$  and  $\sigma_y^*$  are to be compressive stresses, in order to apply the stress reduction according to the following formulae:

$$\sigma_x = (\sigma_x^* - 0,3 \cdot \sigma_y^*) / 0,91$$

$$\sigma_y = (\sigma_y^* - 0,3 \cdot \sigma_x^*) / 0,91$$

$\sigma_x^*$ ,  $\sigma_y^*$  = stresses containing the Poisson-effect

Where compressive stress fulfils the condition  $\sigma_y^* < 0,3 \sigma_x^*$ , then  $\sigma_y = 0$  and  $\sigma_x = \sigma_x^*$

Where compressive stress fulfils the condition  $\sigma_x^* < 0,3 \sigma_y^*$ , then  $\sigma_x = 0$  and  $\sigma_y = \sigma_y^*$

$F_1$  = correction factor for boundary condition at the longitudinal stiffeners according to Tab.4.

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Tab. 4 Correction factor  $F_1$

Stiffeners sniped at both ends	1,00
Guidance values <sup>1</sup> where both ends are effectively connected to adjacent structures	1,05 for flat bars 1,10 for bulb sections 1,20 for angle and tee-sections 1,30 for u-type sections <sup>2</sup> and girders of high rigidity
An average value of $F_1$ is to be used for plate panels having different edge stiffeners	
<sup>1</sup> Exact values may be determined by direct calculations <sup>2</sup> Higher value may be taken if it is verified by a buckling strength check of the partial plate field using non-linear FEA and deemed appropriate by the individual class society but not greater than 2.0	

$\sigma_e$  = reference stress, in  $\text{N/mm}^2$ , taken equal to

$$= 0,9 \cdot E \left( \frac{t}{b} \right)^2$$

$\Psi$  = edge stress ratio taken equal to

$$= \sigma_2 / \sigma_1 \text{ where}$$

$\sigma_1$  = maximum compressive stress

$\sigma_2$  = minimum compressive stress or tension stress

S = safety factor (based on net scantling approach), taken equal to

= 1.25 for hatch covers when subjected to the vertical weather design load according to 2.1

= 1.10 for hatch covers when subjected to loads according to 2.2 to 2.5

$\lambda$  = reference degree of slenderness, taken equal to:

$$= \sqrt{\frac{\sigma_F}{K \cdot \sigma_e}}$$

K = buckling factor according to Tab.6.

### 3.6.1 Proof of top and lower hatch cover plating

Proof is to be provided that the following condition is complied with for the single plate field a · b:

$$\left( \frac{|\sigma_x| \cdot S}{\kappa_x \cdot \sigma_F} \right)^{e1} + \left( \frac{|\sigma_y| \cdot S}{\kappa_y \cdot \sigma_F} \right)^{e2} - B \left( \frac{\sigma_x \cdot \sigma_y \cdot S^2}{\sigma_F^2} \right) + \left( \frac{|\tau| \cdot S \cdot \sqrt{3}}{\kappa_\tau \cdot \sigma_F} \right)^{e3} \leq 1,0$$

The first two terms and the last term of the above condition shall not exceed 1,0.



**S21A**  
(cont)

The reduction factors  $\kappa_x$ ,  $\kappa_y$  and  $\kappa_\tau$  are given in Tab.6.

Where  $\sigma_x \leq 0$  (tension stress),  $\kappa_x = 1,0$ .

Where  $\sigma_y \leq 0$  (tension stress),  $\kappa_y = 1,0$ .

The exponents  $e_1$ ,  $e_2$  and  $e_3$  as well as the factor  $B$  are to be taken as given by Tab.5.

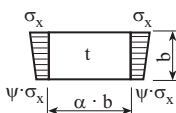
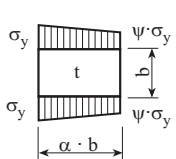
**Tab. 5 Coefficients  $e_1$ ,  $e_2$ ,  $e_3$  and factor  $B$**

Exponents $e_1$ - $e_3$ and factor $B$	Plate panel
$e_1$	$1 + \kappa_x^4$
$e_2$	$1 + \kappa_y^4$
$e_3$	$1 + \kappa_x \cdot \kappa_y \cdot \kappa_\tau^2$
$B$ $\sigma_x$ and $\sigma_y$ positive (compression stress)	$(\kappa_x \cdot \kappa_y)^5$
$B$ $\sigma_x$ or $\sigma_y$ negative (tension stress)	1

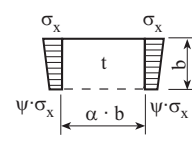
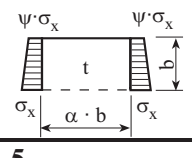
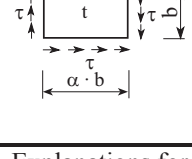
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**Tab. 6 Buckling and reduction factors for plane elementary plate panels**

Buckling-Load Case	Edge stress ratio $\psi$	Asp. ratio $\alpha = a/b$	Buckling factor K	Reduction factor $\kappa$
<b>1</b> 	$1 \geq \psi \geq 0$	$\alpha \geq 1$	$K = \frac{8,4}{\psi + 1,1}$	$\kappa_x = 1$ for $\lambda \leq \lambda_c$ $\kappa_x = c \left( \frac{1}{\lambda} - \frac{0,22}{\lambda^2} \right)$ for $\lambda > \lambda_c$ $c = (1,25 - 0,12\psi) \leq 1,25$ $\lambda_c = \frac{c}{2} \left( 1 + \sqrt{1 - \frac{0,88}{c}} \right)$
	$0 > \psi > -1$		$K = 7,63 - \psi(6,26 - 10\psi)$	
	$\psi \leq -1$		$K = (1 - \psi)^2 \cdot 5,975$	
<b>2</b> 	$1 \geq \psi \geq 0$	$\alpha \geq 1$	$K = F_1 \left( 1 + \frac{1}{\alpha^2} \right)^2 \cdot \frac{2,1}{(\psi + 1,1)}$	$\kappa_y = c \left( \frac{1}{\lambda} - \frac{R + F^2(H - R)}{\lambda^2} \right)$ $c = (1,25 - 0,12\psi) \leq 1,25$
	$0 > \psi > -1$	$1 \leq \alpha \leq 1,5$	$K = F_1 \left[ \left( 1 + \frac{1}{\alpha^2} \right)^2 \cdot \frac{2,1(1 + \psi)}{1,1} - \frac{\psi}{\alpha^2} (13,9 - 10\psi) \right]$	$R = \lambda \left( 1 - \frac{\lambda}{c} \right)$ for $\lambda < \lambda_c$ $R = 0,22$ for $\lambda \geq \lambda_c$ $\lambda_c = \frac{c}{2} \left( 1 + \sqrt{1 - \frac{0,88}{c}} \right)$
		$\alpha > 1,5$	$K = F_1 \left[ \left( 1 + \frac{1}{\alpha^2} \right)^2 \cdot \frac{2,1(1 + \psi)}{1,1} - \frac{\psi}{\alpha^2} \cdot (5,87 + 1,87\alpha^2 + \frac{8,6}{\alpha^2} - 10\psi) \right]$	$F = \left( 1 - \frac{K}{0,91 \lambda_p^2} - 1 \right) \cdot c_1 \geq 0$ $\lambda_p^2 = \lambda^2 - 0,5$ for $1 \leq \lambda_p^2 \leq 3$ $c_1 = \left( 1 - \frac{F_1}{\alpha} \right) \geq 0$ $H = \lambda - \frac{2\lambda}{c \left( T + \sqrt{T^2 - 4} \right)} \geq R$ $T = \lambda + \frac{14}{15\lambda} + \frac{1}{3}$
	$\psi \leq -1$	$1 \leq \alpha \leq \frac{3(1 - \psi)}{4}$	$K = F_1 \left( \frac{1 - \psi}{\alpha} \right)^2 \cdot 5,975$	
		$\alpha > \frac{3(1 - \psi)}{4}$	$K = F_1 \left[ \left( \frac{1 - \psi}{\alpha} \right)^2 \cdot 3,9675 + 0,5375 \left( \frac{1 - \psi}{\alpha} \right)^4 + 1,87 \right]$	
	Explanations for boundary conditions			----- plate edge free ————— plate edge simply supported

## S21A (cont)

<b>3</b> 	$1 \geq \psi \geq 0$	$\alpha > 0$	$K = \frac{4 \left( 0,425 + \frac{1}{\alpha^2} \right)}{3\psi + 1}$	$\kappa_x = 1$ for $\lambda \leq 0,7$ $\kappa_x = \frac{1}{\lambda^2 + 0,51}$ for $\lambda > 0,7$
	$0 > \psi \geq -1$		$K = 4 \left( 0,425 + \frac{1}{\alpha^2} \right) (1 + \psi) - 5\psi(1 - 3,42\psi)$	
<b>4</b> 	$1 \geq \psi \geq -1$	$\alpha > 0$	$K = \left( 0,425 + \frac{1}{\alpha^2} \right) \frac{3 - \psi}{2}$	
<b>5</b> 	≡		$K = K_\tau \cdot \sqrt{3}$	$\kappa_\tau = 1$ for $\lambda \leq 0,84$ $\kappa_\tau = \frac{0,84}{\lambda}$ for $\lambda > 0,84$
		$\alpha \geq 1$	$K_\tau = \left[ 5,34 + \frac{4}{\alpha^2} \right]$	
		$0 < \alpha < 1$	$K_\tau = \left[ 4 + \frac{5,34}{\alpha^2} \right]$	
Explanations for boundary conditions		- - - - - plate edge free ————— plate edge simply supported		

### 3.6.2 Webs and flanges of primary supporting members

For non-stiffened webs and flanges of primary supporting members sufficient buckling strength as for the hatch cover top and lower plating is to be demonstrated according to 3.6.1.

### 3.6.3 Proof of partial and total fields of hatch covers

#### 3.6.3.1 Longitudinal and transverse secondary stiffeners

It is to be demonstrated that the continuous longitudinal and transverse stiffeners of partial and total plate fields comply with the conditions set out in 3.6.3.3 through 3.6.3.4.

#### 3.6.3.2 Effective width of top and lower hatch cover plating

For demonstration of buckling strength according to 3.6.3.3 through 3.6.3.4 the effective width of plating may be determined by the following formulae:

$$b_m = \kappa_x \cdot b \quad \text{for longitudinal stiffeners}$$

$$a_m = \kappa_y \cdot a \quad \text{for transverse stiffeners}$$

see also Fig.6.

The effective width of plating is not to be taken greater than the value obtained from 3.5.1.

The effective width  $e'_m$  of stiffened flange plates of primary supporting members may be determined as follows:

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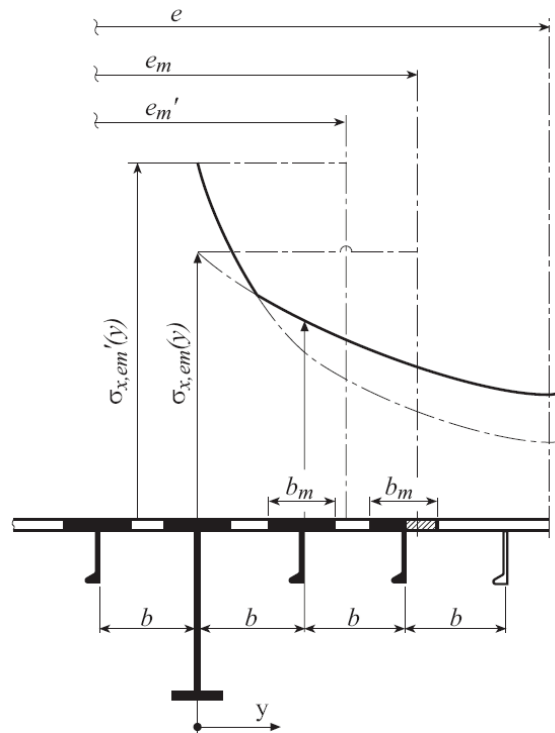


Fig. 7 Stiffening parallel to web of primary supporting member

$$b < e_m$$

$$e'_m = n \cdot b_m$$

$n$  = integer number of stiffener spacings  $b$  inside the effective breadth  $e_m$  according to 3.5.1

$$= \text{int} \left( \frac{e_m}{b} \right)$$

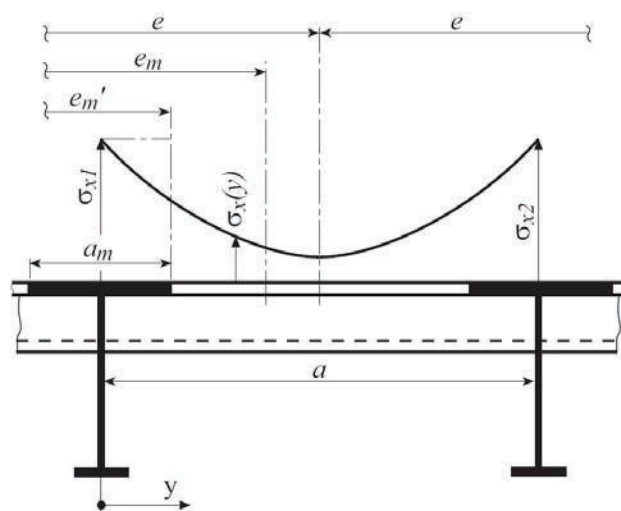


Fig. 8 Stiffening perpendicular to web of primary supporting member

## S21A (cont)

$$a \geq e_m$$

$$e'_m = n \cdot a_m < e_m$$

$$n = 2,7 \cdot \frac{e_m}{a} \leq 1$$

$e$  = width of plating supported according to 3.5.1

For  $b \geq e_m$  or  $a < e_m$ , respectively,  $b$  and  $a$  have to be exchanged.

$a_m$  and  $b_m$  for flange plates are in general to be determined for  $\psi = 1$ .

### Note:

*Scantlings of plates and stiffeners are in general to be determined according to the maximum stresses  $\sigma_x(y)$  at webs of primary supporting member and stiffeners, respectively. For stiffeners with spacing  $b$  under compression arranged parallel to primary supporting members no value less than  $0,25 \cdot \sigma_F$  shall be inserted for  $\sigma_x(y=b)$ .*

*The stress distribution between two primary supporting members can be obtained by the following formula:*

$$\sigma_x(y) = \sigma_{x1} \cdot \left\{ 1 - \frac{y}{e} \left[ 3 + c_1 - 4 \cdot c_2 - 2 \frac{y}{e} (1 + c_1 - 2 c_2) \right] \right\}$$

$$c_1 = \frac{\sigma_{x2}}{\sigma_{x1}} \quad 0 \leq c_1 \leq 1$$

$$c_2 = \frac{1,5}{e} \cdot (e''_{m1} + e''_{m2}) - 0,5$$

$e''_{m1}$  = proportionate effective breadth  $e_{m1}$  or proportionate effective width  $e'_{m1}$  of primary supporting member 1 within the distance  $e$ , as appropriate

$e''_{m2}$  = proportionate effective breadth  $e_{m2}$  or proportionate effective width  $e'_{m2}$  of primary supporting member 2 within the distance  $e$ , as appropriate

$\sigma_{x1}, \sigma_{x2}$  = normal stresses in flange plates of adjacent primary supporting member 1 and 2 with spacing  $e$ , based on cross-sectional properties considering the effective breadth or effective width, as appropriate

$y$  = distance of considered location from primary supporting member 1

*Shear stress distribution in the flange plates may be assumed linearly.*

### 3.6.3.3 Lateral buckling of secondary stiffeners

$$\frac{\sigma_a + \sigma_b}{\sigma_F} S \leq 1$$

$\sigma_a$  = uniformly distributed compressive stress, in  $\text{N/mm}^2$  in the direction of the stiffener axis.

$\sigma_a$  =  $\sigma_x$  for longitudinal stiffeners

$\sigma_a$  =  $\sigma_y$  for transverse stiffeners

## S21A

(cont)

$$\begin{aligned}\sigma_b &= \text{bending stress, in N/mm}^2, \text{ in the stiffener} \\ &= \frac{M_0 + M_1}{Z_{st} \cdot 10^3}\end{aligned}$$

$M_0$  = bending moment, in Nmm, due to the deformation  $w$  of stiffener, taken equal to:

$$M_0 = F_{Ki} \frac{p_z \cdot w}{c_f - p_z} \quad \text{with } (c_f - p_z) > 0$$

$M_1$  = bending moment, in Nmm, due to the lateral load  $p$  equal to:

$$M_1 = \frac{p \cdot b \cdot a^2}{24 \cdot 10^3} \quad \text{for longitudinal stiffeners}$$

$$M_1 = \frac{p \cdot a(n \cdot b)^2}{c_s \cdot 8 \cdot 10^3} \quad \text{for transverse stiffeners}$$

$n$  is to be taken equal to 1 for ordinary transverse stiffeners.

$p$  = lateral load in kN/m<sup>2</sup>

$F_{Ki}$  = ideal buckling force, in N, of the stiffener

$$F_{Kix} = \frac{\pi^2}{a^2} \cdot E \cdot I_x \cdot 10^4 \quad \text{for longitudinal stiffeners}$$

$$F_{Kiy} = \frac{\pi^2}{(n \cdot b)^2} \cdot E \cdot I_y \cdot 10^4 \quad \text{for transverse stiffeners}$$

$I_x, I_y$  = net moments of inertia, in cm<sup>4</sup>, of the longitudinal or transverse stiffener including effective width of attached plating according to 3.6.3.2.  $I_x$  and  $I_y$  are to comply with the following criteria:

$$I_x \geq \frac{b \cdot t^3}{12 \cdot 10^4}$$

$$I_y \geq \frac{a \cdot t^3}{12 \cdot 10^4}$$

$p_z$  = nominal lateral load, in N/mm<sup>2</sup>, of the stiffener due to  $\sigma_x$ ,  $\sigma_y$  and  $\tau$

$$p_{zx} = \frac{t}{b} \left( \sigma_{xl} \left( \frac{\pi \cdot b}{a} \right)^2 + 2 \cdot c_y \cdot \sigma_y + \sqrt{2} \tau_1 \right) \quad \text{for longitudinal stiffeners}$$

$$p_{zy} = \frac{t}{a} \left( 2 \cdot c_x \cdot \sigma_{xl} + \sigma_y \left( \frac{\pi \cdot a}{n \cdot b} \right)^2 \left( 1 + \frac{A_y}{a \cdot t} \right) + \sqrt{2} \tau_1 \right) \quad \text{for transverse stiffeners}$$

$$\sigma_{xl} = \sigma_x \left( 1 + \frac{A_x}{b \cdot t} \right)$$

$c_x, c_y$  = factor taking into account the stresses perpendicular to the stiffener's axis and distributed variable along the stiffener's length

## S21A

(cont)

$$= 0,5 \cdot (1 + \Psi) \quad \text{for } 0 \leq \Psi \leq 1$$

$$= \frac{0,5}{1 - \Psi} \quad \text{for } \Psi < 0$$

$A_x, A_y$  = net sectional area, in  $\text{mm}^2$ , of the longitudinal or transverse stiffener, respectively, without attached plating

$$\tau_1 = \left[ \tau - t \sqrt{\sigma_F \cdot E \left( \frac{m_1}{a^2} + \frac{m_2}{b^2} \right)} \right] \geq 0$$

for longitudinal stiffeners:

$$\frac{a}{b} \geq 2,0 \quad : \quad m_1 = 1,47 \quad m_2 = 0,49$$

$$\frac{a}{b} < 2,0 \quad : \quad m_1 = 1,96 \quad m_2 = 0,37$$

for transverse stiffeners:

$$\frac{a}{n \cdot b} \geq 0,5 \quad : \quad m_1 = 0,37 \quad m_2 = \frac{1,96}{n^2}$$

$$\frac{a}{n \cdot b} < 0,5 \quad : \quad m_1 = 0,49 \quad m_2 = \frac{1,47}{n^2}$$

$$w = w_0 + w_1$$

$w_0$  = assumed imperfection in mm

$$w_{0x} \leq \min\left(\frac{a}{250}, \frac{b}{250}, 10\right) \quad \text{for longitudinal stiffeners}$$

$$w_{0y} \leq \min\left(\frac{a}{250}, \frac{n \cdot b}{250}, 10\right) \quad \text{for transverse stiffeners}$$

### Note:

For stiffeners sniped at both ends  $w_0$  must not be taken less than the distance from the midpoint of plating to the neutral axis of the profile including effective width of plating.

$w_1$  = Deformation of stiffener, in mm, at midpoint of stiffener span due to lateral load  $p$ .

In case of uniformly distributed load the following values for  $w_1$  may be used:

$$w_1 = \frac{p \cdot b \cdot a^4}{384 \cdot 10^7 \cdot E \cdot I_x} \quad \text{for longitudinal stiffeners}$$

$$w_1 = \frac{5 \cdot a \cdot p \cdot (n \cdot b)^4}{384 \cdot 10^7 \cdot E \cdot I_y \cdot c_s^2} \quad \text{for transverse stiffeners}$$

$c_f$  = elastic support provided by the stiffener, in  $\text{N}/\text{mm}^2$

i. For longitudinal stiffeners:

$$c_{fx} = F_{Kix} \cdot \frac{\pi^2}{a^2} \cdot (1 + c_{px})$$

## S21A

(cont)

$$c_{px} = \frac{1}{1 + \frac{0,91 \cdot \left( \frac{12 \cdot 10^4 \cdot I_x}{t^3 \cdot b} - 1 \right)}{c_{xa}}}$$

$$c_{xa} = \left[ \frac{a}{2b} + \frac{2b}{a} \right]^2 \quad \text{for } a \geq 2b$$

$$c_{xa} = \left[ 1 + \left( \frac{a}{2b} \right)^2 \right]^2 \quad \text{for } a < 2b$$

ii. For transverse stiffeners:

$$c_{fy} = c_s \cdot F_{Kiy} \cdot \frac{\pi^2}{(n \cdot b)^2} \cdot (1 + c_{py})$$

$$c_{py} = \frac{1}{1 + \frac{0,91 \cdot \left( \frac{12 \cdot 10^4 \cdot I_y}{t^3 \cdot a} - 1 \right)}{c_{ya}}}$$

$$c_{ya} = \left[ \frac{n \cdot b}{2a} + \frac{2a}{n \cdot b} \right]^2 \quad \text{for } n \cdot b \geq 2a$$

$$c_{ya} = \left[ 1 + \left( \frac{n \cdot b}{2a} \right)^2 \right]^2 \quad \text{for } n \cdot b < 2a$$

$c_s$  = factor accounting for the boundary conditions of the transverse stiffener

= 1,0 for simply supported stiffeners

= 2,0 for partially constraint stiffeners

$Z_{st}$  = net section modulus of stiffener (long. or transverse) in  $\text{cm}^3$  including effective width of plating according to 3.6.3.2.

If no lateral load  $p$  is acting the bending stress  $\sigma_b$  is to be calculated at the midpoint of the stiffener span for that fibre which results in the largest stress value. If a lateral load  $p$  is acting, the stress calculation is to be carried out for both fibres of the stiffener's cross sectional area (if necessary for the biaxial stress field at the plating side).

### 3.6.3.4 Torsional buckling of secondary stiffeners

#### 3.6.3.4.1 Longitudinal secondary stiffeners

The longitudinal ordinary stiffeners are to comply with the following criteria:

$$\frac{\sigma_x \cdot S}{\kappa_T \cdot \sigma_F} \leq 1,0$$

$\kappa_T$  = coefficient taken equal to:



# S21A

(cont)

$$\kappa_T = 1,0 \text{ for } \lambda_T \leq 0,2$$

$$\kappa_T = \frac{1}{\Phi + \sqrt{\Phi^2 - \lambda_T^2}} \text{ for } \lambda_T > 0,2$$

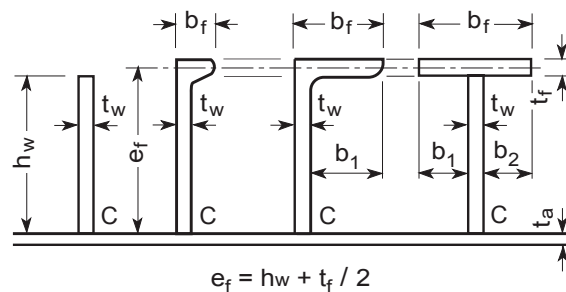
$$\Phi = 0,5(1 + 0,21(\lambda_T - 0,2) + \lambda_T^2)$$

$\lambda_T$  = reference degree of slenderness taken equal to:

$$\lambda_T = \sqrt{\frac{\sigma_F}{\sigma_{KiT}}}$$

$$\sigma_{KiT} = \frac{E}{I_p} \left( \frac{\pi^2 \cdot I_\omega \cdot 10^2}{a^2} \varepsilon + 0,385 \cdot I_T \right), \text{ in N/mm}^2$$

For  $I_p$ ,  $I_T$ ,  $I_\omega$  see Fig.9 and Tab.7.



**Fig. 9 Dimensions of stiffener**

$I_p$  = net polar moment of inertia of the stiffener, in  $\text{cm}^4$ , related to the point C

$I_T$  = net St. Venant's moment of inertia of the stiffener, in  $\text{cm}^4$

$I_\omega$  = net sectorial moment of inertia of the stiffener, in  $\text{cm}^6$ , related to the point C

$\varepsilon$  = degree of fixation taken equal to:

$$\varepsilon = 1 + 10^{-3} \sqrt{\frac{a^4}{\frac{3}{4} \pi^4 \cdot I_\omega \left( \frac{b}{t^3} + \frac{4h_w}{3t_w^3} \right)}}$$

$h_w$  = web height, in mm

$t_w$  = net web thickness, in mm

$b_f$  = flange breadth, in mm

$t_f$  = net flange thickness, in mm

$A_w$  = net web area equal to:  $A_w = h_w \cdot t_w$

$A_f$  = net flange area equal to:  $A_f = b_f \cdot t_f$

$$e_f = h_w + \frac{t_f}{2}, \text{ in mm}$$

# S21A

(cont)

**Tab. 7 Moments of inertia**

Section	$I_P$	$I_T$	$I_\omega$
Flat bar	$\frac{h_w^3 \cdot t_w}{3 \cdot 10^4}$	$\frac{h_w \cdot t_w^3}{3 \cdot 10^4} \left(1 - 0,63 \frac{t_w}{h_w}\right)$	$\frac{h_w^3 \cdot t_w^3}{36 \cdot 10^6}$
Sections with bulb or flange	$\left(\frac{A_w \cdot h_w^2}{3} + A_f \cdot e_f^2\right) 10^{-4}$	$\frac{h_w \cdot t_w^3}{3 \cdot 10^4} \left(1 - 0,63 \frac{t_w}{h_w}\right) + \frac{b_f \cdot t_f^3}{3 \cdot 10^4} \left(1 - 0,63 \frac{t_f}{b_f}\right)$	for bulb and angle sections: $\frac{A_f \cdot e_f^2 \cdot b_f^2}{12 \cdot 10^6} \left(\frac{A_f + 2.6 A_w}{A_f + A_w}\right)$ for tee-sections: $\frac{b_f^3 \cdot t_f \cdot e_f^2}{12 \cdot 10^6}$

### 3.6.3.4.2 Transverse secondary stiffeners

For transverse secondary stiffeners loaded by compressive stresses and which are not supported by longitudinal stiffeners, sufficient torsional buckling strength is to be demonstrated analogously in accordance with 3.6.3.4.1.

## 4 Details of hatch covers

### 4.1 Container foundations on hatch covers

Container foundations are to be designed to the satisfaction of the individual class society. The substructures of container foundations are to be designed for cargo and container loads according to 2, applying the permissible stresses according to 3.1.1.

### 4.2 Weather tightness

Further to the following requirements IACS Rec. 14 is applicable to hatch covers.

#### 4.2.1 Packing material (General)

The packing material is to be suitable for all expected service conditions of the ship and is to be compatible with the cargoes to be transported. The packing material is to be selected with regard to dimensions and elasticity in such a way that expected deformations can be carried. Forces are to be carried by the steel structure only.

The packings are to be compressed so as to give the necessary tightness effect for all expected operating conditions. Special consideration shall be given to the packing arrangement in ships with large relative movements between hatch covers and coamings or between hatch cover sections.

## S21A (cont)

### 4.2.2 Dispensation of weather tight gaskets

For hatch covers of cargo holds solely for the transport of containers, upon request by the owners and subject to compliance with the following conditions the fitting of weather tight gaskets according to 4.2.1 may be dispensed with:

- The hatchway coamings shall be not less than 600 mm in height.
- The exposed deck on which the hatch covers are located is situated above a depth  $H(x)$ .  $H(x)$  is to be shown to comply with the following criteria:

$$H(x) \geq T_{fb} + f_b + h \text{ in m}$$

$T_{fb}$  = draught, in m, corresponding to the assigned summer load line

$f_b$  = minimum required freeboard, in m, determined in accordance with ICLL Reg. 28 as modified by further regulations as applicable

$$h = 4,6 \text{ m for } \frac{x}{L_{LL}} \leq 0,75$$

$$= 6,9 \text{ m for } \frac{x}{L_{LL}} > 0,75$$

- Labyrinths, gutter bars or equivalents are to be fitted proximate to the edges of each panel in way of the coamings. The clear profile of these openings is to be kept as small as possible.
- Where a hatch is covered by several hatch cover panels the clear opening of the gap in between the panels shall be not wider than 50mm.
- The labyrinths and gaps between hatch cover panels shall be considered as unprotected openings with respect to the requirements of intact and damage stability calculations.
- With regard to drainage of cargo holds and the necessary fire-fighting system reference is made to the sections *Piping Systems, Valves and Pumps* and *Fire Protection and Fire Extinguishing Equipment* of the individual classification society's rules.
- Bilge alarms should be provided in each hold fitted with non-weather-tight covers.
- Furthermore, Chapter 3 of IMO MSC/Circ. 1087 is to be referred to concerning the stowage and segregation of containers containing dangerous goods.

### 4.2.3 Drainage arrangements

Cross-joints of multi-panel covers are to be provided with efficient drainage arrangements.

## 5 Hatch coaming strength criteria

### 5.1 Local net plate thickness of coamings

The net thickness of weather deck hatch coamings shall not be less than the larger of the following values:

## S21A (cont)

$$t = 14,2 \cdot s \cdot \sqrt{\frac{p_A}{0,95 \cdot \sigma_F}} \text{ in mm}$$

$$t_{min} = 6 + \frac{L_1}{100} \text{ in mm}$$

s = stiffener spacing in m

$L_1 = L$ , need not be taken greater than 300 m

Longitudinal strength aspects are to be observed.

### 5.2 Net scantling of secondary stiffeners of coamings

The stiffeners must be continuous at the coaming stays. For stiffeners with both ends constraint the elastic net section modulus  $Z$  in  $\text{cm}^3$  and net shear area  $A_s$  in  $\text{cm}^2$ , calculated on the basis of net thickness, must not be less than:

$$Z = \frac{83}{\sigma_F} \cdot s \cdot l^2 \cdot p_A$$

$$A_s = \frac{10 \cdot s \cdot l \cdot p_A}{\sigma_F}$$

l = secondary stiffener span, in m, to be taken as the spacing of coaming stays

s = stiffener spacing in m

For sniped stiffeners at coaming corners section modulus and shear area at the fixed support have to be increased by 35 %. The gross thickness of the coaming plate at the sniped stiffener end shall not be less than

$$t = 19,6 \cdot \sqrt{\frac{p_A \cdot s \cdot (l - 0,5 s)}{\sigma_F}} \text{ in mm}$$

Horizontal stiffeners on hatch coamings, which are part of the longitudinal hull structure, are to be designed according to the individual classification society's rules.

### 5.3 Coaming stays

Coaming stays are to be designed for the loads transmitted through them and permissible stresses according to 3.1.1.

#### 5.3.1 Coaming stay section modulus

The net section modulus  $Z$  of coaming stays with a height of  $h_s < 1,6$  m and which are to be designed for the load  $p_A$ , shall not be less than:

$$Z = \frac{526}{\sigma_F} \cdot e \cdot h_s^2 \cdot p_A \text{ in cm}^3$$

e = spacing of coaming stays in m

Coaming stays of coamings having a height of 1,6m or more are to be designed using direct calculations under consideration of the permissible stresses according to 3.1.1. The effective breadth of the coaming plate shall not be larger than the effective plate breadth according to 3.5.1.

## S21A (cont)

Coaming stays are to be supported by appropriate substructures. Face plates may only be included in the calculation if an appropriate substructure is provided and welding provides an adequate joint.

### 5.3.2 Web thickness of coaming stays

Web gross thickness at the root point shall not be less than:

$$t_w = \frac{2}{\sigma_F} \cdot \frac{e \cdot h_S \cdot p_A}{h_w} + t_S$$

$h_w$  = web height of coaming stay at its lower end in m

$t_S$  = corrosion addition, in mm, according to 7

Webs are to be connected to the deck by fillet welds on both sides with a throat thickness of  $a = 0,44t_w$ . The size of welding for toes of webs at the lower end of coaming stays should be according to the individual class society's rules.

### 5.3.3 Coaming stays under friction load

For coaming stays, which transfer friction forces at hatch cover supports, sufficient fatigue strength is to be verified according to individual class society's rules, refer to 6.2.2.

## 5.4 Further requirements for hatch coamings

### 5.4.1 Longitudinal strength

Hatch coamings which are part of the longitudinal hull structure are to be designed according to the requirements for longitudinal strength of the individual classification society.

For structural members welded to coamings and for cutouts in the top of coamings sufficient fatigue strength is to be verified.

Longitudinal hatch coamings with a length exceeding  $0,1 \cdot L$  m are to be provided with tapered brackets or equivalent transitions and a corresponding substructure at both ends. At the end of the brackets they are to be connected to the deck by full penetration welds of minimum 300 mm in length.

### 5.4.2 Local details

If the design of local details is not regulated in 5, local details are to comply with the individual classification society's requirement for the purpose of transferring the loads on the hatch covers to the hatch coamings and, through them, to the deck structures below. Hatch coamings and supporting structures are to be adequately stiffened to accommodate the loading from hatch covers, in longitudinal, transverse and vertical directions.

Structures under deck are to be checked against the load transmitted by the stays.

Unless otherwise stated, weld connections and materials are to be dimensioned and selected in accordance with the individual classification society's requirements.

## S21A (cont)

### 5.4.3 Stays

On ships carrying cargo on deck, such as timber, coal or coke, the stays are to be spaced not more than 1,5 m apart.

### 5.4.4 Extend of coaming plates

Coaming plates are to extend to the lower edge of the deck beams; they are to be flanged or fitted with face bars or half-round bars. Fig.10 gives an example.

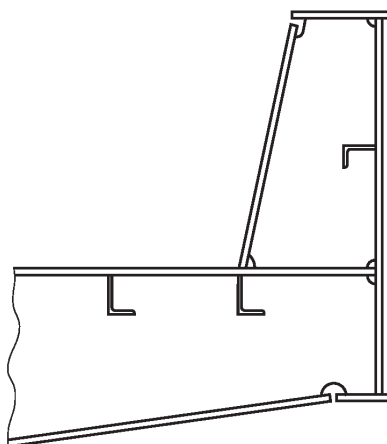


Fig. 10 Example for the extend of coaming plates

### 5.4.5 Drainage arrangement at the coaming

If drain channels are provided inside the line of gasket by means of a gutter bar or vertical extension of the hatch side and end coaming, drain openings are to be provided at appropriate positions of the drain channels.

Drain openings in hatch coamings are to be arranged with sufficient distance to areas of stress concentration (e.g. hatch corners, transitions to crane posts).

Drain openings are to be arranged at the ends of drain channels and are to be provided with non-return valves to prevent ingress of water from outside. It is unacceptable to connect fire hoses to the drain openings for this purpose.

If a continuous outer steel contact between cover and ship structure is arranged, drainage from the space between the steel contact and the gasket is also to be provided for.

## 6 Closing arrangements

### 6.1 Securing devices

#### 6.1.1 General

Securing devices between cover and coaming and at cross-joints are to be installed to provide weathertightness. Sufficient packing line pressure is to be maintained.

Securing devices must be appropriate to bridge displacements between cover and coaming due to hull deformations.

## S21A (cont)

Securing devices are to be of reliable construction and effectively attached to the hatchway coamings, decks or covers. Individual securing devices on each cover are to have approximately the same stiffness characteristics.

Sufficient number of securing devices is to be provided at each side of the hatch cover considering the requirements of 3.4.2. This applies also to hatch covers consisting of several parts.

The materials of stoppers, securing devices and their weldings are to be to the satisfaction the individual class society. Specifications of the materials are to be shown in the drawings of the hatch covers.

### 6.1.2 Rod cleats

Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

### 6.1.3 Hydraulic cleats

Where hydraulic cleating is adopted, a positive means is to be provided so that it remains mechanically locked in the closed position in the event of failure of the hydraulic system.

### 6.1.4 Cross-sectional area of the securing devices

The gross cross-sectional area in cm<sup>2</sup> of the securing devices is not to be less than:

$$A = 0,28 \cdot q \cdot s_{SD} \cdot k_l$$

q = packing line pressure in N/mm, minimum 5 N/mm

s<sub>SD</sub> = spacing between securing devices in m, not to be taken less than 2 m

$k_l = \left( \frac{235}{\sigma_F} \right)^e$ ,  $\sigma_F$  is the minimum yield strength of the material in N/mm<sup>2</sup>, but is not to be taken

greater than  $0,7 \cdot \sigma_m$ , where  $\sigma_m$  is the tensile strength of the material in N/mm<sup>2</sup>.

e = 0,75 for  $\sigma_F > 235$  N/mm<sup>2</sup>

= 1,00 for  $\sigma_F \leq 235$  N/mm<sup>2</sup>

Rods or bolts are to have a gross diameter not less than 19 mm for hatchways exceeding 5 m<sup>2</sup> in area.

Securing devices of special design in which significant bending or shear stresses occur may be designed as anti-lifting devices according to 6.1.5. As load the packing line pressure q multiplied by the spacing between securing devices s<sub>SD</sub> is to be applied.

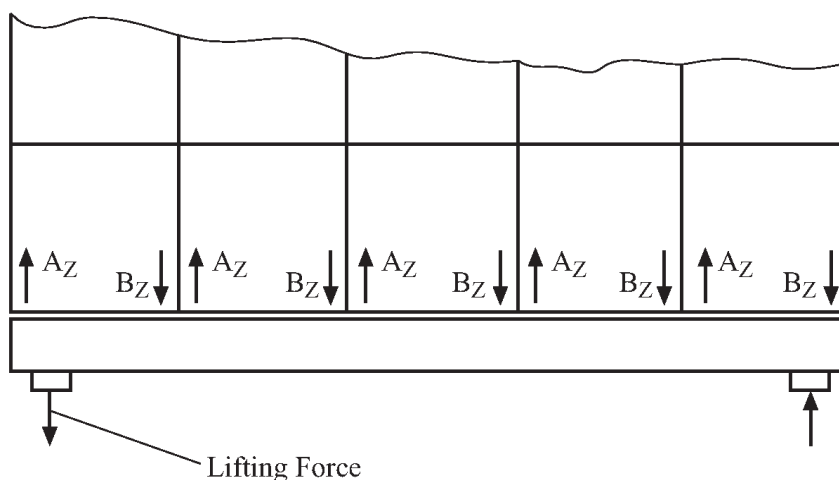
### 6.1.5 Anti lifting devices

The securing devices of hatch covers, on which cargo is to be lashed, are to be designed for the lifting forces resulting from loads according to 2.4, refer Fig.11. Unsymmetrical loadings, which may occur in practice, are to be considered. Under these loadings the equivalent stress in the securing devices is not to exceed:

## S21A (cont)

$$\sigma_v = \frac{150}{k_l} \text{ in N/mm}^2$$

Chapter 5.6 of IACS Rec. 14 should be referred to for the omission of anti lifting devices.



**Fig. 11 Lifting forces at a hatch cover**

## 6.2 Hatch cover supports, stoppers and supporting structures

### 6.2.1 Horizontal mass forces

For the design of the securing devices against shifting the horizontal mass forces  $F_h = m \cdot a$  are to be calculated with the following accelerations:

$$a_x = 0,2 \cdot g \quad \text{in longitudinal direction}$$

$$a_y = 0,5 \cdot g \quad \text{in transverse direction}$$

$m$  = Sum of mass of cargo lashed on the hatch cover and mass of hatch cover

### 6.2.2 Hatch cover supports

For the transmission of the support forces resulting from the load cases specified in 2 and of the horizontal mass forces specified in 6.2.1, supports are to be provided which are to be designed such that the nominal surface pressures in general do not exceed the following values:

$$p_{n \max} = d \cdot p_n \text{ in N/mm}^2$$

$$d = 3,75 - 0,015 L$$

$$d_{\max} = 3,0$$

$$d_{\min} = 1,0 \text{ in general}$$

$$= 2,0 \text{ for partial loading conditions, see 2.4.1}$$

$$p_n = \text{see Tab.8}$$



## S21A

(cont)

For metallic supporting surfaces not subjected to relative displacements the nominal surface pressure applies:

$$p_{n \max} = 3 \cdot p_n \text{ in N/mm}^2$$

Drawings of the supports must be submitted. In the drawings of supports the permitted maximum pressure given by the material manufacturer related to long time stress must be specified.

**Tab. 8 Permissible nominal surface pressure  $p_n$**

Support material	$p_n$ [N/mm <sup>2</sup> ] when loaded by	
	Vertical force	Horizontal force (on stoppers)
Hull structural steel	25	40
Hardened steel	35	50
Plastic materials on steel	50	–

Where large relative displacements of the supporting surfaces are to be expected, the use of material having low wear and frictional properties is recommended.

If necessary, sufficient abrasive strength may be shown by tests demonstrating an abrasion of support surfaces of not more than 0,3 mm per year in service at a total distance of shifting of 15 000 m/year.

The substructures of the supports must be of such a design, that a uniform pressure distribution is achieved.

Irrespective of the arrangement of stoppers, the supports must be able to transmit the following force  $P_h$  in the longitudinal and transverse direction:

$$P_h = \mu \cdot \frac{P_v}{\sqrt{d}}$$

$P_v$  = vertical supporting force

$\mu$  = frictional coefficient

= 0,5 in general

For non-metallic, low-friction support materials on steel, the friction coefficient may be reduced but not to be less than 0,35 and to the satisfaction of the individual class society.

Supports as well as the adjacent structures and substructures are to be designed such that the permissible stresses according to 3.1.1 are not exceeded.

For substructures and adjacent structures of supports subjected to horizontal forces  $P_h$ , a fatigue strength analysis is to be carried out according to the individual classification society's rules.

## S21A (cont)

### 6.2.3 Hatch cover stoppers

Hatch covers shall be sufficiently secured against horizontal shifting. Stoppers are to be provided for hatch covers on which cargo is carried.

The greater of the loads resulting from 2.2 and 6.2.1 is to be applied for the dimensioning of the stoppers and their substructures.

The permissible stress in stoppers and their substructures, in the cover, and of the coamings is to be determined according to 3.1.1. In addition, the provisions in 6.2.2 are to be observed.

## 7 Corrosion addition and steel renewal

### 7.1 Corrosion addition for hatch covers and hatch coamings

The scantling requirements of the above sections imply the following general corrosion additions  $t_s$ :

**Tab. 9 Corrosion additions  $t_s$  for hatch covers and hatch coamings**

Application	Structure	$t_s$ [mm]
Weather deck hatches of container ships, car carriers, paper carriers, passenger vessels	Hatch covers	1,0
	Hatch coamings	according to individual class society's rules
Weather deck hatches of all other ship types covered by this UR	Hatch covers in general	2,0
	Weather exposed plating and bottom plating of double skin hatch covers	1,5
	Internal structure of double skin hatch covers and closed box girders	1,0
	Hatch coamings not part of the longitudinal hull structure	1,5
	Hatch coamings part of the longitudinal hull structure	according to individual class society's rules
	Coaming stays and stiffeners	1,5

### 7.2 Steel renewal

For single skin hatch covers and for the plating of double skin hatch covers, steel renewal is required where the gauged thickness is less than  $t_{net} + 0,5$  mm. Where the gauged thickness is within the range  $t_{net} + 0,5$  mm and  $t_{net} + 1,0$  mm, coating (applied in accordance with the coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal. Coating is to be maintained in GOOD condition, as defined in UR Z10.2.1.2.

For the internal structure of double skin hatch covers, thickness gauging is required when hatch cover top or bottom plating renewal is to be carried out or when this is deemed necessary, at the discretion of the individual class society's surveyor, on the basis of the

**S21A**  
(cont)

plating corrosion or deformation condition. In these cases, steel renewal for the internal structures is required where the gauged thickness is less than  $t_{net}$ .

For corrosion addition  $t_s = 1,0$  mm the thickness for steel renewal is  $t_{net}$  and the thickness for coating or annual gauging is when gauged thickness is between  $t_{net}$  and  $t_{net} + 0,5$  mm.

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