



RULES
R005AM01-2024

CHINA CLASSIFICATION SOCIETY

RULES FOR CONSTRUCTION OF SEA-GOING SHIPS ENGAGED ON DOMESTIC VOYAGES

AMENDMENTS

2024

Effective from 1 July 2024

Beijing



CHINA CLASSIFICATION SOCIETY

RULES FOR CONSTRUCTION OF SEA-GOING SHIPS ENGAGED ON DOMESTIC VOYAGES

AMENDMENTS

2024

PART TWO HULL

CONTENTS

CHAPTER 1	GENERAL	2-1
Section 4	WELDING DESIGN FOR HULL STRUCTURES	2-1
Section 7	SHIPS NAVIGATING IN RESTRICTED SERVICE	2-1
Section 9	FORE DECK FITTINGS	2-1
CHAPTER 2	HULL STRUCTURES	2-3
Section 1	GENERAL PROVISIONS	2-3
Section 17	SUPERSTRUCTURES AND DECKHOUSES	2-3
Section 20	HATCHWAYS AND HATCH COVERS	2-4
Appendix 4	BUCKLING STRENGTH ASSESSMENT OF SHIP STRUCTURAL ELEMENTS	2-44
CHAPTER 3	EQUIPMENT AND OUTFITS	2-89
Section 1	RUDDERS	2-89
Section 2	ANCHORING AND MOORING EQUIPMENT	2-93
Appendix 1	GUIDELINES FOR CALCULATION OF BENDING MOMENT AND SHEAR FORCE DISTRIBUTION	2-96
Appendix 3	DIRECT FORCE CALCULATION FOR ANCHORING EQUIPMENT	2-99
CHAPTER 8	BULK CARRIERS	2-103
Section 1	GENERAL PROVISIONS	2-103
Section 8	EVALUATION OF SCANTLINGS OF HATCH COVERS OF CARGO HOLDS	2-103
Section 9	DOUBLE SIDE STRUCTURES	2-103
CHAPTER 9	ROLL ON-ROLL OFF SHIPS, PASSENGER SHIPS, RO-RO PASSENGER SHIPS AND FERRIES	2-105
Section 1	GENERAL PROVISIONS	2-105
Section 2	HULL STRUCTURE	2-105
Section 8	EXTERNAL GLASS BALUSTRADES	2-105
CHAPTER 12	BARGES	2-109
Section 1	GENERAL PROVISIONS	2-109

CHAPTER 1 GENERAL

Section 4 WELDING DESIGN FOR HULL STRUCTURES

1.4.3 Butt, lap and slot welds

1.4.3.1 Where plates of different thicknesses are to be butt welded and the difference in thickness of one side is less than or equal to 4 mm, the transition may be achieved within the width of the weld. Where the difference in thickness of one side is greater than 4 mm, the edge of the thicker plate is to be tapered so as to ensure a uniform transition with the weld. The width ~~of taper~~ is not to be less than 3 times the difference in thickness of one side, and the difference in height of the two sides of the groove d is not to be greater than 4 mm, as shown in Figure 1.4.3.1(1). Where ~~the difference in thickness is more than 4 mm and~~ the groove width is not less than 3 times the difference in thickness of one side, taper may not be necessary and the transition may be achieved within the width of the weld, as shown in Figure 1.4.3.1(2).

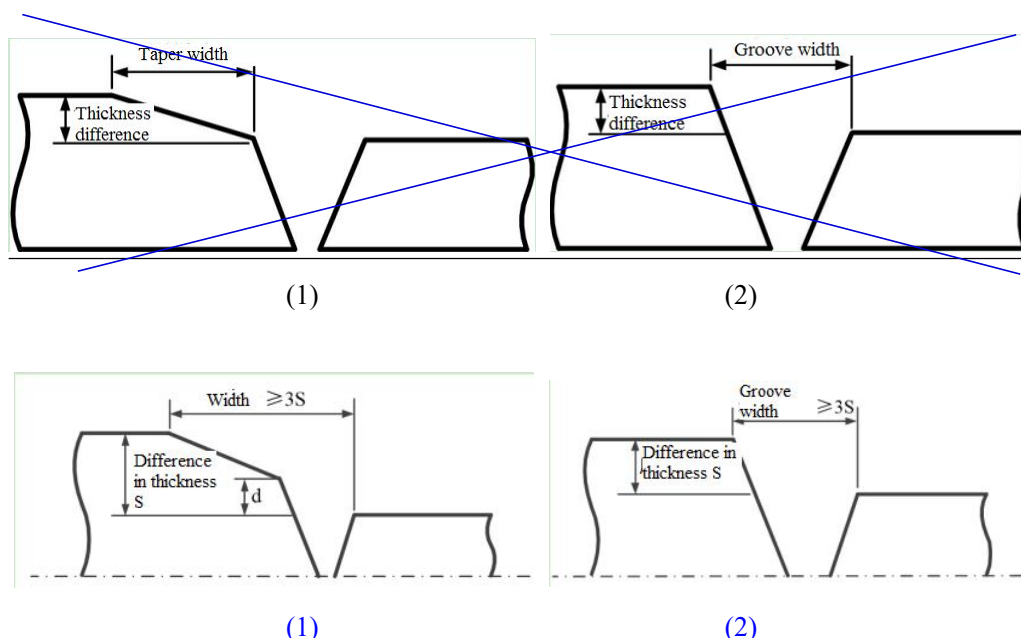


Figure 1.4.3.1 Butt welding of steel plates of different thickness

Section 7 SHIPS NAVIGATING IN RESTRICTED SERVICE

1.7.3 Reduction of rule scantlings of structural members

1.7.3.6 The thickness of the plate keels is not to be less than the rule-specified calculated thickness that of the bottom plating plus 1.5 mm, and in no case less than that of the adjacent bottom plating.

Section 9 FORE DECK FITTINGS

1.9.2 Strength and securing of small hatches on the exposed fore deck

1.9.2.1 The provisions of this Section apply to the strength of, and securing devices for, small hatches fitted on the exposed deck over the forward $0.25 L$, where the height of the exposed deck in way of the hatch is less than $0.1 L$ or 22 m above the summer load waterline, whichever is the lesser, for all ships of 80 m or over in length. [This regulation does not apply to small hatches on container ship giving access to a cargo hold which comply with UI LL64 except the requirement of clauses 4 & 5. Such hatch covers are considered non-weather-tight regardless of whether it is actually weather-tight or not. However, for scantlings of small hatches, the strength requirements in 1.7.2.4-1.7.2.7 of this Section could be applied instead of clause 6 of UI LL64.](#)

CHAPTER 2 HULL STRUCTURES

Section 1 GENERAL PROVISIONS

2.1.1 Application

2.1.1.1 This Chapter applies mainly to dry cargo ships. If not covered in this Chapter, the requirements of Chapter 1 of this PART are to be complied with.

2.1.1.2 This Chapter applies to the basic structural configuration of a multi-deck or a single deck hull which includes a double bottom, or a single bottom arrangement, and with the hatch openings of normal dimensions.

2.1.1.3 Longitudinal framing is in general to be adopted at the strength deck outside the line of openings and at the bottom.

2.1.1.4 For ships with self-unloading system, such system is to meet the relevant requirements of CCS Rules for Lifting Appliances of Ships and Offshore Installations.

~~2.1.3 Additional requirements for dry cargo ships occasionally carrying bulk cargo~~

~~2.1.3.1 For dry cargo ships occasionally carrying bulk cargo, the hull structure within the cargo region is to comply with the following requirements, in addition to the requirements of this Chapter:~~

- ~~(1) the strength of bottom framing is to comply with the requirements of Section 2, Chapter 8 of this PART;~~
- ~~(2) the strength of watertight bulkhead is to comply with the requirements of Section 4, Chapter 8 of this PART;~~
- ~~(3) the loading manual and loading instruments are to comply with the requirements of Section 7, Chapter 8 of this PART;~~
- ~~(4) where the load line length L_L is 100 m and above, double side skin structure is to be provided and is to comply with the requirements of Section 9, Chapter 8 of this PART.~~

Section 17 SUPERSTRUCTURES AND DECKHOUSES

2.17.3 End bulkheads of superstructures and boundary bulkheads of deckhouses

2.17.3.1 The thickness t of end bulkhead plating of superstructures and boundary bulkhead plating of deckhouses is not to be less than:

$$t = 3s\sqrt{hK} \quad \text{mm}$$

The minimum thickness of the plate, $t_{\min}$, is to comply with the following requirements:

If $L_1 \geq 65$ m: $t = (0.01L_1 + 5.0)\sqrt{K}$ mm, for lowest tier

$t = (0.01L_1 + 4.0)\sqrt{K}$ mm, for upper tiers, and not less than 5 mm

If $L_1 < 65$ m: $t_{\min} = 5.0$ mm, for the lowest unprotected front

$t_{\min} = 4.0$ mm for all other cases

where: s — spacing of stiffeners, in m;

- h — design pressure head, in m, to be calculated according to 2.17.2 of this Section;
 L_1 — length of ship, in m, L_1 need not be taken greater than 300 m;
 K — material factor.

Section 20 HATCHWAYS AND HATCH COVERS

2.20.1 General requirements

2.20.1.1 In addition to the requirements of this Section, exposed hatchways and hatch covers are to comply with the relevant requirements of the Amendments to Annex I to Annex B of the Protocol of 1988 Relating to the International Convention on Load Lines, 1966.

2.20.1.2 The structural scantlings of non-exposed hatch covers may be determined according to the relevant requirements of this Section, depending on their structural configuration and with only permissible cargo loads being taken into account.

2.20.1.3 The scantlings of steel hatch covers for deep tanks may be determined according to the relevant requirements of this Section and depending on the position of hatch covers, but in no case are to be less than those required in Section 13 of this Chapter for deep tank deck and its framing.

2.20.1.4 Where wheeled vehicles are to be stowed on hatch covers or used for cargo handling, the scantlings of hatch covers are also to comply with the requirements for vehicle deck in Section 21 of this Chapter.

2.20.1.5 The scantlings of hatch covers used as helicopter deck are also to comply with the requirements for helicopter decks in Section 18 of this Chapter.

2.20.1.6 Except as otherwise provided, the width of the attached plating of hatch cover stiffeners and girders is to be determined according to 1.2.2 of Section 2, Chapter 1 of this PART. However, the areas of stiffeners are not to be included in the area of the attached plating of girders.

2.20.1.7 For the hatch covers on the lower deck within cargo holds, the strength is to be checked according to the requirements of 2.20.3.

2.20.1.8 Height of hatch coamings

- (1) at Position 1, the height is not to be less than 600 mm;
- (2) at Position 2, the height is not to be less than 450 mm;
- (3) for ships provided with steel weathertight hatch covers, with the consent of the flag State Administration, the height of hatch coamings may be suitably reduced provided that efficient measures have been taken and that the safety of the ship is not impaired;
- (4) for hatchways on unexposed freeboard decks or exposed superstructure decks, hatchway coamings with a suitable height may be provided depending upon the position of the hatchways and the protection necessitated by such hatchways.

2.20.1.9 Hatch cover types

(1) 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 to be weathertight and fitted with gaskets and clamping devices unless specifically exempted from such fittings.

(2) 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.

(3) 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.

Note: Modern designs of lift-away hatch covers are in many cases called pontoon covers. This definition does not fit to the (3) above. Modern lift-away hatch covers are to fall into one of the two categories of single skin covers and double skin covers.

2.20.2 Weathertight steel hatch covers

2.20.2.1 General requirements

(1) These requirements ~~apply to all ships other than bulk carriers, self-unloading bulk carriers, ore carriers and combination carriers as defined in Appendix 2, Chapter 2 of PART ONE of the Rules, and~~ are for all cargo hatch covers and coamings on exposed decks. As specified in this Section, parts of the requirements are for some specific ship types as categorized below:

- Type-1 ships, including all ships except bulk carriers, self-unloading bulk carriers, ore carriers and combination carriers.
- Type-2 ships, including all bulk carriers, self-unloading bulk carriers, ore carriers and combination carriers.

(2) The strength requirements are applicable to hatch covers and hatch coamings of stiffened plate construction and their closing arrangements.

(3) These requirements are applicable to hatch covers and coamings made of steel. The materials of hatch covers and hatch coamings are to meet the relevant requirements of Section 3, Chapter 1 of this PART. The material class I is to be applied for top plate, bottom plate and primary supporting members of hatch covers. Equivalent materials and novel designs subject to approval by CCS.

(4) 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 member. When strength calculation is carried out by FE analysis using plane strain or shell elements, this requirement may be relaxed appropriately. Secondary stiffeners of hatch coamings are to be continuous over the breadth and length of hatch coamings.

(5) Unless stipulated otherwise, the thickness t in these requirements is net thickness.

The net thicknesses are the member thicknesses necessary to obtain the minimum net scantlings required by 2.20.2.3 to 2.20.2.6 and 2.20.2.8 of this Section.

The required gross thickness is obtained by adding the corrosion addition t_s , given in 2.20.2.10 of this Section, to the net thickness t_s .

Strength calculations using ~~grillage analysis or~~ FEM are to be performed with net scantlings.

2.20.2.2 Hatch cover and coaming load model

The structural strength evaluation of hatch covers and hatch coamings is to be carried out using the design loads defined as follows:

Definitions:

L = length of ship, in m;

L_L = load line length, in m;

x = longitudinal distance measured from midpoint of structural member to the aft end of L or L_L , in m;

$D_{\min}$ = the least moulded depth, in m, as defined in Regulation 3 of ICLL Annex I;

h_N = standard superstructure height, in m, to be calculated as follows:

$$h_N = 1.05 + 0.01L_L, \text{ and } 1.8 \leq h_N \leq 2.3.$$

(1) Vertical weather design load

The pressure p_H , in kN/m², on the hatch cover panel is given by ICLL. This may be taken from Table 2.20.2.2(1). The vertical weather design load is not to be combined with cargo loads in 2.20.2.2(3) and (4).

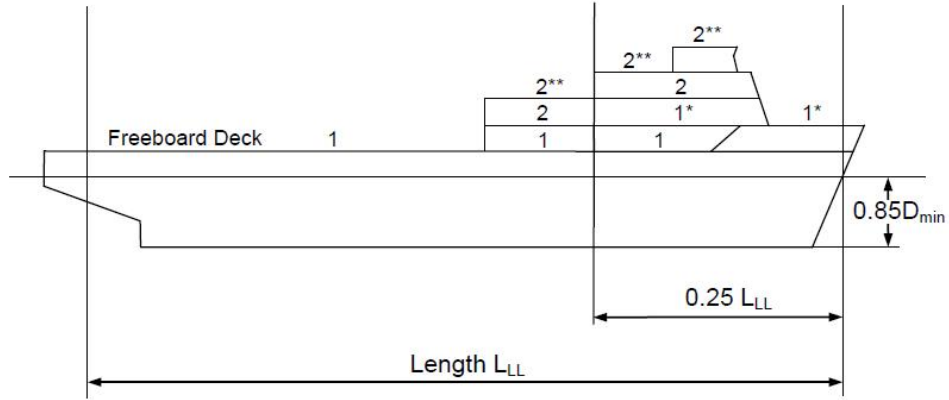
For Position 1 and Position 2, see Figure 2.20.2.2(1).

Where an increased freeboard is assigned, the design load for hatch covers on the actual freeboard deck may be as required for a superstructure deck, provided that 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 Figure 2.20.2.2(2).

Vertical Design Load p_H of Weather Deck Hatches

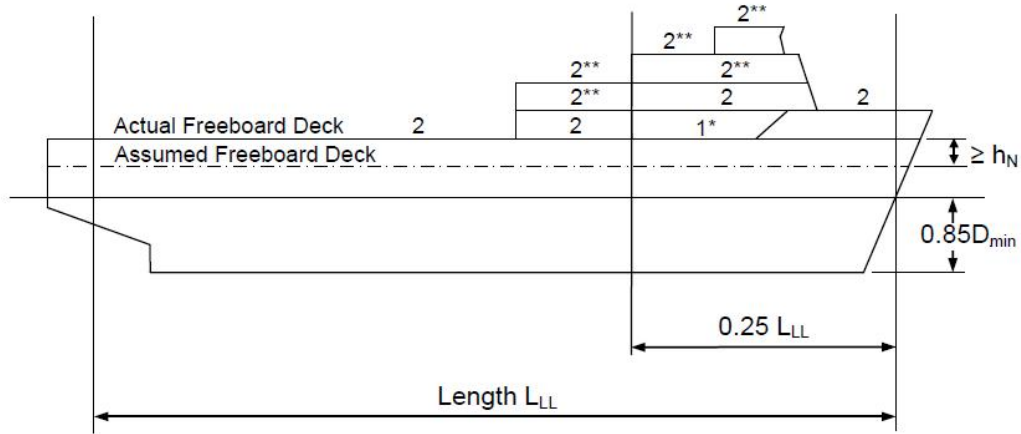
Table 2.20.2.2(1)

Position	Vertical design load p_H , kN/m ²	
	$\frac{x}{L_L} \leq 0.75$	$0.75 < \frac{x}{L_L} \leq 1.0$
1	For $24\text{m} \leq L_L \leq 100\text{m}$	
	$\frac{9.81}{76}(1.5L_L + 116)$	On freeboard deck: $\frac{9.81}{76} \left[(4.28L_L + 28) \frac{x}{L_L} - 1.71L_L + 95 \right]$
		Upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck: $\frac{9.81}{76}(1.5L_L + 116)$
	For $L_L > 100\text{ m}$	
	9.81×3.5	On freeboard deck for type B ships according to ICLL: $9.81 \left[(0.0296L_1 + 3.04) \frac{x}{L_L} - 0.0222L_1 + 1.22 \right]$
		On freeboard deck for ships with less freeboard than type B according to ICLL: $9.81 \left[(0.1452L_1 - 8.52) \frac{x}{L_L} - 0.1089L_1 + 9.89 \right]$
		$L_1 = L_L$, but not more than 340 m
		Upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck: 9.81×3.5
2	For $24\text{ m} \leq L_L \leq 100\text{ m}$	
	$\frac{9.81}{76}(1.1L_L + 87.6)$	
	For $L_L > 100\text{ m}$	
	9.81×2.6	
	Upon exposed superstructure decks located at least one superstructure standard height above the lowest Position 2 deck: 9.81×2.1	



- * — 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 $L_L > 100$ m located at least one superstructure standard height above the lowest Position 2 deck.

Figure 2.20.2.2(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 $L_L > 100$ m located at least one superstructure standard height above the lowest Position 2 deck.

Figure 2.20.2.2(2) Positions 1 and 2 for an Increased Freeboard

(2) Horizontal weather design load

① [General horizontal weather design load](#)

The horizontal weather design load p_A , in kN/m^2 , for determining the scantlings of outer edge girders (skirt plates) of weather deck hatch covers and of hatch coamings is to be calculated by the following formula:

$$p_A = ac(bfc_L - z) \quad \text{kN/m}^2$$

where: $f = \frac{L}{25} + 4.1$, for $L < 90$ m;

$$f = 10.75 - \left(\frac{300 - L}{100} \right)^{1.5}, \text{ for } 90\text{m} \leq L < 300\text{m};$$

$$f = 10.75, \text{ for } 300\text{m} \leq L < 350\text{m};$$

$$f = 10.75 - \left(\frac{L - 350}{150} \right)^{1.5}, \text{ for } 350\text{m} \leq L \leq 500\text{m};$$

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

$$c_L = 1, \text{ for } L \geq 90\text{m};$$

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

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

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

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

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

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

$$b = 1.0 + \left(\frac{\frac{x'}{L} - 0.45}{C_b + 0.2} \right)^2, \text{ for } \frac{x'}{L} < 0.45;$$

$$b = 1.0 + 1.5 \left(\frac{\frac{x'}{L} - 0.45}{C_b + 0.2} \right)^2, \text{ for } \frac{x'}{L} \geq 0.45;$$

C_b — block coefficient, $0.6 \leq C_b \leq 0.8$, 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;

x' — distance in m, between the transverse coaming or hatch cover skirt plate considered and aft end of the length L . For 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;

$$c = 0.3 + 0.7 \frac{b'}{B'}, \text{ the } \frac{b'}{B'} \text{ is not to be less than } 0.25;$$

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.

The horizontal design load is not to be taken less than the minimum values given in Table 2.20.2.2(2).

Minimum Horizontal Design Load P_{Amin} Table 2.20.2.2(2)

L	P_{Amin} kN/m ²	
	Unprotected fronts	elsewhere
$\leq 50\text{m}$	30	15
$> 50\text{m}$	$25 + \frac{L}{10}$	$12.5 + \frac{L}{20}$
$< 250\text{m}$		
$\geq 250\text{m}$	50	25

Note: The horizontal weather design load need not be included in the direct strength calculation of the hatch cover, unless it is utilized for the design of substructures of horizontal support according to 2.20.2.9(2)③.

② Horizontal weather design load applicable to coamings of Type-2 ships

The pressure P_{coam} , in kN/m², on the No. 1 forward transverse hatch coaming is given by:

$P_{coam} = 220$ kN/m², when a forecastle is fitted in accordance with Section 13, Chapter 8, PART TWO of CCS Rules for Classification of Sea-going Steel Ships;

$P_{coam} = 290$ kN/m² in the other cases;

The pressure P_{coam} , in kN/m², on the other coamings is given by:

$P_{coam} = 220$ kN/m²

Note: The horizontal weather design loads p_A and P_{coam} need not be included in the direct strength calculation of the hatch cover, unless it is utilized for the design of substructures of horizontal support according to 2.20.2.9(2)③.

(3) Cargo loads

① Distributed loads

The uniform cargo load on hatch covers due to cargo loads p_L , resulting from heave and pitch (i.e. ship in upright condition) is to be determined according to the following formula:

$$p_L = p_C(1 + a_V) \quad \text{kN/m}^2$$

where: p_C — uniform cargo load, in kN/m²;
 a_V — vertical acceleration addition as follows:

$$a_V = Fm;$$

$$F = \frac{0.11v_0}{\sqrt{L}};$$

$$m = m_0 - 5(m_0 - 1)\frac{x}{L} \quad \text{for } 0 \leq \frac{x}{L} \leq 0.2;$$

$$m = 1.0 \quad \text{for } 0.2 < \frac{x}{L} \leq 0.7;$$

$$m = 1 + \frac{m_0 + 1}{0.3} \left[\frac{x}{L} - 0.7 \right] \quad \text{for } 0.7 < \frac{x}{L} \leq 1.0;$$

$$m_0 = 1.5 + F;$$

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

② Point loads

The load P , in kN, due to a concentrated force P_S , in kN, except for container load, resulting from heave and pitch (i.e. ship in upright condition) is to be determined as follows:

$$P = P_S(1 + a_V) \quad \text{kN}$$

where: P_S — point force, in kN;

a_V — vertical acceleration addition.

(4) Container loads

① The loads defined in ② [and to](#) ④ are to be applied where containers are stowed on the hatch cover.

② [Corner loads for ship in upright condition](#)

The load P , in kN, applied at each corner of a container stack, and resulting from heave and pitch (i.e. ship in upright condition) is to be determined as follows:

$$P = 9.81 \frac{M}{4} (1 + a_V) \quad \text{kN}$$

where: a_V — vertical acceleration addition according to (3)①;

M — maximum designed mass of container stack, in t.

③ [Corner loads for ship in heel condition](#)

Where containers are stowed on hatch covers, the loads due to heave, pitch and the ship's rolling motion are to be determined as follows (see Figure 2.20.2.2(4)):

$$A_z = 9.81 \frac{M}{2} (1 + a_V) \left(0.45 - 0.42 \frac{h_m}{b} \right) \quad \text{kN}$$

$$B_z = 9.81 \frac{M}{2} (1 + a_V) \left(0.45 + 0.42 \frac{h_m}{b} \right) \quad \text{kN}$$

$$B_y = 2.4M \quad \text{kN}$$

where:

a_V — acceleration addition according to 2.20.2.2(3);

M — maximum designed mass of container stack, in t;

h_m — designed height of centre of gravity of stack above hatch cover top, in m, may be calculated as weighted mean value of the stack, where the centre of gravity of each tier is assumed to be located at the centre of each container, $= \sum(z_i \cdot W_i) / M$;

z_i — distance from hatch cover top to the centre of i th container, in m;

W_i — mass of i th container, in t;

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 forces in y -direction at the forward and aft stack corners.

[Note: When strength of the hatch cover structure is assessed by grillage analysis according to 2.20.2.4, \$h_m\$](#)

and z_i need to be taken above the hatch cover supports. Forces B_y need not be considered in this case.

Values of A_z and B_z applied for the hatch cover strength evaluation are to be shown in the drawings of the hatch covers.

Note: It is recommended that container loads as calculated above are considered as limit for foot point loads of container stacks in the calculations of cargo securing (container lashing).

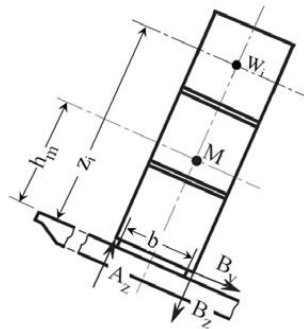


Figure 2.20.2.2(4)

④ Load cases with partial loading

The load cases in ② and ③ above are also to be considered for partial non-homogeneous loading which may occur in practice, e.g. where specified container stack places are empty.

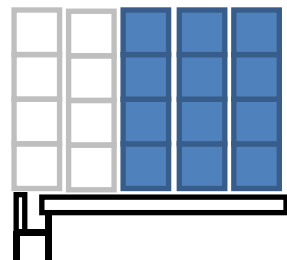
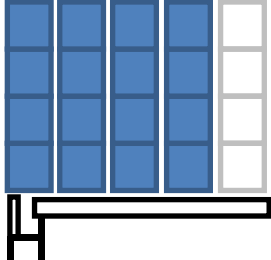
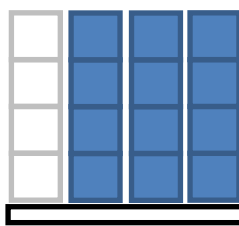
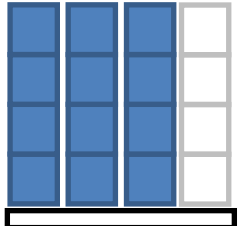
For each hatch cover, the heel directions, as shown in Table 2.20.2.2(4), are to be considered.

The load case of partial loading of container hatch covers may be evaluated using a simplified approach, where the hatch cover is loaded without the outermost stacks that are located completely on the hatch cover. If there are additional stacks that are supported partially by the hatch cover and partially by container stanchions then the loads from these stacks may be neglected, refer to Table 2.20.2.2(4) Partial loading of container hatch covers.

In addition, the case where only the stack places supported partially by the hatch cover and partially by container stanchions are left empty is to be assessed in order to consider the maximum loads in the vertical hatch cover supports.

It may be necessary to also consider partial load cases where more or different container stack places are left empty. Therefore, CCS may require that additional partial load cases other than those in Table 2.20.2.2(4) be considered.

Partial loading of container hatch covers		Table 2.20.2.2(4)
Heel direction	←	→
Hatch covers supported by the longitudinal hatch coaming with all container stacks located completely on the hatch cover		

Heel direction		
Hatch covers supported by the longitudinal hatch coaming with the outermost container stack supported partially by the hatch cover and partially by container stanchions		
Hatch covers not supported by the longitudinal hatch coaming (center hatch covers)		

⑤ Mixed stowage of 20' and 40' containers on hatch cover

In the case of mixed stowage (20'+40' container combined stack), the foot point forces at the fore and aft end of the hatch cover are not to be higher than resulting from the design stack weight for 40' containers, and the foot point forces at the middle of the cover are not to be higher than resulting from the design stack weight for 20' containers.

(5) Hatch covers, which in addition to the loads according to (1) to (4) above 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 allowable value given in 2.20.2.5.

2.20.2.3 The net structural scantling of weathertight steel hatch covers is to be in compliance with the following requirements:

(1) Local net plate thickness

The local net plate thickness of the hatch cover top plating is not to be less than that obtained from the following formulae, and not less than 6 mm:

$$t = 15.8 F_p s \sqrt{\frac{p}{0.95 R_{eH}}} \quad \text{mm}$$

$$t = 10 s \quad \text{mm}$$

where: F_p — factor for combined membrane and bending response, calculated as follows:

$$F_p = 1.5 \quad \text{in general;}$$

$$F_p = 1.9 \frac{\sigma}{\sigma_a} \quad \text{for } \frac{\sigma}{\sigma_a} \geq 0.8 \quad \text{for the attached plate flange of primary supporting members;}$$

s — stiffener spacing, in mm;

p — pressure p_H and p_L , calculated according to 2.20.2.2 of this Section, in kN/m²;

σ — maximum normal stress of hatch cover top plating, in N/mm², determined according to Figure 2.20.2.3;

$\sigma_a = 0.8 R_{eH}$ — permissible stress, see Table 2.20.2.5, in N/mm²;

R_{eH} — yield stress of materials, in N/mm².

For flange plates under compression, the buckling strength requirements of 2.20.2.6 of this Section are to be complied with.

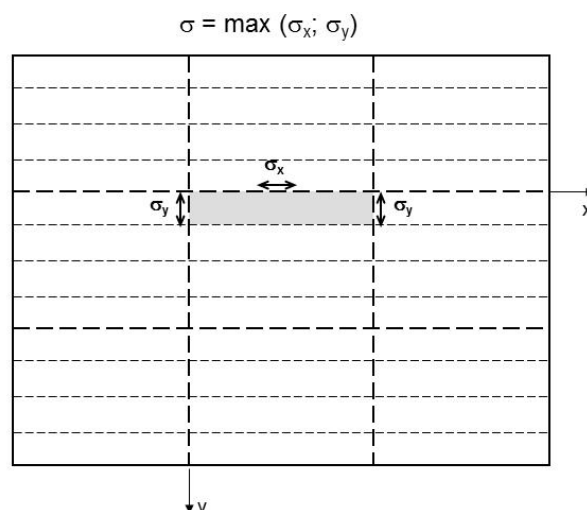


Figure 2.20.2.3

- ① The local net plate thickness of hatch covers for wheel loading is also to meet the relevant requirements of Section 21 of this Chapter.
- ② The local net plate thickness of lower plating of double skin hatch covers and box girders are to comply with the following requirements:

The thickness to fulfill the strength requirements is to be obtained from the calculation according to 2.20.2.4 under consideration of allowable stresses according to 2.20.2.5 of this Section. When the lower plating is taken into account as a strength member of the hatch cover, the net thickness, in mm, of lower plating is to be taken not less than 5 mm. When project cargo is intended to be carried on a hatch cover, the net thickness is not to be less than:

$$t = 6.5s \times 10^{-3} \quad \text{mm}$$

where: s — stiffener spacing, in mm.

When the lower plating is not considered as a strength member of the hatch cover, the thickness of the lower plating is not to be less than 5 mm.

Note:

Project cargo means especially large or bulky cargo lashed to the hatch cover. Examples are parts of cranes or wind power stations, turbines, etc. Cargoes that may be considered as uniformly distributed over the hatch cover, e.g. timber, pipes or steel coils need not to be considered as project cargo.

- (2) The stiffeners of hatch covers are to comply with the following requirements:

The net section modulus Z_w and net shear area A_{shr} of uniformly loaded hatch cover stiffeners constrained at both ends are not to be less than:

$$W = \frac{104}{R_{eH}} s p l^2 \text{ — cm}^3, \text{ for design load according to 2.20.2.2(1);}$$

$$W = \frac{93}{R_{eH}} s p l^2 \text{ — cm}^3, \text{ for design loads according to 2.20.2.2(3)⊕;}$$

$$A_s = \frac{10.8}{R_{eH}} s p l \text{ — cm}^2, \text{ for design load according to 2.20.2.2(1);}$$

$$A_s = \frac{9.6}{R_{eH}} s p l^2 \text{ cm}^2, \text{ for design loads according to 2.20.2.2(3) } \oplus$$

$$Z = \frac{p s l^2}{f_{bc} \sigma_a} \text{ cm}^3$$

$$A_{shr} = \frac{8.7 p s l}{\sigma_a} 10^{-3} \text{ cm}^2$$

where: l — secondary stiffener span, in m, to be taken as the spacing 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 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 unsupported span, for each bracket;

s — spacing of stiffeners, in mm;

p — p_H and p_L , to be calculated according to 2.20.2.2 of this Section, in kN/m²;

f_{bc} — boundary coefficient of stiffener, taken equal to:

$f_{bc} = 8$, in the case of stiffener simply supported at both ends or simply supported at one end and clamped at the other end

$f_{bc} = 12$, in the case of stiffener clamped at both ends.

$\sigma_a R_{eH}$ — allowable stress as defined in Tab.2.20.2.5 yield stress of materials, in N/mm².

For secondary stiffeners of lower plating of double skin hatch covers, requirements mentioned above are not applied due to the absence of lateral loads. For double skin hatch covers of holds designed for ballast or liquid cargo, the stiffeners on lower plating are to be strengthened according to CCS requirements.

The net thickness, in mm, of the stiffener (except U-beams/trapeze stiffeners) web is not to be less than 4 mm.

The net section modulus of 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 of h/t_w is to be not greater than $15k^{0.5}$, where h is height of the stiffener, t_w is net thickness of the stiffener, $k = 235/R_{eH}$.~~

~~Stiffeners parallel to primary supporting members and arranged within the effective breadth according to 2.20.2.4 of this Section~~ are to be continuous at crossing primary supporting members, and may be considered for calculations regarding cross-sectional properties of primary 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 allowable stresses according to 2.20.2.5 of this Section. When the lower plating is not taken into account as a strength member of the hatch cover, the requirements of this paragraph are not necessary for the stiffeners of lower plating.

For hatch cover stiffeners under compression, sufficient safety against lateral and torsional buckling according to 2.20.2.6 of this Section is to be verified.

For hatch covers subject to wheel loading, the relevant requirements of Section 21 of this Chapter are to be complied with. For hatch covers subject to point loads, stiffener scantlings are to be determined by direct calculations under consideration of the allowable stresses as required in 2.20.2.5 of this Section.

(3) The net scantlings of primary supporting members are to comply with the following requirements:

- ① Scantlings of primary supporting members are to be obtained from direct calculations according to 2.20.2.4 under consideration of allowable stresses according to 2.20.2.5 of this Section.

For all components of primary supporting members sufficient safety against buckling is to be verified according to 2.20.2.6 of this Section. For biaxially compressed flange plates, the buckling strength is to be verified within the effective width according to 2.20.2.6(3)② of this Section.

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

$$t = 6.5s \times 10^{-3} \quad \text{mm}$$

$$t = 5 \quad \text{mm}$$

where: s — spacing of stiffeners, in mm.

- ② The net scantlings of edge girders are to comply with the following requirements:

Scantlings of edge girders are to be verified according to 2.20.2.4 under consideration of allowable stresses according to 2.20.2.5 of this Section.

The net thickness of the outer edge girders exposed to wash of seawater is not to be less than the largest of the following values:

$$t = 15.8s \sqrt{\frac{P_A}{0.95R_{eH}}} \quad \text{mm}$$

$$t = 8.5s \times 10^{-3} \quad \text{mm}$$

$$t = 6 \quad \text{mm}$$

where: S — spacing of stiffeners, in mm;

P_A — horizontal weather design pressure, calculated according to 2.20.2.2 of this Section, in kN/m²;

R_{eH} — yield stress of material, in N/mm².

For the required moment of inertia of edge girders, refer to 2.20.2.9(1)④.

~~The stiffness of edge girders is to be sufficient to maintain adequate packing line pressure between securing devices. The moment of inertia of edge girders is not to be less than:~~

$$I = 6qs_{SD}^4 \quad \text{cm}^4$$

~~where: q — packing line pressure, in N/mm, taken as minimum of 5 N/mm;~~

~~s_{SD} — spacing of securing devices, in m.~~

2.20.2.4 Strength calculation

The stresses in hatch covers are to be determined by FE analysis.

The stress calculation model in this section is to be used for both yielding and buckling strength assessments in accordance with 2.20.2.5 and 2.20.2.6, respectively.

The net scantlings as defined in 2.20.2.1(5) are to be used.

Strength calculation for hatch covers may be carried out using grillage analysis or FEM. Double skin hatch covers or hatch covers with box girders are to be assessed using FEM, refer to (2) below.

(1) Effective cross-sectional properties for calculation by 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 are to be taken into account, as shown in Figure 2.20.2.6(2) of this Section.

The effective breadth e_m of plating of primary supporting members is to be determined according to Table 2.20.2.4(1), 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 that 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 2.20.2.6(3)② of this Section.

Effective Breadth e_m of Plating of Primary Supporting Members **Table 2.20.2.4(1)**

l/e	0	1	2	3	4	5	6	7	≥ 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 constrained;
 — where l_0 is the unsupported length of the primary supporting members.
 e —width of plating supported, measured from centre to centre of the adjacent unsupported fields.

(2) General requirements for FEM calculations

For strength calculations of hatch covers by means of finite elements, the cover geometry is to be idealized as realistically as possible. ~~Element size is to be appropriate to account for effective breadth.~~ In no case element width is to 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 is not to exceed 4.~~

The element height of webs of primary supporting members is not to exceed one-third of the web height. ~~Stiffeners and supporting plates against pressure loads have to be included in the idealization. Stiffeners may be modelled using shell elements, plane stress elements or beam elements.~~ Stiffeners, which support plates subjected to lateral pressure loads, are to be included in the FE model idealization. Stiffeners may be modelled by using beam elements, or shell/plate elements. Buckling stiffeners may be disregarded for the stress calculation.

Hatch covers fitted with U-type stiffeners as shown in Figure 2.20.2.4(1) are to be assessed by means of FE analysis. The geometry of the U-type stiffeners is to be accurately modelled using shell/plate elements. Nodal points are to be properly placed on the intersections between the webs of a U-type stiffener and the hatch cover plate, and between the webs and flange of the U-type stiffener.

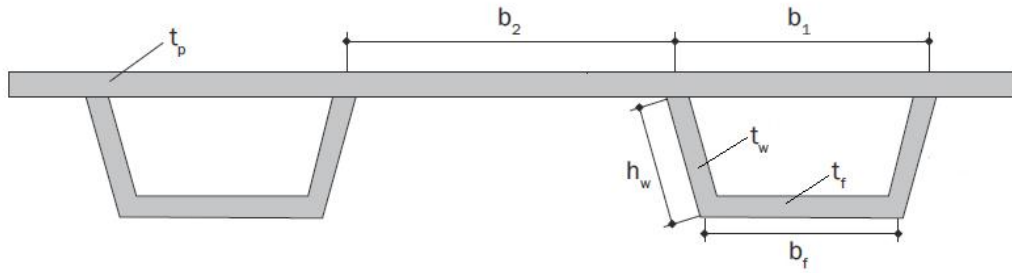


Fig. 2.20.2.4(1) Example of hatch cover fitted with U-type stiffeners

- ① A right-handed coordinate system is to be used with:
 - the x -axis measured in the longitudinal direction, positive forward;
 - the y -axis measured in the transverse direction, positive to port from the centerline;
 - the z -axis measured in the vertical direction, position upward.
- ② The FEM is to be performed with net scantlings.
- ③ The finite element model is to be limited as follows:
 - (a) for symmetry of the hatch cover girders, loads and supporting boundary conditions about only the x -axis or y -axis, it may be limited to a half of the hatch cover for check;
 - (b) for non-symmetry of hatch cover girders, loads or supporting boundary conditions about any of the axes, the whole hatch cover may be taken for strength evaluation, see Figure 2.20.2.4(42).

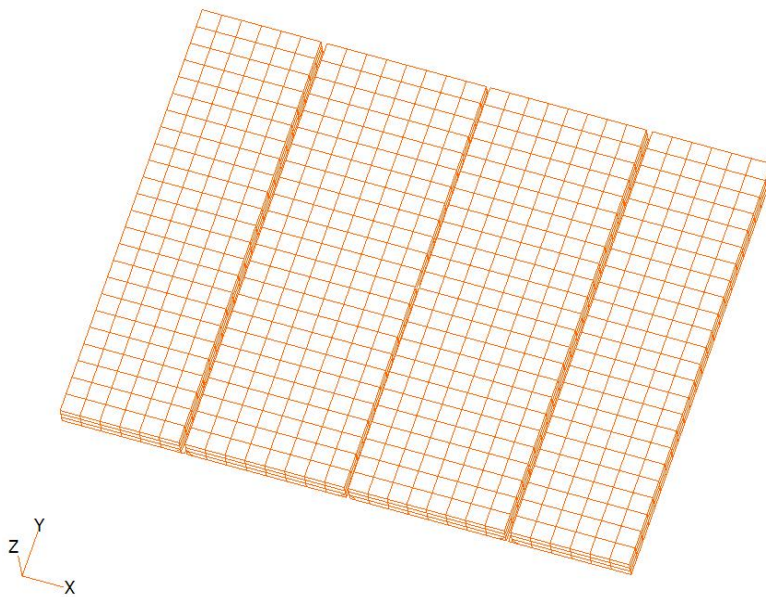


Figure 2.20.2.4(42) Finite Element Hatch Cover Model

- ④ The model element is to comply with the following requirements:
 - (a) all plating, including girders and stiffeners, is to be represented by the finite element model;
 - (b) all plating, such as top plates, bottom plates, brackets, and girder webs, face plates of primary supporting members is to modeled using plate elements, triangular elements are to be avoided where possible;

- (c) all stiffeners are to be modeled using beam, rod or plate elements.
- ⑤ The element mesh size is to be controlled as follows:
- (a) the mesh size is not to be greater than the spacing of stiffeners;
 - (b) the girders are to be represented by at least 3 elements in the depth;
 - (c) triangular and distorted quadrilateral elements with corner angles less than 60 degrees and greater than 120 degrees are to be avoided.
- ⑥ Boundary conditions are to be determined as follows:
- (a) for symmetry of the hatch cover girders and loads about the x-axis~~yz-plane~~, the longitudinal displacement of nodes in the symmetric plane and the rotations about the y and z axes are to be taken as 0 respectively, i.e. $\delta_x = \theta_y = \theta_z = 0$, as shown in Figure 2.20.2.4(23);
 - (b) for symmetry of the hatch cover girders and loads about the y-axis~~xz-plane~~, the transverse displacement of nodes in the symmetric plane and rotation about the x and z axes are to be taken as 0 respectively i.e. $\delta_y = \theta_x = \theta_z = 0$, as shown in Figure 2.20.2.4(23);
 - (c) boundary nodes in way of bearing pads on the hatch coamings are generally to be fixed against displacement in the z direction, i.e. $\delta_z = 0$;
 - (d) lifting stoppers are to be fixed against displacements in the direction determined by the stoppers;
 - (e) hinges in folding type hatch covers are to be represented as rigid links which tie together displacements in the z direction.

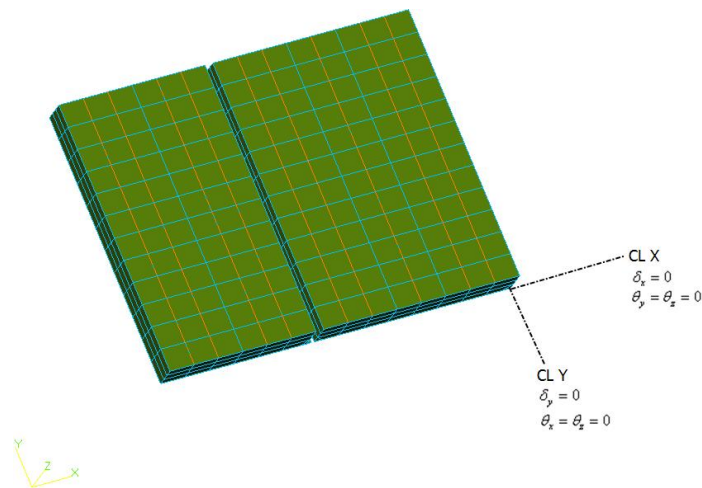


Figure 2.20.2.4(23) Boundary Conditions of Hatch Cover Model

2.20.2.5 Yield strength and deflection criteria of hatch cover structures

(1) Allowable stresses

~~The equivalent stress σ_e in steel hatch cover structures related to the net thickness is not to exceed $0.8R_{eH}$, where R_{eH} is the minimum yield stress, in N/mm^2 , of the material. For design loads according to 2.20.2.2(2) to (6) of this Section, the equivalent stress σ_e related to the net thickness is not to exceed $0.9 R_{eH}$ when the stresses are analysed by means of FEM.~~

For steels with a yield stress of 390 N/mm², it is taken as 368 N/mm² for calculation.

For grillage analysis, the equivalent stress may be taken as follows:

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

where: σ — normal stress, in N/mm²;

τ — shear stress, in N/mm².

All hatch cover structures are to comply with the following formulae:

$$\sigma_{vm} \leq \sigma_a, \text{ for shell element;}$$

$$\sigma_{axial} \leq \sigma_a, \text{ for rod or beam elements.}$$

where: σ_a — allowable stress in Table 2.20.2.5;

R_{eff} — yield stress of the material;

σ_{vm} — For FEM calculations, the equivalent stress may be taken as follows:

$$\sigma_{vm} = \sqrt{\sigma_x^2 - \sigma_x \cdot \sigma_y + \sigma_y^2 + 3\tau^2} \quad \text{N/mm}^2$$

where: σ_x — normal stress, in N/mm², in x-direction;

σ_y — normal stress, in N/mm², in y-direction;

τ — shear stress, in N/mm², in the x-y plane;

σ_{axial} — axial stress in rod or beam elements, in N/mm².

In case of FEM calculations using shell or plane strain elements, the stresses are to be read from the centre of the individual element. It is to be observed that, in particular, at flanges of unsymmetrical girders, the evaluation of stress from element centre may lead to non-conservative results. Thus, a sufficiently fine mesh is to be applied in these cases or, the stress at the element edges is not to exceed the allowable stress. Where shell elements are used, the stresses are to be evaluated at the mid plane of the element.

For steels with a yield stress of 390 N/mm², it is taken as 368 N/mm² for calculation.

Stress concentrations are to be evaluated according to the actual conditions.

Allowable stress

Table 2.20.2.5

Members of	Subject to	σ_a , in N/mm ²
Hatch cover structure	External pressure, as defined in 2.20.2.2(1)	$0.80R_{eff}$
	Other loads, as defined in 2.20.2.2(2)~(5)	$0.90R_{eff}$ for static+dynamic load case $0.72R_{eff}$ for static load case

(2) Deflection

The vertical deflection of primary supporting members due to the load stipulated in 2.20.2.2 of this Section is to be not more than $0.0056l_g$, where l_g is the greatest span of primary supporting

member.

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

2.20.2.6 Buckling strength of hatch cover structures

(1) General

Buckling strength of all hatch cover structures is to be checked. Buckling assessments are to be performed in compliance with the requirements in Appendix 5.

The net scantlings as defined in 2.20.2.1(5) are to be used for buckling check.

(2) Slenderness requirements

The slenderness requirements are to be in accordance with those specified in Sec 2 of Appendix 5.

The slenderness requirements need not be applied to the lower boundary of double skin hatch covers unless the cargo hold is designed for carriage of ballast or liquid cargo.

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.

(3) Buckling requirements

① These requirements apply to the buckling assessment of hatch cover structures subjected to compressive and shear stresses and lateral pressures. The buckling assessment is to be performed for the following structural elements:

- Stiffened and unstiffened panels, including curved panels and panels stiffened with U-type stiffeners.
- Web panels of primary supporting members in way of opening.

The buckling strength assessment of coaming parts is to be done according to this paragraph.

For rule application, the panel types and assessment methods, the applied lateral pressure and stresses, safety factors and buckling check criteria are defined in 2.20.2.6(3)②-2.20.2.6(3)⑤, respectively. The procedure and detailed requirements for buckling assessment are given in Section 4 of Appendix 5, including idealization of irregular plate panels, definition of reference stresses and buckling criteria.

Unless otherwise specified, the symbols used in 2.20.2.6(3) are defined in Appendix 5.

② Panel types and assessment methods

The plate panel of a hatch cover structure is to be modelled as stiffened panel (SP) or unstiffened panel (UP) as defined in 4.2, Section 4 of Appendix 5. Assessment Method A (-A) and Method B (-B) as defined in 1.3, Section 1 of Appendix 5 are to be used in accordance with Table 2.20.2.6(3)①, Figure 2.20.2.6(3)① and Figure 2.20.2.6(3)②. For a web panel with opening, the procedure for opening should be used for its buckling assessment.

For a hatch cover fitted with U-type stiffeners, the additional buckling assessment requirements specific for panels with U-type stiffeners in 5.2.5, Section 5 of Appendix 5 are also to be followed.

Structural members and assessment methods

Table 2.20.2.6(3)①

<u>Structural elements</u>	<u>Assessment method⁽¹⁾⁽²⁾</u>	<u>Normal panel definition</u>
----------------------------	---	--------------------------------

<u>Hatch cover top/bottom plating structures, see Figure 2.20.2.6(3)①</u>		
<u>Hatch cover top/bottom plating</u>	<u>SP-A</u>	<u>Length: between transverse girders</u> <u>Width: between longitudinal girders</u>
<u>Irregularly stiffened panels</u>	<u>UP-B</u>	<u>Plate between local stiffeners/PSM</u>
<u>Hatch cover web panels of primary supporting members, see Figure 2.20.2.6(3)②</u>		
<u>Web of transverse/longitudinal girder (single skin type)</u>	<u>UP-B</u>	<u>Plate between local stiffeners/face plate/PSM</u>
<u>Web of transverse/longitudinal girder (double skin type)</u>	<u>SP-B⁽³⁾</u>	<u>Length: between PSM</u> <u>Width: full web depth</u>
<u>Web panel with opening</u>	<u>Procedure for opening</u>	<u>Plate between local stiffeners/face plate/PSM</u>
<u>Irregularly stiffened panels</u>	<u>UP-B</u>	<u>Plate between local stiffeners/face plate/PSM</u>
<u>Note 1: SP and UP stand for stiffened and unstiffened panel respectively.</u>		
<u>Note 2: A and B stand for Method A and Method B respectively.</u>		
<u>Note 3: In case that the buckling carlings/brackets are irregularly arranged in the web of transverse/longitudinal girder, UP-B method may be used.</u>		

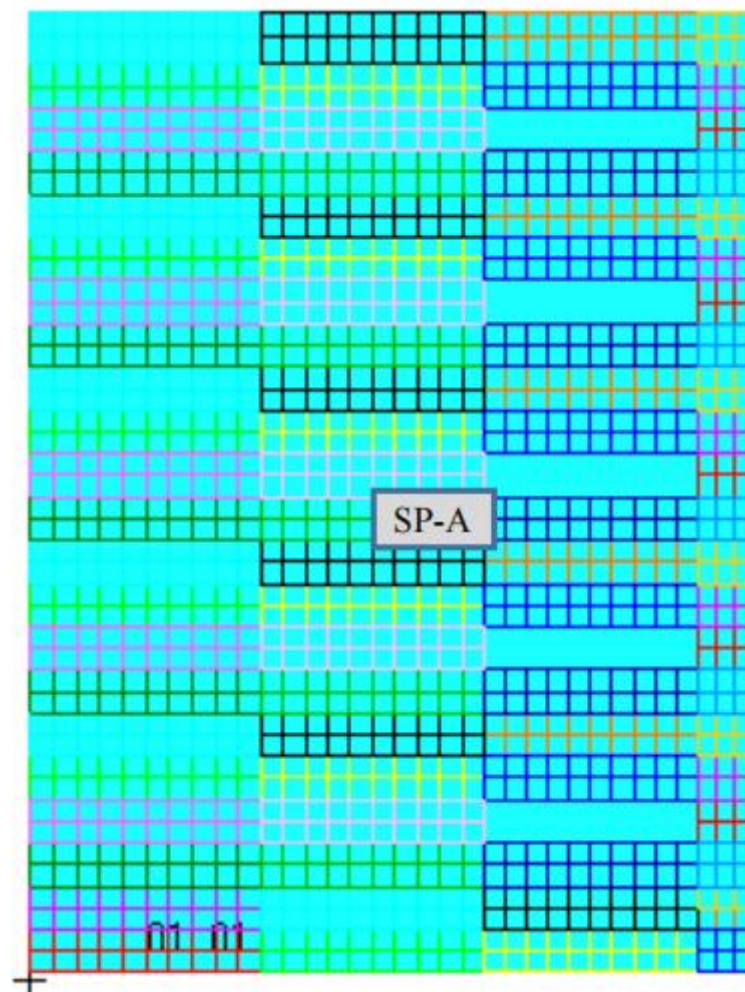


Figure 2.20.2.6(3)①

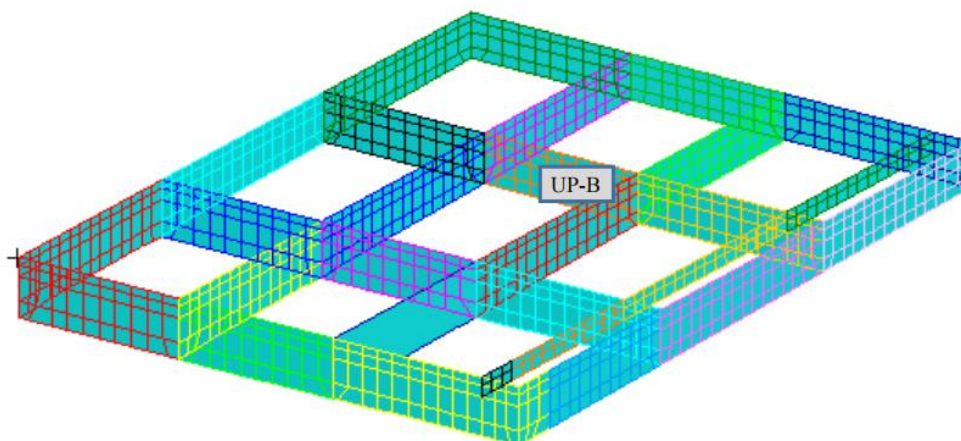


Figure 2.20.2.6(3)②

③ Applied lateral pressure and stresses

The buckling assessment of hatch covers is based on the lateral pressure as defined in 2.1 and 2.2, and stresses obtained from FE analysis, refer to 2.20.2.4.

④ Safety factors

For all hatch cover structural members, safety factor S=1.0 is to be applied to both of the plating and stiffener buckling capacity formulas as defined in 5.2.2, Section 5 of Appendix 5 and 5.2.3, Section 5 of Appendix 5, respectively.

⑤ Buckling acceptance criteria

A structural member is considered to have an acceptable buckling strength if it satisfies the following criterion:

$$\eta_{act} \leq \eta_{all}$$

where: η_{act} —Buckling utilisation factor based on the applied stress, as defined in 1.3.2.2, Section 1 of Appendix 5 and Section 4 of Appendix 5, and calculated per Section 5 of Appendix 5.

η_{all} —Allowable buckling utilisation factor, taken as given in Tab.2.20.2.6(3)⑤.

Allowable buckling utilisation factors

Table 2.20.2.6(3)⑤

<u>Structural component</u>	<u>Subject to</u>	<u>η_{all}, allowable buckling utilisation factor</u>
<u>Plates and stiffeners</u> <u>Web of PSM</u>	<u>External pressure, as defined in 2.20.2.2(1)</u>	<u>0.80</u>
	<u>Other loads, as defined in 2.20.2.2(2)~(5)</u>	<u>0.90 for static+dynamic load case</u> <u>0.72 for static load case</u>

2.20.2.7 Details of hatch covers

(1) Container foundation on hatch covers

Container foundations on hatch covers are to be in compliance with the relevant requirements of Appendix 1 of Chapter 7 of this PART. The calculated stresses of substructures of container foundations under cargo and container loads according to 2.20.2.2 of this Section are to comply

with the requirements of 2.20.2.5 of this Section.

(2) Weathertightness

In addition to the following requirements, the hatch covers are also to meet the relevant requirements of IACS REC14.

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 may 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 is to be given to the packing arrangement in ships with large relative movements between hatch covers and coamings or between hatch cover sections.

② Dispensation of weathertight gaskets

For hatch covers of cargo holds intended solely for the transport of containers, upon request by the Owner and subject to compliance with the following conditions, the fitting of weathertight gaskets according to 2.20.2.7(2) may be dispensed with:

- The hatchway coamings are to be not less than 600 mm in height.
- For weather deck hatch covers located above a depth $H(x)$, $H(x)$ is to comply with the following criterion:

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

where: T_{fb} — draught, in m, corresponding to the assigned summer load line;

f_b — minimum required freeboard, in m, determined in accordance with ICLL Regulation 28 as modified by further regulations as applicable;

$$h = 4.6 \text{ m} \quad \text{for } \frac{x}{L_L} \leq 0.75;$$

$$h = 6.9 \text{ m} \quad \text{for } \frac{x}{L_L} > 0.75.$$

- 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 is to be not wider than 50 mm.
- The labyrinths and gaps between hatch cover panels are to 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, refer to the relevant requirements of Chapter 6, PART EIGHT of the Rules.
- Bilge alarms are to be provided in each hold fitted with non-weathertight covers.
- Furthermore, Chapter 3 of IMO MSC/Circ.1087 is to be complied with for the storage and segregation of containers carrying dangerous goods.

③ Cross-joint of multi-panel covers are to be provided with efficient drainage arrangements.

2.20.2.8 Hatch coamings are to comply with the following requirements:

- (1) The net thickness of weather deck hatch coamings is not to be less than the larger of the

following values:

- For Type-1 ships:

$$t = 0.0142s \sqrt{\frac{P_A}{0.95R_{eH}}} \quad \text{mm}$$

$$t = 6 + \frac{L_1}{100} \quad \text{mm}$$

- For Type-2 ships:

$$t = 0.016s \sqrt{\frac{p_{coam}}{0.95R_{eH}}} \quad \text{mm}$$

$$\underline{t_{\min} = 9.5 \quad \text{mm}}$$

where: s — stiffener spacing, in m;

P_A — horizontal weather design load, in kN/m², to be calculated according to 2.20.2.2(2)

① of this Section;

p_{coam} — horizontal weather design load, in kN/m², to be calculated according to 2.20.2.2(2)

② of this Section;

R_{eH} — yield stress of material, in N/mm²;

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

The continuous longitudinal hatch coamings within 0.4L amidships are also to comply with the relevant requirements of Section 2 of this Chapter.

(2) The stiffeners of hatch coaming are to meet the following requirements:

The stiffeners are to be continuous at the coaming stays.

For stiffeners with both ends constrained, the net section modulus $\underline{W}$ and net shear area A_{shr} , calculated on the basis of net thickness, are not to be less than:

- For Type-1 ships:

$$W = \frac{83sl^2 p_A}{R_{eH}} \quad \text{cm}^3$$

$$A_s = \frac{10sl p_A}{R_{eH}} \quad \text{cm}^2$$

$$Z = \frac{p_A s l^2}{f_{bc} R_{eH}} \quad \text{cm}^3$$

$$\underline{A_{shr} = \frac{p_A s l^2}{R_{eH}} 10^{-2} \quad \text{cm}^2}$$

where: f_{bc} =12 in general

= 8 for the end spans of stiffeners sniped at the coaming corners

l — stiffener span, in m, to be taken as the spacing of coaming stays;

s — stiffener spacing, in m;

P_A — horizontal weather design load, in kN/m², to be calculated according to 2.20.2.2(2)① of this Section;

R_{eH} — yield stress of material, in N/mm²;

For sniped stiffeners of coaming at hatch 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 is not to be less than:

$$t = 19.6 \sqrt{\frac{p_A s (l - 0.5s)}{R_{eH}}} \text{ mm}$$

- For Type-2 ships:

$$Z = 1.21 \frac{p_{coam} s l^2}{f_{bc} c_p R_{eH}}$$

where: f_{bc} — 16 in general

12 for the end spans of stiffeners sniped at the coaming corners

l — stiffener span, in m, to be taken as the spacing of coaming stays;

s — stiffener spacing, in m;

p_A — horizontal weather design load, in kN/m², to be calculated according to 2.20.2.2(2)① of this Section;

p_{coam} — horizontal weather design load, in kN/m², to be calculated according to 2.20.2.2(2)② of this Section;

c_p — ratio of the plastic section modulus to the elastic section modulus of the stiffeners with an attached plate breadth, in mm, equal to $40t$, where t is the plate net thickness

c_p — 1.16 in the absence of more precise evaluation

The horizontal stiffeners of continuous longitudinal hatch coamings within $0.4L$ amidships are also to comply with the relevant requirements of Section 2 of this Chapter.

(3) Coaming stays are to be designed for the loads transmitted through them and are to comply with the following requirements, in addition to the allowable stresses stipulated in 2.20.2.5 of this Section.

- ① Coaming stay section modulus and web thickness

At the connection with deck, the net section modulus W , in cm³, and the gross thickness t_w , in mm, of the coaming stays designed as beams with flange (examples 1 and 2 are shown in Figure 2.20.2.8(3)) are to be taken not less than:

$$W = \frac{526 e h_s^2 p_A}{R_{eH}} \text{ cm}^3$$

$$t_w = \frac{2}{R_{eH}} \frac{e h_s p_A}{h_w} + t_s \text{ mm}$$

$$Z = \frac{P_s H_c^2}{1.9 R_{eH}} \text{ cm}^3$$

$$t_w = \frac{2 P_s H_c}{h R_{eH}} \text{ mm}$$

where: H_c — stay height, in m

$s_c h_s$ — stay spacing, in mm

h_w — stay depth, in mm, at the connection with the deck

~~its lower end, in m;~~

p_t — pressure on coaming, in kN/m^2 , taken as p_A defined in 2.20.2.2(2)① in general
and as p_{coam} defined in 2.20.2.2(2)② for Type-2 ships ~~corrosion addition, in mm,~~

according to 2.20.2.10 of this Section;

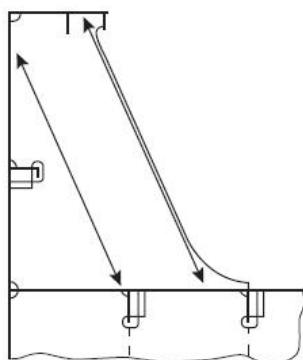
P_A — horizontal weather design load, in kN/m^2 , to be calculated according to 2.20.2.2(2)
of this Section.

For other designs of coaming stays, such as those shown in Figure 2.20.2.8(3), examples 3 and 4, the stresses are to be determined through a grillage analysis or FEM. The calculated stresses are to comply with the permissible stresses according to 2.20.2.5 of this Section.

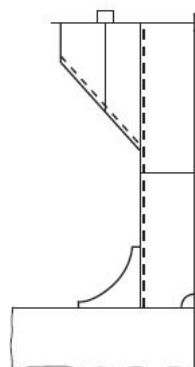
Coaming stays are to be supported by appropriate substructures. Face plates may only be included in the calculation of section modulus of coaming stays if an appropriate substructure is provided and welding provides an adequate joint.

Webs are to be connected to the deck by fillet welds on both sides with a throat thickness of not less than $0.44t_w$.

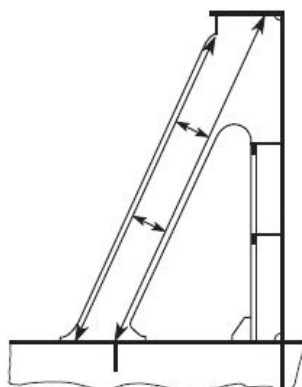
For Type-2 ships, toes of stay webs are to be connected to the deck plating with full or partial penetration double bevel welds extending over a distance not less than 15% of the stay width. For other ship types the ~~The~~ size of welding for toes of webs at the lower end of coaming stays is to comply with the relevant requirements of Chapter 1 of this PART.



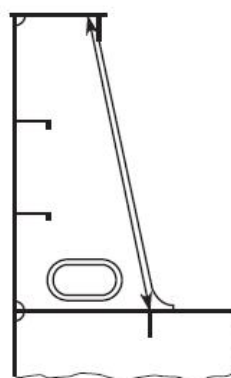
Example 1



Example 2



Example 3



Example 4

Figure 2.20.2.8(3) Examples of coaming stays

- ② For coaming stays, which transfer friction forces at hatch cover supports, fatigue strength is to be considered.
- (4) The hatch coaming is also to comply with the following requirements:
 - ① Hatch coamings which are part of the longitudinal hull structure are to be designed according to the relevant requirements of Section 2 of this Chapter.
 - ② For structural members welded to coamings and for cutouts in the top of coamings, sufficient fatigue strength is to be verified.
 - ③ Longitudinal hatch coamings with a length exceeding $0.1L$ 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.
 - ④ The local details are to be designed to transfer 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, welding and material are to comply with the relevant requirements of CCS.
 - ⑤ 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.
 - ⑥ Coaming plates are to extend to the lower edge of the deck beams or hatch side girders are to be fitted that extend to the lower edge of the deck beams. Extended coaming plates and hatch side girders are to be flanged or fitted with face bars or half-round bars. See Figure 2.20.2.8(4).

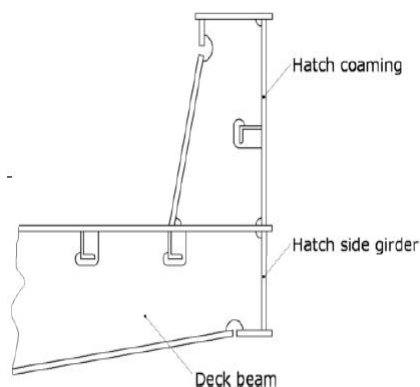


Figure 2.20.2.8(4) Example for the Extension of Coaming Plates

- ⑦ Drainage arrangement at the coaming is to comply with the following requirements:
 - 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 covers, 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.

2.20.2.9 Closing arrangements of weathertight steel hatch covers

(1) Securing arrangements

① General requirements

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 are to be appropriate to bridge displacements between cover and coaming due to hull deformations.

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. According to the requirements of 2.20.2.3(3)② of this Section, a sufficient number of securing devices is to be provided at each side of the hatch cover, including that consisting of several parts.

The materials of stoppers, securing devices and their welding are to comply with the relevant requirements of CCS Rules for Materials and Welding. Specifications of the materials are to be shown in the drawings of the hatch covers.

② Rod cleats

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

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.

④ Cross-sectional area of the securing devices

The gross cross-sectional area of the securing devices is not to be less than:

$$A = 0.28qS_{SD}k_l \quad \text{cm}^2$$

where: q —packing line pressure, in N/mm, minimum 5 N/mm;

S_{SD} — spacing between securing devices, in m, not to be taken less than 2 m;

$$k_l = \left(\frac{235}{R_{eH}}\right)^e;$$

R_{eH} — the minimum yield stress of material, in N/mm², but not to be taken greater than $0.7R_m$;

R_m — tensile strength of material, in N/mm²;

$$e = 0.75 \quad \text{for } R_{eH} > 235 \text{ N/mm}^2;$$

$$e = 1.00 \quad \text{for } R_{eH} \leq 235 \text{ N/mm}^2.$$

Rods or bolts are to have a gross diameter not less than 19 mm for hatchways exceeding 5m² in area.

Securing devices of special design in which significant bending or shear stresses occur may be designed as anti-lifting devices according to 2.20.2.9(1)⑤. The design load is taken as the packing line pressure q multiplied by the spacing S_{SD} between securing devices.

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 2.20.2.2(4) of this Section, refer to Figure 2.20.2.9(1). 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:

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

where: k_l — as in 2.20.2.9(1)④.

Note: The partial load cases given in Table 2.20.2.2(4) may not cover all unsymmetrical loadings, critical for hatch cover lifting.

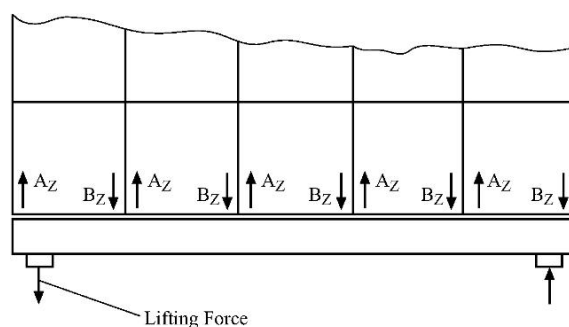


Figure 2.20.2.9(1) Lifting Forces at a Hatch Cover

The anti-lifting devices may be dispensed with according to the following requirements:

In the absence of hatch cover lifting under loads arising from the ship's rolling motion, securing devices for hatch covers may be omitted. In such cases, it is to be proven by means of grillage or finite element analysis that an equilibrium condition is achieved using compression only boundary elements for the vertical hatch cover supports. If securing devices are omitted, transverse cover guides are to be effective up to a height h_E , as

shown in Figure 2.20.2.9(2), where h_E is not to be less than:

$$h_E = 1.75(2se + d^2)^{0.5} - 0.75d \quad \text{mm}$$

$$h_{E \min} = \text{height of the cover edge plate} + 150 \quad \text{mm}$$

where: e — largest distance from the inner edge of the transverse cover guide to the end of the cover edge plate, in mm;

s — total clearance within the transverse cover guide, with $10 \leq s \leq 40$, in mm;

d — distance between upper edge of transverse stopper and hatch cover support, in mm.

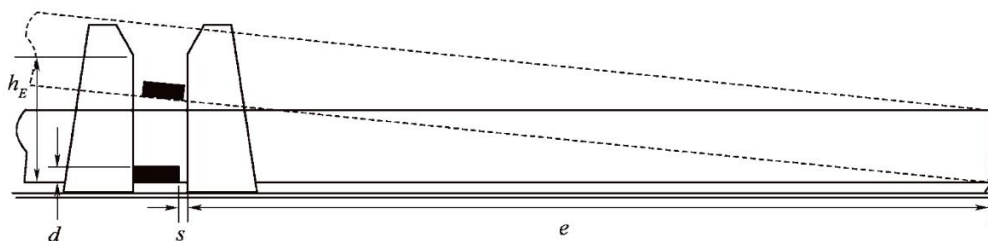


Figure 2.20.2.9(2) Height of Transverse Cover Guide

The transverse cover guides and their substructure are to be dimensioned in accordance with the transverse loads acting at a height h_E .

(2) Hatch cover supports, stoppers and supporting structures

① Horizontal mass forces

For the design of hatch cover supports, the horizontal mass force is to be taken as follows:

$$F_h = ma$$

where: F_h — horizontal mass force, in kN;

$a_x = 0.2g$ in longitudinal direction;

$a_y = 0.5g$ in transverse direction;

m — sum of mass of cargo lashed on the hatch cover and mass of hatch cover.

The accelerations in longitudinal direction and in transverse direction need not be considered as acting simultaneously.

② Hatch cover supports

For the transmission of the support forces resulting from the load cases specified in 2.20.2.2 of this Section and of the horizontal mass forces specified in (2)①, supports are to be provided which are to be designed such that the nominal surface pressures in general do not exceed the values obtained from the following formula:

$$p_{n\max} = dp_n \quad \text{N/mm}^2$$

where: $d = 3.75 - 0.015L$;

$$d_{\max} = 3.0;$$

$$d_{\min} = 1.0, \text{ in general};$$

$$d_{\min} = 2.0, \text{ for partial loading conditions, see 2.20.2.2(5);}$$

P_n — Allowable nominal surface pressure, see Table 2.20.2.9(2).

Allowable Nominal Surface Pressure P_n Table 2.20.2.9(2)

Support material	P_n (N/mm ²) when loaded by	
	Vertical force	Horizontal force (on stoppers)
Hull structural steel	25	40
Hardened steel	35	50
Lower friction materials	50	—

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

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

Note: When the maker of vertical hatch cover support material can provide proof that the material is sufficient for the increased surface pressure, not only statically but under dynamic conditions including relative motion for adequate number of cycles, permissible nominal surface pressure may be relaxed at the discretion of CCS. However, realistic long term distribution of spectra for vertical loads and relative horizontal motion is to be assumed and agreed with CCS.

Drawings of the supports are to be submitted for approval. In the drawings of supports, the permitted maximum pressure given by the material manufacturer is to be indicated.

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

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

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

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

where: P_v — vertical supporting force;

μ — frictional coefficient;

$\mu = 0.5$ steel to steel.

For non-metallic, low-friction support materials on steel, the friction coefficient μ may be reduced but not to be less than 0.35 and it is to be submitted to CCS for approval.

Supports as well as the adjacent structures and substructures are to be designed such that the allowable stresses in 2.20.2.5 of this Section are not exceeded.

For substructures and adjacent structures of supports subjected to horizontal forces P_h , a fatigue strength is to be considered.

③ Hatch cover stoppers

Hatch covers are to 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 2.20.2.2(2) of this Section and 2.20.2.9(2)① is to be applied for the dimensioning of the stoppers and their substructures.

The allowable stress in stoppers and their substructures, in the cover, and of the coamings is to be determined according to 2.20.2.5 of this Section and in addition, the requirements in 2.20.2.9(2)② are to be taken into consideration.

Specifically for Type-2 ships, the following additional requirements are to be complied with:

Hatch covers are to be effectively secured, by means of stoppers, against the transverse forces arising from a pressure of 175 kN/m².

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/m².

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/m².

This pressure may be reduced to 175 kN/m² when a forecastle is fitted in accordance with Section 13, Chapter 8, PART TWO of CCS Rules for Classification of Sea-going Steel Ships.

The equivalent stress in stoppers and their supporting structures, and calculated in the throat of the stopper welds is not to exceed the allowable value of $0.8R_{eH}$.

2.20.2.10 Corrosion addition and steel renewal

(1) Corrosion addition for hatch covers and hatch coamings

For scantlings of hatch cover components, the general corrosion additions t_s , as shown in Table 2.20.2.10, is required.

Corrosion Addition t_s for Hatch Covers and Hatch Coamings **Table 2.20.2.10**

Application	Structure	t_s [mm]
Weather deck hatches of container ships, car carriers, paper carriers and passenger vessels	Hatch covers	1.0
	Hatch coamings	1.5 for $t \leq 10$
		$\frac{0.1t}{\sqrt{K}} + 0.5$, but not greater than 3, for $t > 10$
<u>Weather deck cargo hatches of Type-2 ships</u>	<u>Hatch covers in general</u>	<u>2.0</u>
	<u>Top and bottom plating of double skin hatch covers</u>	<u>2.0</u>
	<u>Internal structure of double skin hatch covers</u>	<u>1.5</u>
	<u>Hatch coamings and coaming stays</u>	<u>1.5</u>
Weather deck hatches of all other ships	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	1.5 for $t \leq 10$
		$\frac{0.1t}{\sqrt{K}} + 0.5$, but not greater than 3, for $t > 10$
	Coaming stays and stiffeners	1.5

Notes:

t : net thickness of hatch coaming required by the Rules.

K : material factor.

(2) Steel renewal

Steel renewal is required where the gauged thickness is less than $t_{net} + 0.5$ mm for

- single skin hatch covers,

- the plating of double skin hatch covers, and
- coaming structures the corrosion additions t_s of which are given in Table 2.20.2.10.

Coating is to be maintained in GOOD condition, as defined in 5.1.5.1(15), Chapter 5 of PART ONE of the Rules.

For 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 it is deemed necessary by CCS surveyor, on the basis of the plating corrosion or deformation. In these cases, steel renewal for the internal structures is to be 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 coating or annual gauging may be used for substitution of renewal when gauged thickness is between t_{net} and $t_{net} + 0.5$ mm.

For coaming structures, the corrosion additions t_s of which are not given in Table 2.20.2.10, steel renewal and coating or annual gauging are to be in accordance with the relevant requirements of CCS.

2.20.3 Steel pontoon covers

2.20.3.1 The design load of steel pontoon covers is to comply with the following requirements:

(1) The design load of vertical exposed hatch covers is to be calculated according to Table 2.20.2.2(1) of this Section.

(2) The permissible cargo load p on hatch covers is to be specified by the Owner or designer and included in the loading manual, complying with the following requirements:

- ① The permissible cargo load p for 'tween deck hatch covers is not to be less than:

$$p = 7.06h \quad \text{kN/m}^2$$

where: h — the vertical distance, in m, measured from the hatch cover to the underside of hatch cover stiffeners on deck above.

This requirement does not apply to multi-purpose ships of which the 'tween deck hatch covers are used as 'tween deck, see Figure 2.20.3.1(2) of this Section.

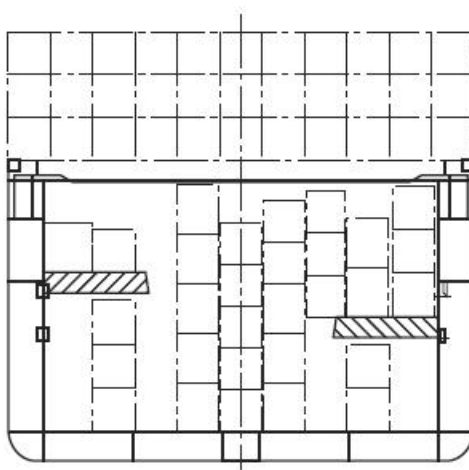


Figure 2.20.3.1(2)

- ② The permissible cargo load p for hatch covers in the accommodation spaces is not to be less than 12.7 kN/m².

2.20.3.2 The local scantlings of hatch covers are to comply with the following requirements:

(1) The thickness t of the top plating of steel hatch covers is not to be less than that obtained from the following formula:

$$t = 10s \sqrt{t = 0.01s} \quad \text{mm, but in no case to be less than 6 mm.}$$

where: s — spacing of stiffeners, in mm.

(2) The scantlings of stiffeners and girders of steel pontoon covers are to comply with the following requirements:

- ① Where the uniformly distributed design load of vertical exposed hatch covers is applied, the section modulus W and the section moment of inertia I of stiffeners are not to be less than:

$$W = 0.782Ksp^2 \sqrt{W = 7.82Kspl^2 \times 10^{-4}} \quad \text{cm}^3$$

$$I = 1.44sp^3 \sqrt{I = 1.44spl^3 \times 10^{-3}} \quad \text{cm}^4$$

where: p — vertical weather design load, in kN/m²;

s — spacing of stiffeners, in mm;

l — span of stiffener, in m;

K —material factor.

- ② Where the uniformly distributed cargo load is applied, the section modulus W and the section moment of inertia I of stiffeners are not to be less than:

$$W = 1.064Ksp^2 \sqrt{W = 1.064Kspl^2 \times 10^{-3}} \quad \text{cm}^3$$

$$I = 1.8sp^3 \sqrt{I = 1.8spl^3 \times 10^{-3}} \quad \text{cm}^4$$

where: p —permissible cargo load, in kN/m²;

s —spacing of stiffeners, in mm;

l —span of stiffener, in m;

K —material factor.

- ③ Where the ends of stiffeners are effectively bracketed or continuous, the values of section modulus and moment of inertia may be reduced respectively by 33% and 80% than those obtained from ① or ②.
- ④ The scantlings of girders of steel pontoon covers are to be determined by direct calculations. Where steel pontoon covers are subject to uniformly distributed loading and girders are fitted in one direction only, however, the scantlings of girders may also be determined according to ① and ②.

~~(3) The scantlings of stiffeners and girders with variable cross section are to comply with the following requirements:~~

- ~~① The section modulus at the mid-span of stiffener and girder with a variable cross-section (see Figure 2.20.3.2(3)) is to be not less than the greater of the values obtained from the following formulae:~~

$$W = W_{es} \quad \text{cm}^3$$

$$W = \left(1 + \frac{3.2\alpha - \gamma - 0.8}{7\gamma + 0.4} \right) W_{cs} \quad \text{cm}^3$$

where: W_{cs} —section modulus, in cm^3 , for a constant cross-section, complying with this Section;—

$\alpha = \frac{l_1}{l_0}$, where l_0 is span, in m, l_1 is length of the variable cross-section, in m;

$\gamma = \frac{W_1}{W_0}$, where W_0 is section modulus at mid-span, in cm^3 , W_1 is section modulus at ends, in cm^3 .

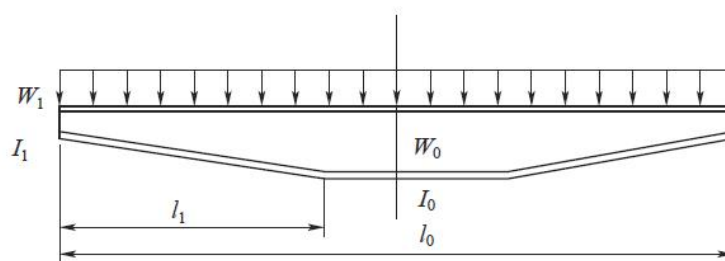


Figure 2.20.3.2(3)

- ② The section moment of inertia I at the mid-span of stiffener and girder with a variable cross-section is not to be less than the greater of the values obtained, from the following formulae:

$$I = I_{cs} \text{ — cm}^4$$

$$I = \left(1 + \frac{8\alpha^3(1-\beta)}{0.2+3\sqrt{\beta}} \right) I_{cs} \text{ — cm}^4$$

where: I_{cs} —moment of inertia, in cm^4 , for a constant cross-section, complying with this Section;—

$\alpha = \frac{l_1}{l_0}$, where l_0 is span, in m, l_1 is length of the variable cross-section, in m;

$\beta = \frac{I_1}{I_0}$, where I_0 is section moment of inertia at mid-span, in cm^4 , I_1 is section moment of inertia at ends, in cm^4 .

- ③ The web depth of the stiffeners and girders at ends is not to be less than 2/5 of that at the mid-span, and is in no case to be less than 150 mm and the section modulus of the stiffeners and girders at ends is not to be less than 35% of that at the mid-span.

2.20.3.3 The direct strength calculation of steel pontoon covers is to be in compliance with the requirements of 2.20.2.4 of this Section.

2.20.3.4 Yield strength and deformation criteria of steel hatch covers of steel pontoon covers

The yield strength and deflection of steel pontoon covers are to meet the requirements of Table 2.20.3.4.

Steel Pontoon Covers

Table 2.20.3.4

Load	Allowable positive stress [σ] (N/mm ²)	Allowable deflection (m)
Vertical weather design load	$0.70R_{eH}$	$0.0049 l$
Loads other than vertical weather design load	$0.65R_{eH}$	$0.0044 l$

2.20.3.5 The buckling strength of steel pontoon covers is to meet the requirements of Table

2.20.3.5.

Table 2.20.3.5

Structural member		Criteria
Top panels of hatch covers	Girders fitted in uni-axial direction	The normal stress of top panels in compression of girders is not to exceed 0.8 times the critical buckling stress σ_c , σ_c may be calculated according to 8.11.3.6(1), Section 11, Chapter 8 of this PART2.20.3.5(1)
	Girders fitted in bi-axial directions	Biaxial compressive stress of top panels, when calculated by means of finite plate element model, is to be in accordance with the relevant requirements in 2.20.2.6(1) of this Section
Girder webs		The shear stress of girder web panels is not to exceed 0.8 times the critical shear buckling stress τ_c , τ_c may be calculated according 8.11.3.6(3), Section 11, Chapter 8 of this PART2.20.3.5(3)
Stiffeners parallel to girders		The normal stress of attached plating of stiffeners in compression of girders parallel to stiffeners is not to exceed 0.8 times the critical buckling stress σ_c , σ_c may be calculated according to 8.11.3.6(2), Section 11, Chapter 8 of this PART2.20.3.5(2)

(1) Hatch cover plating critical stress

The compressive stress σ 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 σ_{c1} , to be evaluated as defined below:

$$\sigma_{c1} = \sigma_{E1} \quad \text{for } \sigma_{E1} \leq \frac{R_{eH}}{2}$$

$$\sigma_{c1} = R_{eH} \left(1 - \frac{R_{eH}}{4\sigma_{E1}}\right) \quad \text{for } \sigma_{E1} > \frac{R_{eH}}{2}$$

where: R_{eH} — yield stress of the material, in N/mm²;

$$\sigma_{E1} = 3.6E \left(\frac{t}{1000s}\right)^2, \text{ in N/mm}^2;$$

E — modulus of elasticity, in N/mm², = 2.06×10^5 for steel;

t — net thickness of plate panel, in mm;

s — spacing of secondary stiffeners, in m.

The mean compressive stress σ 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 σ_{c2} , to be evaluated as defined below:

$$\sigma_{c2} = \sigma_{E2} \quad \text{for } \sigma_{E2} \leq \frac{R_{eH}}{2}$$

$$\sigma_{c2} = R_{eH} \left(1 - \frac{R_{eH}}{4\sigma_{E2}}\right) \quad \text{for } \sigma_{E2} > \frac{R_{eH}}{2}$$

where: R_{eH} — yield stress of the material, in N/mm²;

$$\sigma_{E2} = 0.9mE \left(\frac{t}{1000s_s}\right)^2, \text{ in N/mm}^2;$$

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

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

t — net thickness of plate panel, in mm;

s_s — length of the shorter side of the plate panel, in m;

l_s — length of the longer side of the plate panel, in m;

ψ — 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 the requirements of 2.20.2.6, Chapter 2 of this PART.

(2) Hatch cover secondary stiffeners critical stress

The compressive stress σ 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 σ_{cs} , to be evaluated as defined below:

$$\sigma_{CS} = \sigma_{ES} \quad \text{for } \sigma_{ES} \leq \frac{R_{eH}}{2}$$

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

where: R_{eH} — yield stress of the material, in N/mm^2 ;

σ_{ES} — ideal elastic buckling stress of the secondary stiffener, in N/mm^2 , = minimum between σ_{E3} and σ_{E4} ;

$$\sigma_{E3} = \frac{0.001EI_a}{Al^2}, \text{ in } \text{N/mm}^2;$$

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

I_a — moment of inertia of the secondary stiffener, in cm^4 , including a top flange equal to the spacing of secondary stiffeners;

A — cross-sectional area of the secondary stiffener, in cm^2 , including a top flange equal to the spacing of secondary stiffeners;

l — span of the secondary stiffener, in m;

$$\sigma_{E4} = \frac{\pi^2 EI_w}{10^4 I_p l^2} \left(m^2 + \frac{K}{m^2}\right) + 0.385E \frac{I_t}{I_p}, \text{ N/mm}^2;$$

$$K = \frac{Cl^4}{\pi^4 EI_w} \times 10^6;$$

m — number of half waves, given by Table 2.20.3.5(2);

I_w — sectorial moment of inertia of the secondary stiffener about its connection with the plating, in cm^6 :

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

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

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

I_p — polar moment of inertia of the secondary stiffener about its connection with the plating, in cm^4 :

$$I_p = \frac{h_w^3 t_w^3}{3} \times 10^{-4}, \text{ for flat bar secondary stiffeners;}$$

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

I_t — St Venant's moment of inertia of the secondary stiffener without top flange, in cm^4 :

$$I_t = \frac{h_w^3 t_w^3}{3} \times 10^{-4}, \text{ for flat bar secondary stiffeners;}$$

$$I_t = \frac{1}{3} [h_w^3 t_w^3 + b_f t_f^3 (1 - 0.63 \frac{t_f}{b_f})] \times 10^{-4}, \text{ for flanged secondary stiffeners;}$$

h_w — web height of the secondary stiffener, in mm;

t_w — web net thickness of the secondary stiffener, in mm;

b_f — width of the secondary stiffener bottom flange, in mm;

t_f — net thickness of the secondary stiffener bottom flange, in mm;

s — spacing of secondary stiffeners, in m;

C — spring stiffness exerted by the hatch cover top plating, calculated by the following formula:

$$C = \frac{k_p E t_p^3}{3s(1 + \frac{1.33 k_p h_w t_p^3}{1000 s t_w^3})} \times 10^{-3};$$

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

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

σ — as given in 8.11.3.5;

σ_{E1} — as given in 2.20.3.5(1);

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

Number of Half Waves (m value)				Table 2.20.3.5(2)
K	$0 < K \leq 4$	$4 < K \leq 36$	$36 < K \leq 144$	$\frac{(m-1)^2 m < K \leq m^2(m+1)^2}{1)^2}$
m	1	2	3	m

(3) Web panels of hatch cover primary supporting members critical stress

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 τ in the hatch cover primary supporting member web panels is not to exceed 0.8 times the critical buckling stress τ_c , to be evaluated as defined below:

$$\tau_c = \tau_E \quad \text{for } \tau_E \leq \frac{\tau_F}{2}$$

$$\tau_c = \tau_F \left(1 - \frac{\tau_F}{4\tau_E}\right) \quad \text{for } \tau_E > \frac{\tau_F}{2}$$

where: $\tau_F = \frac{R_{eH}}{\sqrt{3}}$ N/mm²;

R_{eH} — yield stress of the material, in N/mm²;

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

E — modulus of elasticity, in N/mm², = 2.06×10^5 for steel;

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

$$k_t = 5.35 + 4.0 \left(\frac{d}{a} \right)^2;$$

a — greater dimension of web panel of primary supporting member, in m;

d — smaller dimension of web panel of primary supporting member, in m.

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 τ_c . In such a case, the average shear stress τ between the values calculated at the ends of this panel is to be considered.

2.20.3.6 Steel pontoon covers are to be provided with tarpaulins and securing devices in accordance with the following requirements:

- (1) At least two layers of tarpaulin in good condition are to be provided for each hatchway in exposed freeboard and superstructure decks.
- (2) Tarpaulins are to be free from jute, and the minimum weight in unit area of the material before treatment is to be:

0.65 kg/mm², if the material is tarred;

0.65 kg/mm², if the material is chemically dressed;

0.55 kg/mm², if the material is dressed with black oil.

- (3) Cleats are to be welded to the hatch coamings or the horizontal stiffeners, and the cleats are to be so set as to fit the taper of the wedges. The width of cleats is not to be less than 65 mm, and the cleats are to be spaced not more than 600 mm from centre to centre. The first and last cleats along each side or end are to be arranged not more than 150 mm from the hatch covers.

- (4) Wedges are to be of tough wood. They are to have a taper of not more than 1 in 6 and are not to be less than 13 mm in thickness at the point.

- (5) For all hatchways situated in exposed freeboard and superstructure decks, steel bars or other equivalent means are to be provided in order to efficiently secure each section of hatch covers after the tarpaulins are battened down. Hatch covers of more than 1.5 m in length are to be secured by at least two such securing appliances.

- (6) For all hatchways situated in other exposed positions, ring bolts or other fittings for lashings are to be provided.

2.20.3.7 The hatch coamings of steel pontoon covers are to comply with the following requirements:

- (1) Construction of exposed hatch coamings

- ① The thickness t of hatch coamings is not to be less than that obtained from the following formula:

$$t = 0.05L + 6.5 \quad \text{mm}$$

where: L — length of ship, in m, need not be greater than 90 m.

- ② Coamings of 600 mm or more in height are to be stiffened on their upper edges or at about 250 mm below the upper edge by a horizontal bulb flat or equivalent strength member. The web depth of the horizontal bulb flat is not to be less than 180 mm, and an additional support is to be afforded by fitting vertical stays or brackets from the bulb flat to the deck at intervals of not more than 3 m. The web depth of the stiffeners or brackets is to be not less than that of the horizontal bulb flat and they are to be flanged or fitted with a face plate. Where the coamings are more than 900 mm in height, the spacing of the above-mentioned stays or brackets is to be suitably reduced. Where the coamings are equal to or more than 1,200 mm in height, an additional horizontal bulb flat or equivalent strength member is to be fitted in way of half height of the coaming. Where the coamings are subject to loaded containers, the hatch coamings and their supporting members are to be strengthened correspondingly.

- ③ Where no face plate is fitted, the upper edges of coamings are to be stiffened by half round bars or other rolled bars to ensure the rigidity of coamings and the smoothness of their upper edges.
 - ④ Where the deck plating does not extend inside the coamings, the coamings at the corners of hatchways are to be rounded. For openings within $0.5L$ amidships, the radius of the rounded corner is to comply with the requirements of 2.4.4 of this Chapter.
If the deck plating extends inside the coamings, the coamings at the corners of hatchways may be square provided that the corners of deck openings are in compliance with the requirements of 2.4.4 of this Chapter and that the longitudinal coamings at hatch corners are extended in the form of a tapered bracket.
 - ⑤ Extension brackets or rails arranged approximately in line with the cargo hatch side coamings and intended for the stowage of steel covers are not to be welded to a deckhouse or masthouse, unless upon calculation it shows that the hatch coamings may be used as longitudinal strength members of the hull.
 - ⑥ Where the exposed hatch coamings act as deck girders, they are also to comply with the relevant requirements of 2.8.8 of this Chapter.
- (2) Where the 'tween deck hatch coamings act as deck girders, they are also to comply with the relevant requirements of 2.8.8 of this Chapter.

2.20.4 Hatch covers with portable beams

2.20.4.1 The design load of hatch covers with portable beams is to comply with the following requirements:

- (1) The vertical weather design load of exposed hatch covers is to comply with Table 2.20.2.2(1) of this Section.
- (2) The permissible cargo load on hatch covers is to comply with the requirements of 2.20.3.1(2) of this Section.

2.20.4.2 Hatch covers with portable beams are to be in compliance with the following requirements:

- (1) Hatch covers with portable beams, where the cover is made of steel, are to meet the requirements of 2.20.3.2(1) of this Section; where the cover is made of wood, the thickness t is not to be less than that obtained from the following formula:

$$t = 40S \text{ mm, but in no case to be less than 60 mm}$$

where: S — spacing of portable hatch beams, in m.

Where the design load exceeds 18.4 kN/m^2 , the thickness of wood covers is to be increased in direct proportion to the load.

Both ends of wood hatch covers are to be protected by encircling galvanized steel bands, about 65 mm wide and 3 mm thick, efficiently secured.

- (2) Where the vertical design load is applied, the exposed hatch covers with portable beams are to comply with the following requirements:

- ① The section modulus W and the section moment of inertia I of the portable beams are not to be less than:

$$\begin{aligned} W &= 0.782 K S p l^2 & \text{cm}^3 \\ I &= 1.44 S p l^3 & \text{cm}^4 \end{aligned}$$

where:

- p — vertical weather design load, in kN/m^2 , to be calculated according to 2.20.4.1 of this Section;
 S — spacing of portable beams, in m;
 l — span of portable beam, in m;
 K — material factor.

- ② The ends of web plates are to be doubled, or inserts fitted for at least 180 mm along length of web.
 ③ The portable beams are to be stiffened at their upper and lower edges by continuous face plates. The width of the upper face plate is to be sufficient to provide a bearing surface of not less than 65 mm for hatch covers, and a vertical flat bar with a height of 50 mm is to be arranged on the upper face plate.
 ④ Carriers or sockets are to provide means for the efficient fitting and securing of portable hatch beams. The width of bearing surface is at least to be 75 mm.
 ⑤ The section modulus W and the section moment of inertia I of stiffeners of steel covers are not to be less than:

$$W = 0.664Ksp l^2 \quad \text{cm}^3$$

$$I = 1.13s p l^3 \quad \text{cm}^4$$

where:

- p — vertical weather design load, in kN/m^2 , to be calculated according to 2.20.4.1 of this Section;
 l — span of stiffener, in m;
 s — spacing of stiffeners, in m;
 K — material factor.

(3) Where the uniformly distributed cargo load is applied, the hatch covers with portable beams are to comply with the following requirements:

- ① The section modulus W and the section moment of inertia I of portable beams are not to be less than:

$$W = 1.064KSp l^2 \quad \text{cm}^3$$

$$I = 1.8S p l^3 \quad \text{cm}^4$$

where:

- p — permissible cargo load, in kN/m^2 ;
 S — spacing of portable beams, in m;
 l — span of portable beam, in m;
 K — material factor.

- ② Portable beams are also to comply with the requirements of 2.20.4.2(2)② to ④.
 ③ The section modulus W and the section moment of inertia I of portable beams are not to be less than:

$$W = 1.064Ksp l^2 \quad \text{cm}^3$$

$$I = 1.8s p l^3 \quad \text{cm}^4$$

where:

- p — permissible cargo load, in kN/m^2 ;
 l — span of portable beam, in m;
 s — spacing of portable beams, in m;
 K — material factor.

(4) The scantling of stiffeners and girders with a variable cross-section for hatch covers with portable beams are to comply with the requirements of 2.20.3.2(3) of this Section.

2.20.4.3 The direct strength calculation of hatch covers with portable beams is to comply with the requirements of 2.20.2.4 of this Section.

2.20.4.4 The yield strength and deformation of hatch covers with portable beams is to comply with the requirements of 2.20.3.4 of this Section.

2.20.4.5 The buckling strength of hatch covers with portable beams is to comply with the requirements of 2.20.3.5 of this Section.

2.20.4.6 The closing appliances of hatch covers with portable beams are to comply with the requirements of 2.20.3.6 of this Section.

2.20.4.7 The hatch coamings of hatch covers with portable beams are to comply with the requirements of 2.20.3.7 of this Section.

2.20.5 Miscellaneous openings

2.20.5.1 Miscellaneous openings are to comply with the requirements of 1.12.7 of Chapter 1 of this PART.

2.20.5.2 Small hatchways on exposed decks are also to comply with the following requirements:

(1) The height of coamings of small hatchways is to comply with the requirements of 2.20.1.8 of this Section. The thickness of the coamings is not to be less than the minimum thickness as required in this Chapter for the deck inside the line of openings for that position, or 11 mm, whichever is the lesser;

(2) Small hatchways are to be provided with steel weathertight hatch covers and reliable securing devices. The means of securing are to be such that weathertightness can be maintained in any condition. The thickness of the hatch covers is not to be less than the minimum thickness required by this Chapter for the deck inside the line of openings for that position, or 8 mm, whichever is the lesser;

(3) Strength and securing of small hatches on the exposed fore deck are also to comply with the relevant requirements of Section 7, Chapter 1 of this PART.

A new appendix is added as follows:

Appendix 4 BUCKLING STRENGTH ASSESSMENT OF SHIP STRUCTURAL ELEMENTS

SECTION 1 APPLICATION AND DEFINITIONS

Abbreviation

<i>EPP</i>	—	Elementary plate panel, as defined in [1.2.3.1];
<i>PSM</i>	—	Primary supporting member;
<i>SP</i>	—	Stiffened panel, as defined in [1.2.3.3];
<i>UP</i>	—	Unstiffened panel, as defined in [1.2.3.3].

1.1 Application

1.1.1 General Requirements

1.1.1.1 Relevant unified requirements concerning strength of ships

This Appendix establishes a general buckling assessment procedure as illustrated in Figure 1.1.1.1, and is to be applied in conjunction with Section 20 of Chapter 2 for hatch cover structures. The Section 20 of Chapter 2 is referred to as Relevant UR-S hereafter in this Appendix.

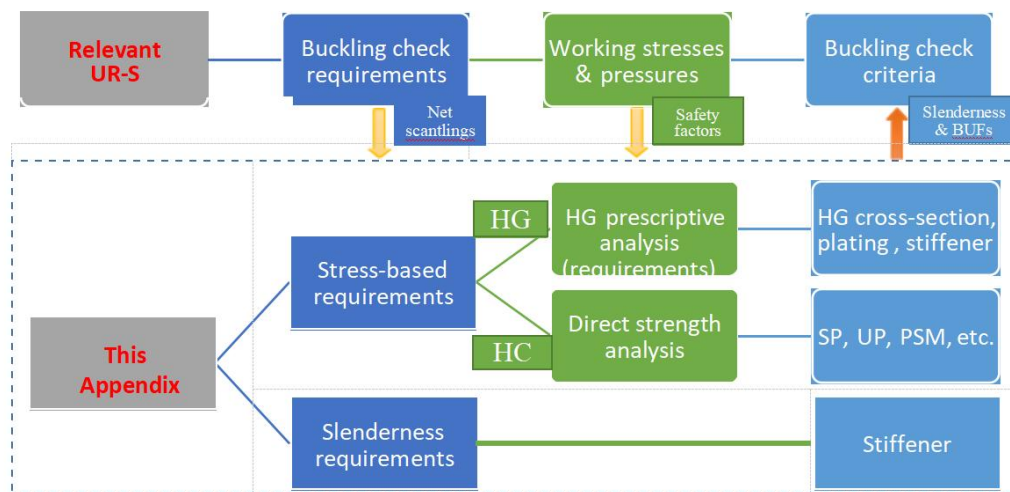


Figure 1.1.1.1 Overview of applying this UR in conjunction with Relevant UR-S

1.1.2 Application of this Appendix

1.1.2.1 Sections of this Appendix and application description

The buckling checks are to be performed according to:

- (1) Section 1 for general definitions regarding buckling capacity, allowable buckling utilisation factors and buckling check criteria.
- (2) Section 2 for the slenderness requirements of longitudinal and transverse stiffeners.
- (3) Section 3 for the prescriptive buckling requirements of plates, longitudinal and transverse stiffeners, primary supporting members and other structures subject to hull girder stresses.
- (4) Section 4 for direct strength analysis (usually by finite element method) buckling

requirements of hatch cover structural members including plates, stiffeners and primary supporting members.

(5) Section 5 for the determination of buckling capacities of plate panels, stiffeners, primary supporting members and column structures.

1.1.2.2 Buckling assessment with this Appendix

For the buckling assessment of a ship hull girder, a hatch cover or other structural components, the slenderness requirements as defined in Section 2 and the buckling requirements as defined in Section 3 or Section 4 are to be checked as per the requirements of the applicable Relevant UR-S.

1.1.2.3 Alternative methods

This Appendix contains the general methods for the determination of buckling capacities of plate panels, stiffeners, primary supporting members, and columns. For special cases not covered in this Appendix, such as a whole plate structure with stiffeners in two directions (i.e., a stiffened panel with both primary and secondary stiffeners), other more advanced methods, such as finite element analysis methods, can be used with the consent of CCS.

1.2 Terminology and Assumptions

1.2.1 Buckling

1.2.1.1 Buckling strength

Buckling strength or capacity refers to the strength of a structure under in-plane compressions and/or shear and lateral load. Buckling strength with consideration of the buckling behaviour in [1.2.1.2] gives a lower bound estimate of ultimate capacity, or the maximum load a structural member can carry without suffering major permanent set.

For each structural member, its buckling strength is to be taken as corresponding to the most unfavourable or critical buckling mode.

1.2.1.2 Buckling behaviour

Buckling strength assessment takes into account both elastic buckling and post-buckling behaviours. Post-buckling can consider the internal redistribution of loads depending on the load situation, slenderness and type of structure. Such as for the buckling assessment of plates, generally its positive elastic post-buckling effect can be utilized.

As such, for slender structures, the calculated buckling strength is typically higher than the ideal elastic buckling stress (minimum eigenvalue). Accepting elastic buckling of slender plate panels implies that large elastic deflections and reduced in-plane stiffness may occur at higher buckling utilisation levels.

1.2.2 Net Scantling Approach

1.2.2.1 General requirements

Unless otherwise specified, all the scantling requirements, including slenderness requirements, in this Appendix are based on net scantlings obtained by removing full corrosion addition t_c from the gross offered thicknesses.

1.2.2.2 Corrosion addition

Corrosion addition t_c referred to in this Appendix is defined in the Relevant UR-S.

1.2.2.3 Stress calculation models

The structural models used for the calculation of stresses to be applied for buckling assessment, which are usually based on net scantlings, are defined in the Relevant UR-S.

1.2.3 Structural Idealisation

1.2.3.1 Elementary plate panel (EPP)

An elementary plate panel (EPP) is the unstiffened part of the plating between stiffeners and/or primary supporting members. The plate panel length, a , and breadth, b , of the EPP are defined respectively as the longest and shortest plate edges, as shown in Figure 1.2.3.1.

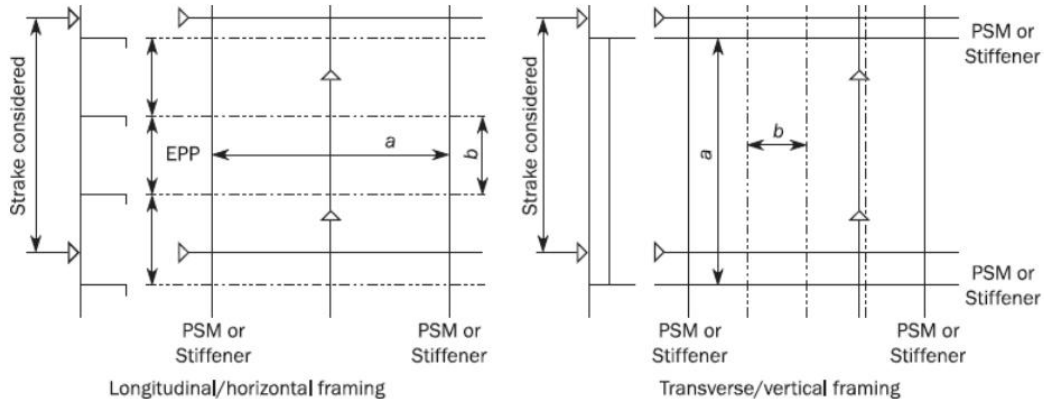


Figure 1.2.3.1 Elementary plate panel (EPP) definition

1.2.3.2 Standard types of stiffeners

Definitions of the cross-sectional dimensions of typical stiffener types are shown in Figure 1.2.3.2(1), which are flat bars, bulb flats, angles, L2 and T bars. If applicable, other types of stiffeners can be idealized to one of the typical types in Figure 1.2.3.2(1) for buckling check. For the U-type stiffener which is usually fitted in some hatch covers, the definition of its cross-sectional dimensions is shown in Figure 1.2.3.2(2).

Unless otherwise specified, the full span or full length l , in mm, of a stiffener is to be used for buckling check, which equals to the spacing between primary supporting members.

Symbolic dimensions of the cross-sections are as below:

- b_1 — Width of the attached plate enclosed by the U-type stiffener, in mm, as shown in Figure 1.2.3.2(2);
- b_2 — Width of the attached plate between adjacent U-type stiffeners, in mm, as shown in Figure 1.2.3.2(2);
- b_f — Width of the flange or face plate of the stiffener, in mm, as shown in Figure 1.2.3.2(1) and Figure 1.2.3.2(2);
- b_{f-out} — Maximum distance, in mm, from mid thickness of the web to the flange edge, in mm, as shown in Figure 1.2.3.2(1);
- d_f — Breadth of the extended part of the flange for L2 profiles, in mm, as shown in Figure 1.2.3.2(1);
- e_f — Distance from attached plating to centre of flange, in mm, as shown in Figure 1.2.3.2(1). For its detailed definition, refer to Section 5, Symbols;
- h_w — Depth of stiffener web, in mm, as shown in Figure 1.2.3.2(1) and Figure 1.2.3.2(2);
- t_f — Net flange thickness, in mm;
- t_p — Net thickness of plate, in mm;
- t_w — Net web thickness, in mm.

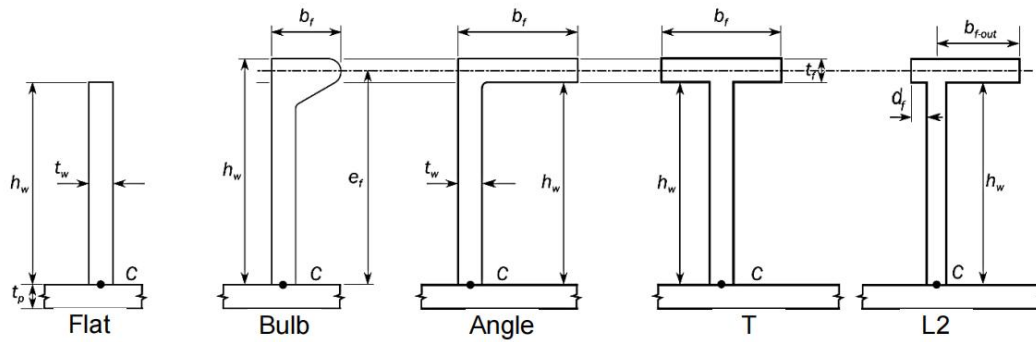


Figure 1.2.3.2(1) Dimensions of typical stiffener cross sections

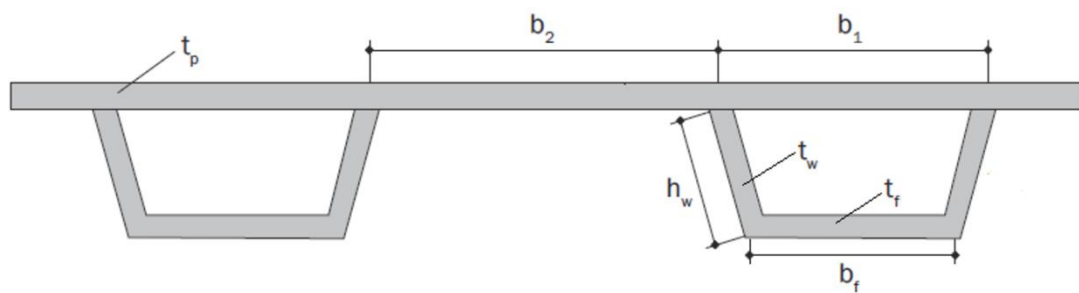


Figure 1.2.3.2(2) Dimensions of a U-type stiffener cross section

1.2.3.3 Stiffened panel (SP) and unstiffened panel (UP)

For a panel with relatively strong interactive effect between the stiffener and its attached plate, each stiffener with its attached plate as a whole is to be modelled as a stiffened panel (SP), so as to be able to consider both of its local and global buckling modes.

However, for an EPP, if its buckling strength can be checked without considering its interactive effect with stiffeners fitted along its edges, it is to be modelled as an unstiffened panel (UP).

1.2.4 Sign Convention

1.2.4.1 Stresses

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

1.3 Assessment Methods and Acceptance Criteria

1.3.1 Assessment Methods

1.3.1.1 Method A and Method B

The buckling assessment is to be carried out according to one of the following two methods taking into account different boundary condition types:

- (1) Method A: All the edges of the EPP are forced to remain straight (but free to move in the in-plane directions) due to the surrounding structure/neighbouring plates.
- (2) Method B: The edges of the EPP are not forced to remain straight due to low in-plane stiffness at the edges and/or no surrounding structure/neighbouring plates.

1.3.1.2 SP-A, SP-B, UP-A and UP-B models

For the buckling assessment of the stiffened panel (SP) and unstiffened panel (UP) structural

models defined in [1.2.3.3], with application of either Method A or Method B for the plate buckling assessment, the following four buckling assessment models are established:

- (1) SP-A: a stiffened panel with application of Method A.
- (2) SP-B: a stiffened panel with application of Method B.
- (3) UP-A: an unstiffened panel with application of Method A.
- (4) UP-B: an unstiffened panel with application of Method B.

1.3.2 Buckling Utilisation Factor

1.3.2.1 The utilisation factor, η , is defined as the ratio between the applied loads and the corresponding buckling capacity.

1.3.2.2 For combined loads, the utilisation factor, η_{act} , is to be defined as the ratio of the applied equivalent stress and the corresponding buckling capacity, as shown in Figure 1.3.2.2, and is to be taken as:

$$\eta_{act} = \frac{W_{act}}{W_U} = \frac{1}{\gamma_c}$$

where:

W_{act}	—	Equivalent applied stress. The actual applied stresses are given in Section 3 and Section 4 respectively for buckling assessment by prescriptive and direct strength analysis;
W_U	—	Equivalent buckling capacity. For plates and stiffeners, their respective buckling or ultimate capacities are given in Section 5;
γ_c	—	Stress multiplier factor at failure.

For each typical failure mode, the corresponding buckling capacity of the panel is calculated by applying the actual stress combination and then increasing or decreasing the stresses proportionally until collapse occurs, i.e., when the increased or decreased stresses are on a buckling strength interaction curve or surface.

Figure 1.3.2.2 illustrates the buckling capacity and the buckling utilisation factor of a structural member subject to σ_x and σ_y stresses.

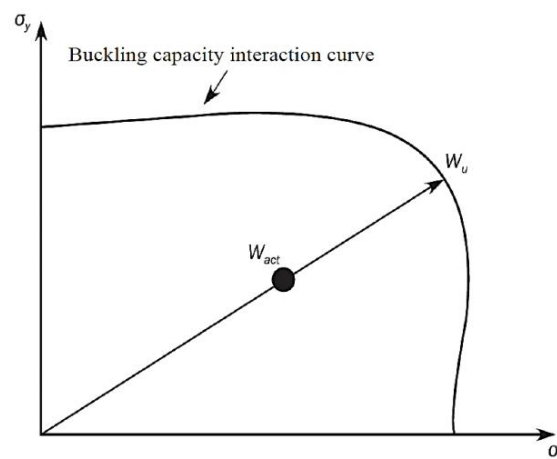


Figure 1.3.2.2 Illustration of buckling capacity and buckling utilisation factor

1.3.3 Allowable Buckling Utilisation Factor

1.3.3.1 The allowable buckling utilisation factor η_{all} is to be taken according to the Relevant UR-S.

1.3.4 Buckling Acceptance Criteria

1.3.4.1 A structural member is considered to have an acceptable buckling strength if it satisfies the following criterion:

$$\eta_{act} \leq \eta_{all}$$

where:

η_{act}	——	Buckling utilisation factor based on the applied stress, defined in [1.3.2.2];
η_{all}	——	Allowable buckling utilisation factor, as defined in [1.3.3.1].

SECTION 2 SLENDERNESS REQUIREMENTS

Symbols

For symbols not defined in this section, refer to Section 1, [1.2.3.2].

R_{eH}	——	Specified minimum yield stress of the structural member being considered, in N/mm ² .
----------	----	--

2.1 General Requirements

2.1.1 Introduction

2.1.1.1 The stiffener elements except for U-type stiffeners are to comply with the applicable slenderness and proportion requirements given in this Section.

2.2 Stiffeners

2.2.1 Proportions of Stiffeners

2.2.1.1 Net thickness of all stiffener types

The net thickness of stiffeners is to satisfy the following criteria:

(1) Stiffener web plate:

$$t_w \geq \frac{h_w}{C_w} \sqrt{\frac{R_{eH}}{235}}$$

(2) Flange:

$$t_f \geq \frac{b_{f-out}}{C_f} \sqrt{\frac{R_{eH}}{235}}$$

where:

C_w, C_f — Slenderness coefficients given in Table 2.2.1.1.

Slenderness coefficient		Table 2.2.1.1
Type of Stiffener	C_w	C_f
Angle and L2 bars	75	12
T-bars	75	12
Bulb flats	45	-
Flat bars	22	-

If requirement b) is not fulfilled, the effective free flange outstand, in mm, used in strength assessment including the calculation of actual net section modulus, is to be taken as:

$$b_{f-out-max} = C_f t_f \sqrt{\frac{235}{R_{eH}}}$$

For built-up profile where the relevant yielding strength for the web of built-up profile without the edge stiffener is acceptable, as an alternative the web can be assessed according to the web requirements of Angle and L2 bars in Table 2.2.1.1, and the edge stiffener can be assessed as a flat bar stiffener according to [2.2.1.1]. The requirement to flange in [2.2.1.2] shall still apply.

2.2.1.2 Net dimensions of angle and T-bars

The total flange breadth, b_f , in mm, for angle and T-bars is to satisfy the following criterion:

$$b_f \geq 0.2h_w$$

2.3 Primary Supporting Members

2.3.1 Proportions and Stiffness

2.3.1.1 Proportions of web plate and flange

The scantlings of webs and flanges of primary supporting members are to comply with the relevant requirements of [4.1], Section 2, Chapter 8, PART NINE of the Rules.

SECTION 3 BUCKLING REQUIREMENTS FOR HULL GIRDER PRESCRIPTIVE ANALYSIS

Symbols

η_{all} : Allowable buckling utilisation factor, as defined in Section 1, [1.3.3.1].

LCP: Load calculation point, as defined in [3.1.2.1].

3.1 General Requirements

3.1.1 Introduction

3.1.1.1 This Section applies to plate panels including plane and curved plate panels, stiffeners and corrugation of longitudinal corrugated bulkheads subject to hull girder compression and shear stresses.

3.1.1.2 The ship longitudinal extent where the buckling check is performed for structural elements subject to hull girder stresses is to be in accordance with the Relevant UR-S.

3.1.1.3 Design load sets: The buckling check is to be performed for all design load sets corresponding to the design loading conditions defined in the Relevant UR-S with the most unfavourable pressure combinations.

For each design load set, for all static and dynamic load cases, the lateral pressure is to be determined at the load calculation point defined in [3.1.2.1], and is to be applied together with the hull girder stress combinations defined in the Relevant UR-S.

3.1.2 Definitions

3.1.2.1 Load calculation point

The load calculation points (LCP) for both elementary plate panels (EPP) and stiffeners are defined as follows:

(1) LCP for hull girder stresses of EPP

The hull girder stresses for EPP are to be calculated at the load calculation points defined in Table 3.1.2.1.

Load calculation points (LCP) coordinates for plate buckling assessment Table 3.1.2.1

LCP coordinates	Hull girder bending stress		Hull girder shear stress
	Non horizontal plating	Horizontal plating	
x coordinate	Mid-length of the EPP		
y coordinate	Both upper and lower ends of the EPP (points A1 and A2 in Figure 3.1.2.1(1))	Outboard and inboard ends of the EPP (points A1 and A2 in Figure 3.1.2.1(1))	Mid-point of EPP (point B in Figure 3.1.2.1(1))
z coordinate	Corresponding to x and y values		

(2) LCP for hull girder stresses of longitudinal stiffeners

The hull girder stresses for longitudinal stiffeners are to be calculated at the following load calculation point:

- at the mid length of the considered stiffener;
- at the intersection point between the stiffener and its attached plate.

(3) LCP for pressure of horizontal stiffeners

The load calculation point for the pressure is located at:

- middle of the full length, l , of the considered stiffener;
- the intersection point between the stiffener and its attached plate.

(4) LCP for pressure of non-horizontal stiffeners

The lateral pressure, P is to be calculated as the maximum between the value obtained at middle of the full length, l , and the value obtained from the following formulae:

$$P = \frac{p_U + p_L}{2}, \text{ when the upper end of the vertical stiffener is below the lowest zero pressure level;}$$

$$P = \frac{l_1}{l} \frac{p_L}{2}, \text{ when the upper end of the vertical stiffener is at or above the lowest zero pressure level.}$$

where: l_1 — Distance, in m, between the lower end of vertical stiffener and the lowest zero pressure level;

p_U 、 p_L — Lateral pressure at the upper and lower end of the vertical stiffener span, l , respectively.

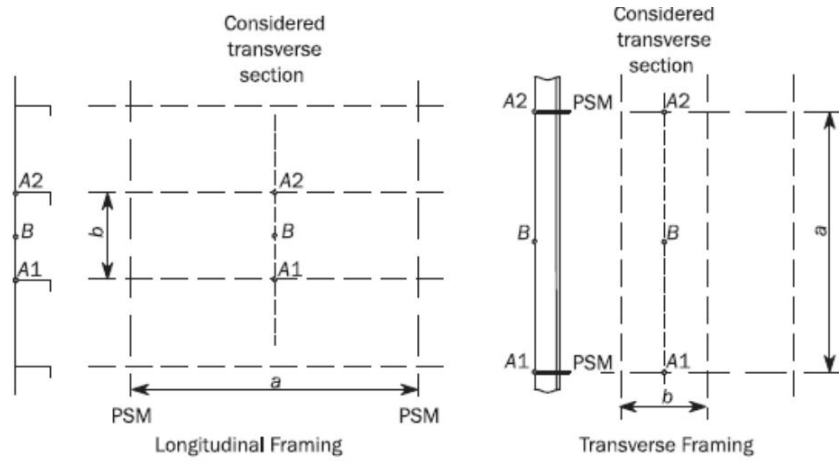


Figure 3.1.2.1(1) LCP for plate buckling assessment (PSM means the primary supporting members)

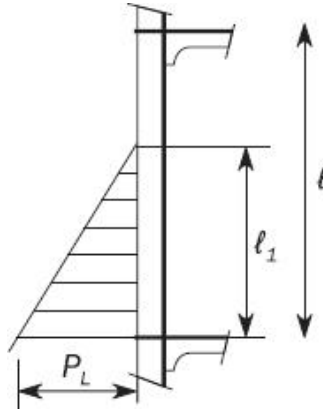


Figure 3.1.2.1(2) Definition of pressure for vertical stiffeners

3.1.3 Equivalent plate panels

3.1.3.1 Longitudinal stiffening with varying plate thickness

In longitudinal stiffening arrangement, when the plate thickness varies over the width b , of a plate panel (EPP), the buckling check is to be performed for an equivalent plate panel width, combined with the smaller plate thickness, t_1 . The width of this equivalent plate panel, b_{eq} , in mm, is defined by the following formula:

$$b_{eq} = l_1 + l_2 \left(\frac{t_1}{t_2} \right)^{1.5}$$

where: l_1 —Width of the part of the plate panel with the smaller plate thickness, t_1 , in mm, as defined in Figure 3.1.3.1;

l_2 —Width of the part of the plate panel with the greater plate thickness, t_2 , in mm, as defined in Figure 3.1.3.1.

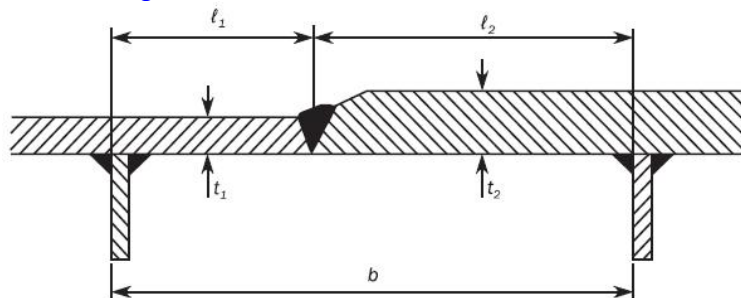


Figure 3.1.3.1 Plate thickness change over the width

3.1.3.2 Transverse stiffening with varying plate thickness

In transverse stiffening arrangement, when an EPP is made with different thicknesses, the buckling check of the plate and stiffeners is to be made for each thickness considered constant on the EPP, the stresses and pressures being estimated for the EPP at the LCP.

3.1.3.3 Plate panel with different materials

When the plate panel is made of different materials, the minimum yield strength is to be used for the buckling assessment.

3.2 Buckling Criteria

3.2.1 Overall Stiffened Panel

3.2.1.1 The buckling strength of overall stiffened panels is to satisfy the following criterion:

$$\eta_{overall} \leq \eta_{all}$$

where: $\eta_{overall}$ —Maximum overall buckling utilisation factor as defined in Section 5, [5.2.1].

3.2.2 Plates

3.2.2.1 The buckling strength of elementary plate panels is to satisfy the following criterion:

$$\eta_{plate} \leq \eta_{all}$$

where: η_{plate} —Maximum plate buckling utilisation factor as defined in Section 5, [5.2.2]
where SP-A model is to be used.

For the determination of η_{plate} of the vertically stiffened side shell plating of single side skin bulk carrier between hopper and topside tanks, the cases 12 and 16 of Section 5, Table 3 corresponding to the shorter edge of the plate panel clamped are to be considered together with a mean σ_y stress and $\varphi_y = 1$.

3.2.3 Stiffeners

3.2.3.1 The buckling strength of stiffeners or of side frames of single side skin bulk carriers is to satisfy the following criterion:

$$\eta_{stiffener} \leq \eta_{all}$$

where: $\eta_{stiffener}$ —Maximum stiffener buckling utilisation factor as defined in Section 5, [5.2.3].

Note 1: This buckling check can only be fulfilled when the overall stiffened panel buckling check, as defined in [3.2.1], is satisfied.

Note 2: The buckling check of the stiffeners is only applicable to the stiffeners fitted along the long edge of the buckling panel.

3.2.4 Vertically Corrugated Longitudinal Bulkheads

3.2.4.1 The shear buckling strength of vertically corrugated longitudinal bulkheads is to satisfy the following criterion:

$$\eta_{shear} \leq \eta_{all}$$

where: η_{shear} —Maximum shear buckling utilisation factor, defined as

$$\eta_{shear} = \frac{\tau_{bhd}}{\tau_c} ;$$

τ_{bhd} —Shear stress, in N/mm², in the bulkhead taken as the hull girder shear stress defined in the Relevant UR-S;

τ_c —Shear critical stress, in N/mm², as defined in Section 5, [2.2.3].

3.2.5 Horizontally Corrugated Longitudinal Bulkheads

3.2.5.1 Each corrugation unit within the extension of half flange, web and half flange (i.e. single corrugation as shown in grey in Figure 3.2.5.1) is to satisfy the following criterion:

$$\eta_{column} \leq \eta_{all}$$

where: η_{column} —Overall column buckling utilisation factor, as defined in Section 5, [5.3.1].

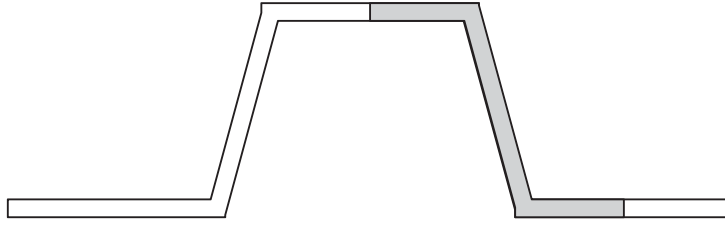


Figure 3.2.5.1 Single corrugation

SECTION 4 BUCKLING REQUIREMENTS FOR DIRECT STRENGTH ANALYSIS OF HATCH COVERS

Symbols

R_{eH_P} ——Yield stress of the plate panel, as defined in [4.2.1.3];

R_{eH_S} ——Yield stress of the stiffener, as defined in [4.2.1.3];

α —— Aspect ratio of the plate panel as defined in the Symbol list of Section 5;

η_{all} ——Allowable buckling utilisation factor, as defined in Section 1, [1.3.3.1].

4.1 General Requirements

4.1.1 Introduction

4.1.1.1 The requirements of this Section apply to the buckling assessment of hatch cover structural members based on direct strength analysis (usually by finite element method) and subjected to normal stress, shear stress and lateral pressure.

4.1.1.2 All structural elements in the direct strength analysis carried out according to the Relevant UR-S are to be assessed individually. The buckling checks are to be performed for the following structural elements:

- Stiffened and unstiffened panels.
- Web plate in way of openings.

4.2 Stiffened and Unstiffened Panels

4.2.1 General Requirements

4.2.1.1 The plate panel of a hatch cover structure is to be modelled as stiffened panel or unstiffened panel, with either Method A or Method B as defined in Section 1, [1.3.1.1] to be used for the calculation of the plate buckling capacity, which in combination is also equivalent to use the buckling assessment models defined in Section 1, [1.3.1.2].

4.2.1.2 Average thickness of plate panel

For FE analysis, where the plate thickness along a plate panel is not constant, the panel used for the buckling assessment is to be modelled with a weighted average thickness taken as:

$$t_{avr} = \frac{\sum_1^n A_i t_i}{\sum_1^n A_i}$$

where: A_i ——Area of the i -th plate element;

t_i ——Net thickness of the i -th plate element;

n ——Number of finite elements defining the buckling plate panel.

4.2.1.3 Yield stress of the plate panel and stiffener

The panel yield stress R_{eH_P} is taken as the minimum value of the specified yield stresses of the elements within the plate panel.

The stiffener yield stress R_{eH_S} is taken as the minimum value of the specified yield stress of the elements within the stiffener.

4.2.2 Stiffened Panels

4.2.2.1 For a stiffened panel (SP), each stiffener with attached plate is to be idealized as a stiffened panel model of the extent defined in the Relevant UR-S.

4.2.2.2 If the stiffener properties or stiffener spacing varies within the stiffened panel, the calculations are to be performed separately for all configurations of the panels, i.e. for each stiffener and plate between the stiffeners. Plate thickness, stiffener properties and stiffener spacing at the considered location are to be assumed for the whole panel.

4.2.2.3 The buckling check of the stiffeners of stiffened panels is only applicable to the stiffeners fitted along the longer side edges of the buckling panel.

4.2.3 Unstiffened Panels

4.2.3.1 Irregular plate panel

In way of web frames, horizontal girders and brackets, the geometry of the panel (i.e. plate bounded by web stiffeners/face plate) may not have a rectangular shape. In this case, an equivalent rectangular panel is to be defined according to [4.2.3.2] for irregular geometry and [4.2.3.3] for triangular geometry and to comply with buckling assessment.

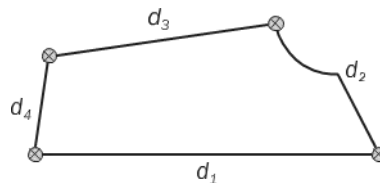
4.2.3.2 Equivalent EPP of an unstiffened panel with irregular geometry

Unstiffened panels with irregular geometry are to be idealised to equivalent panels for plate buckling assessment according to the following procedure:

(1) The four corners closest to a right angle, 90 deg, in the bounding polygon for the plate are identified.



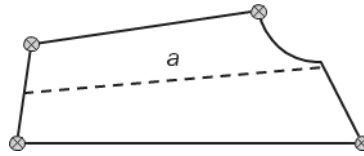
(2) The distances along the plate bounding polygon between the corners are calculated, i.e. the sum of all the straight-line segments between the end points.



(3) The pair of opposite edges with the smallest total length is identified, i.e. minimum of $d_1 + d_3$ and $d_2 + d_4$.

(4) A line joins the middle points of the chosen opposite edges (i.e. a mid-point is defined as the point at half the distance from one end). This line defines the longitudinal direction for the capacity model. The length of the line defines the length of the capacity model, a ,

measured from one end point.



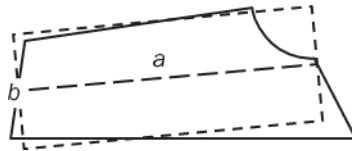
(5) The length of shorter side, b , in mm, is to be taken as:

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

where:

A — Area of the plate in mm^2 ;

a — Length defined in (4), in mm.

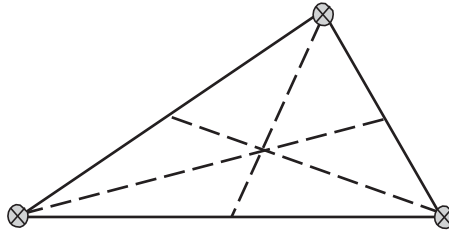


(6) The stresses from the direct strength analysis are to be transformed into the local coordinate system of the equivalent rectangular panel. These stresses are to be used for the buckling assessment.

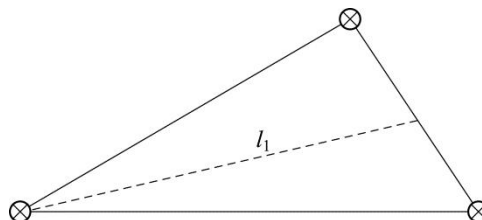
4.2.3.3 Modeling of an unstiffened plate panel with triangular geometry

Unstiffened panels with triangular geometry are to be idealised to equivalent panels for plate buckling assessment according to the following procedure:

(1) Medians are constructed as shown below:



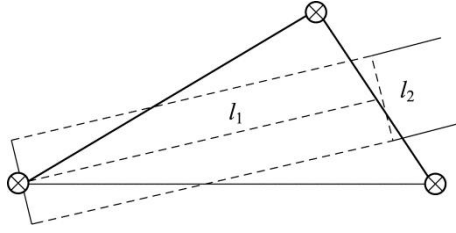
(2) The longest median is identified. This median the length of which is l_1 , in mm, defines the longitudinal direction for the capacity model.



(3) The width of the model, l_2 , in mm, is to be taken as:

$$l_2 = \frac{A}{l_1}$$

where: A — Area of the plate, in mm².



(4) The lengths of shorter side, b , and of the longer side, a , in mm, of the equivalent rectangular plate panel are to be taken as:

$$b = \frac{l_2}{C_{tri}}$$

$$a = l_1 C_{tri}$$

where: $C_{tri} = 0.4 \frac{l_2}{l_1} + 0.6$

(5) The stresses from the direct strength analysis are to be transformed into the local coordinate system of the equivalent rectangular panel and are to be used for the buckling assessment of the equivalent rectangular panel.

4.2.4 Reference Stress

4.2.4.1 The stress distribution is to be taken from the direct strength analysis according to the Relevant UR-S and applied to the buckling model.

4.2.4.2 For FE analysis, the reference stresses are to be calculated using the stress-based reference stresses as defined in Section 6.

4.2.5 Lateral Pressure

4.2.5.1 The lateral pressure applied to the direct strength analysis is also to be applied to the buckling assessment.

4.2.5.2 Where the lateral pressure is not constant over a buckling panel defined by a number of finite plate elements, an average lateral pressure, in N/mm², is calculated using the following formula:

$$P_{avr} = \frac{\sum_1^n A_i P_i}{\sum_1^n A_i}$$

where:

A_i — Area of the i -th plate element, in mm²;

P_i — Lateral pressure of the i -th plate element, in N/mm²;

n — Number of the finite elements in the buckling panel.

4.2.6 Buckling Criteria

4.2.6.1 UP-A

The compressive buckling strength of UP-A is to satisfy the following criterion:

$$\eta_{UP-A} \leq \eta_{all}$$

where: η_{UP-A} — Maximum buckling utilisation factor of plate, calculated according to Method A as defined in Section 5, [5.2.2].

4.2.6.2 UP-B

The compressive buckling strength of UP-B is to satisfy the following criterion:

$$\eta_{UP-B} \leq \eta_{all}$$

where: η_{UP-B} — Maximum buckling utilisation factor of plate, calculated according to Method B as defined in Section 5, [5.2.2].

4.2.6.3 SP-A

The compressive buckling strength of SP-A is to satisfy the following criterion:

$$\eta_{SP-A} \leq \eta_{all}$$

where: η_{SP-A} — Buckling utilisation factor of the stiffened panel, taken as the maximum of the buckling utilisation factors calculated as below:

- The overall stiffened panel buckling utilisation factor $\eta_{overall}$ as defined in Section 5, [5.2.1];
- The plate buckling utilisation factor η_{plate} calculated according to Method A as defined in Section 5 [5.2.2];
- The stiffener buckling utilisation factor $\eta_{stiffener}$ as defined in Section 5, [5.2.3] considering separately the properties (thickness, dimensions), the pressures defined in [4.2.5.2] and the reference stresses of each EPP at both sides of the stiffener.

Note 1: The stiffener buckling strength check can only be fulfilled when the overall stiffened panel capacity check, as defined in Section 5, [5.2.1], is satisfied.

4.2.6.4 SP-B

The compressive buckling strength of SP-B is to satisfy the following criterion:

$$\eta_{SP-B} \leq \eta_{all}$$

where: η_{SP-B} — Buckling utilisation factor of the stiffened panel, taken as the maximum of the buckling utilisation factors calculated as below:

- The overall stiffened panel buckling utilisation factor $\eta_{overall}$ as defined in Section 5, [5.2.1];
- The plate buckling utilisation η_{plate} calculated according to Method B as defined in Section 5, [5.2.2];
- The stiffener buckling utilisation factor $\eta_{stiffener}$ as defined in Section 5, [5.2.3] considering separately the properties (thickness, dimensions), the pressures defined in [4.2.5.2] and the reference stresses of each EPP at both sides of the stiffener.

Note 1: The stiffener buckling strength check can only be fulfilled when the overall stiffened panel capacity check, as defined in Section 5, [5.2.1], is satisfied.

4.2.6.5 Web plate in way of openings

The web plate of primary supporting members with openings is to satisfy the following criterion:

$$\eta_{opening} \leq \eta_{all}$$

where: $\eta_{opening}$ — Maximum web plate utilisation factor in way of openings, calculated with the definition in Section 1, [1.3.2.2] and the stress multiplier factor at

failure γ_c which can be calculated following the requirements in Section 5, [5.2.4].

SECTION 5 BUCKLING CAPACITY

Symbols

A_p	——	Net sectional area of the stiffener attached plating, in mm ² , taken as: $A_p = st_p$;
A_s	——	Net sectional area of the stiffener without attached plating, in mm ² ;
a	——	Length of the longer side of the plate panel, in mm;
b	——	Length of the shorter side of the plate panel, in mm;
b_{eff}	——	Effective width of the attached plating of a stiffener, in mm, as defined in [5.2.3.5];
b_{eff1}	——	Effective width of the attached plating of a stiffener, in mm, without the shear lag effective taken as: (1) For $\sigma_x > 0$, ① For prescriptive assessment: $b_{eff1} = \frac{C_{x1}b_1 + C_{x2}b_2}{2}$ ② For FE analysis: $b_{eff1} = C_x b$ (2) For $\sigma_x \leq 0$, $b_{eff1} = b$;
b_f	——	Breadth of the stiffener flange, in mm;
b_1, b_2	——	Width of plate panel on each side of the considered stiffener, in mm. For stiffened panels fitted with U-type stiffeners, b_1 and b_2 are as defined in Section 1, Figure 1.2.3.2(2);
C_{x1}, C_{x2}	——	Reduction factor defined in Table 5.2.2.3 calculated for the EPP1 and EPP2 on each side of the considered stiffener according to case 1;
d	——	Length of the side parallel to the cylindrical axis of the cylinder corresponding to the curved plate panel as shown in Table 5.2.2.6, in mm;
e_f	——	Distance from attached plating to center of flange, in mm, as shown in Section 1, Figure 1.2.3.2(1), to be taken as: $e_f = h_w \quad \text{for flat bar profile}$ $e_f = h_w - 0.5t_f \quad \text{for bulb profile}$ $e_f = h_w + 0.5t_f \quad \text{for angle, L2 and T profiles.}$
F_{long}	——	Coefficient defined in [5.2.2.4];
F_{tran}	——	Coefficient defined in [5.2.2.5];

h_w	—	Depth of stiffener web, in mm, as shown in Section 1, Figure 1.2.3.2(1);
l	—	Span, in mm, of stiffener equal to spacing between primary supporting members of span of side frame equal to the distance between the hopper tank and top wing tank in way of the side shell;
R	—	Radius of curved plate panel, in mm;
R_{eH_P}	—	Specified minimum yield stress of the plate, in N/mm ² ;
R_{eH_S}	—	Specified minimum yield stress of the stiffener, N/mm ² ;
S	—	Partial safety factor, unless otherwise specified in the Relevant UR-S, to be taken as 1.0;
t_p	—	Net thickness of plate panel, in mm;
t_w	—	Net stiffener web thickness, in mm;
t_f	—	Net flange thickness, in mm;
x -axis	—	Local axis of a rectangular buckling panel parallel to its long edge;
y -axis	—	Local axis of a rectangular buckling panel perpendicular to its long edge;
α	—	Aspect ratio of the plate panel, defined in Table 5.2.2.3, to be taken as: $\alpha = \frac{a}{b}$;
β	—	Coefficient taken as: $\beta = \frac{1-\psi}{\alpha}$;
ω	—	Coefficient taken as: $\omega = \min(3, \alpha)$;
σ_x	—	Normal stress applied on the edge along x -axis of the buckling panel, in N/mm ² ;
σ_y	—	Normal stress applied on the edge along y -axis of the buckling panel, in N/mm ² ;
σ_1	—	Maximum normal stress along a panel edge, in N/mm ² ;
σ_2	—	Minimum normal stress along a panel edge, in N/mm ² ;
σ_E	—	Elastic buckling reference stress, in N/mm ² , to be taken as: (1) For the application of the limit state of plane plate panels according to [5.2.2.1]: $\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)} \left(\frac{t_p}{b} \right)^2$ (2) For the application of the limit state of curved plate panels according to [5.2.2.6]: $\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)} \left(\frac{t_p}{d} \right)^2$
τ	—	Applied shear stress, in N/mm ² ;
τ_c	—	Buckling strength in shear, in N/mm ² ;
ψ	—	Edge stress ratio to be taken as: $\psi = \frac{\sigma_2}{\sigma_1}$;
γ	—	Stress multiplier factor acting on loads. When the factor is such that the loads reach the interaction formulae, $\gamma = \gamma_c$;
γ_c	—	Stress multiplier factor at failure;
γ_{GEB}	—	Stress multiplier factor of global elastic buckling capacity.

5.1 General Requirements

5.1.1 Introduction

5.1.1.1 This Section contains the methods for determination of the buckling capacities of plate panels, stiffeners, primary supporting members and columns.

5.1.1.2 For the application of this Section, the stresses σ_x , σ_y and τ applied on the structural members are defined in:

- (1) Section 3 for hull girder prescriptive buckling requirements.
- (2) Section 4 for direct strength analysis buckling requirements of hatch covers.

5.1.1.3 Buckling capacity

The buckling capacity is calculated by applying the actual stress combination and then increasing or decreasing the stresses proportionally until the interaction formulae defined in [5.2.1.1], [5.2.2.1] and [5.2.3.4] of this Section are equal to 1.0, respectively.

5.1.1.4 Buckling utilisation factor

The buckling utilisation factor of the structural member is equal to the highest utilisation factor obtained for the different buckling modes.

5.1.1.5 Lateral pressure

The lateral pressure is to be applied and considered as constant for the calculation of buckling capacities as defined in [5.1.1.3].

5.2 Buckling Capacity of Plate Panels

5.2.1 Overall Stiffened Panels

5.2.1.1 The elastic stiffened panel limit state is based on the following interaction formula, which sets a precondition for the buckling check of stiffeners in accordance with [5.2.3.4]:

$$\frac{\gamma_c}{\gamma_{GEB}} = 1$$

with the corresponding buckling utilisation factor defined as:

$$\eta_{overall} = \frac{1}{\gamma_c}$$

where: the stress multiplier factor of global elastic buckling capacity, γ_{GEB} , are to be calculated based on the following formulae:

$$\gamma_{GEB} = \gamma_{GEB,bi+\tau} \quad \text{for } \tau \neq 0 \text{ and } (\sigma_x > 0 \text{ or } \sigma_y > 0) ;$$

$$\gamma_{GEB} = \gamma_{GEB,bi} \quad \text{for } \tau = 0 \text{ and } (\sigma_x > 0 \text{ or } \sigma_y > 0) ;$$

$$\gamma_{GEB} = \gamma_{GEB,\tau} \quad \text{for } \tau \neq 0 \text{ and } (\sigma_x \leq 0 \text{ or } \sigma_y \leq 0) .$$

where: $\gamma_{GEB,bi+\tau}$, $\gamma_{GEB,bi}$ and $\gamma_{GEB,\tau}$ are stress multiplier factors of the global elastic buckling capacity for different load combinations as defined in [5.2.1.2], [5.2.1.3] and [5.2.1.4], respectively. For the calculation of $\gamma_{GEB,bi+\tau}$, $\gamma_{GEB,bi}$ and $\gamma_{GEB,\tau}$, neither σ_x nor σ_y are to be taken less than 0.

σ_x, σ_y — Applied normal stress to the plate panel, in N/mm², to be taken as defined in [5.2.2.7];

τ — Applied shear stress, in N/mm², to be taken as defined in [5.2.2.7].

5.2.1.2 The stress multiplier factor $\gamma_{GEB,bi}$ for the stiffened panel subjected to biaxial loads is taken as:

$$\gamma_{GEB,bi} = \frac{\pi^2}{L_{B1}^2 L_{B2}^2} \frac{[D_{11}L_{B2}^4 + 2(D_{12} + D_{33})n^2 L_{B1}^2 L_{B2}^2 + n^4 D_{22}L_{B1}^4]}{L_{B2}^2 N_x + n^2 L_{B1}^2 N_y}$$

where:

- N_x —— Load per unit length applied on the edge along x -axis of the stiffened panel, in N/mm, taken as
 $N_x = \sigma_{x,av}(A_p + A_s)/s$
For stiffened panels fitted with U-type stiffeners, stiffener spacing s is taken as:
 $s = b_1 + b_2$
Where b_1 and b_2 are as defined in Figure 5.3.1.4;
- N_y —— Load per unit length applied on the edge along y -axis of the stiffened panel, in N/mm, taken as:
 $N_y = c\sigma_y t_p$;
- L_{B1} —— Stiffener span, in mm, distance between primary supporting members, i.e.
 $L_{B1} = l$;
- L_{B2} —— Width of stiffened panel between stiffened panels, in mm, taken as 6 times of the stiffer spacing, i.e. $L_{B2} = 6s$;
- n —— Number of half waves along the direction perpendicular to the stiffener axis. The factor $\gamma_{GEB,bi}$ is to be taken as the smallest value larger than 0.
- c —— Factor taking into account the normal stress distribution in the panel boundaries acting perpendicular to the stiffener's axis:
 $c = 0.5(1 + \Psi)$ for $0 \leq \Psi \leq 1$;
 $c = \frac{1}{2(1 - \Psi)}$ for $\Psi < 0$;
- Ψ —— Edge stress ratio for case 2 according to Table 5.3.1.3;
- $\sigma_{x,av}$ —— Average stress, in MPa, for both plate and stiffener after Poisson correction, taken as:
 $\sigma_{x,av} = \sigma_x - \nu c \sigma_y A_s / (A_p + A_s) \geq 0$ for $\sigma_x > 0$ and $\sigma_y > 0$
 $\sigma_{x,av} = \sigma_x$ for $\sigma_x \leq 0$ or $\sigma_y \leq 0$;
- $D_{11}, D_{12}, D_{22}, D_{33}$ —— Bending stiffness coefficients, in N·mm, of the stiffened panel, defined in general as:

$$\left. \begin{aligned} D_{11} &= \frac{EI_{eff} 10^4}{s} \\ D_{12} &= \frac{Et_p^3 \nu}{12(1 - \nu^2)} \\ D_{22} &= \frac{Et_p^3}{12(1 - \nu^2)} \\ D_{33} &= \frac{Et_p^3}{12(1 + \nu)} \end{aligned} \right\}$$

For stiffened panels fitted with U-type stiffeners, D_{12} and D_{22} are defined as:

$$D_{22} = \frac{Et_p^3}{12(1-\nu^2)} \left[1.2 + 4.8 \times \text{Min} \left(1.0, \frac{b_1^2}{h_w(b_1 + b_2)} \right) \times \text{Min} \left(1.0, \left(\frac{t_w}{t_p} \right)^3 \right) \right]$$

$$D_{12} = \nu D_{22}$$

h_w —— Breadth of U-type stiffener web as defined in Figure 5.3.1.4;

I_{eff} ——Moment of inertia, in cm^4 , of the stiffener including the effective width of the attached plating, same as I defined in [5.2.3.4].

5.2.1.3 The stress multiplier factor $\gamma_{GEB,\tau}$, for the stiffened panel subjected to pure shear load is taken as:

$$\gamma_{GEB,\tau} = \frac{\sqrt[4]{D_{11}^3 D_{22}}}{(L_{B1}/2)^2 N_{xy}} \left[8.125 + 5.64 \sqrt{\frac{(D_{12} + D_{33})^2}{D_{11} D_{22}}} - 0.6 \frac{(D_{12} + D_{33})^2}{D_{11} D_{22}} \right] \quad \text{for } D_{11} D_{22} \geq (D_{12} + D_{33})^2$$

$$\gamma_{GEB,\tau} = \frac{\sqrt{2 D_{11} (D_{12} + D_{33})}}{(L_{B1}/2)^2 N_{xy}} \left[8.3 + 1.525 \frac{D_{11} D_{22}}{(D_{12} + D_{33})^2} - 0.493 \frac{D_{11}^2 D_{22}^2}{(D_{12} + D_{33})^4} \right] \quad \text{for } D_{11} D_{22} < (D_{12} + D_{33})^2$$

where: $N_{xy} = \tau t_p$

5.2.1.4 The stress multiplier factor $\gamma_{GEB,bi+\tau}$, for the stiffened panel subjected to combined loads is taken as:

$$\gamma_{GEB,bi+\tau} = \frac{1}{2} \gamma_{GEB,\tau}^2 \left[-\frac{1}{\gamma_{GEB,bi}} + \sqrt{\frac{1}{\gamma_{GEB,bi}^2} + 4 \frac{1}{\gamma_{GEB,\tau}^2}} \right]$$

where: $\gamma_{GEB,bi}$ and $\gamma_{GEB,\tau}$ are as defined in [5.2.1.2] and [5.2.1.3], respectively.

5.2.2 Plates

5.2.2.1 Plate limit state

The plate limit state is based on the following interaction formulae:

$$\left(\frac{\gamma_{c1} \sigma_x S}{\sigma_{cx}} \right)^{e_0} - B \left(\frac{\gamma_{c1} \sigma_x S}{\sigma_{cx}} \right)^{\frac{e_0}{2}} \left(\frac{\gamma_{c1} \sigma_y S}{\sigma_{cy}} \right)^{\frac{e_0}{2}} + \left(\frac{\gamma_{c1} \sigma_y S}{\sigma_{cy}} \right)^{e_0} + \left(\frac{\gamma_{c1} |\tau| S}{\tau_c} \right)^{e_0} = 1$$

$$\left(\frac{\gamma_{c2} \sigma_x S}{\sigma_{cx}} \right)^{\frac{2}{\beta_p^{0.25}}} + \left(\frac{\gamma_{c2} |\tau| S}{\tau_c} \right)^{\frac{2}{\beta_p^{0.25}}} = 1 \quad \text{for } \sigma_x \geq 0$$

$$\left(\frac{\gamma_{c3} \sigma_y S}{\sigma_{cy}} \right)^{\frac{2}{\beta_p^{0.25}}} + \left(\frac{\gamma_{c3} |\tau| S}{\tau_c} \right)^{\frac{2}{\beta_p^{0.25}}} = 1 \quad \text{for } \sigma_y \geq 0$$

$$\frac{\gamma_{c4} |\tau| S}{\tau_c} = 1$$

with:

$$\gamma_c = \text{Min}(\gamma_{c1}, \gamma_{c2}, \gamma_{c3}, \gamma_{c4})$$

and the corresponding buckling utilisation factor defined as:

$$\eta_{plate} = \frac{1}{\gamma_c}$$

where:

σ_x, σ_y _____	Applied normal stress to the plate panel, in N/mm ² , to be taken as defined in [5.2.2.7];
τ _____	Applied shear stress to the plate panel, in N/mm ² ;
σ_{cx} _____	Ultimate buckling stress, in N/mm ² , in direction parallel to the longer edge of the buckling panel as defined in [5.2.2.3];
σ_{cy} _____	Ultimate buckling stress, in N/mm ² , in direction parallel to the shorter edge of the buckling panel as defined in [5.2.2.3];
τ_c _____	Ultimate buckling shear stress, in N/mm ² , as defined in [5.2.2.3];
$\gamma_{c1}, \gamma_{c2}, \gamma_{c3}, \gamma_{c4}$	Stress multiplier factors at failure for each of the above different limit states. γ_{c2} and γ_{c3} are only to be considered when $\sigma_x \geq 0$ and $\sigma_y \geq 0$ respectively.
B _____	Coefficient given in Table 5.2.2.1;
e_0 _____	Coefficient given in Table 5.2.2.1;
	Plate slenderness parameter taken as:
β_p _____	$\beta_p = \frac{b}{t_p} \sqrt{\frac{R_{eH_P}}{E}}$.

Definition of coefficients of B and e_0

Table 5.2.2.1

Applied stress	B	e_0
$\sigma_x \geq 0$ and $\sigma_y \geq 0$	$0.7 - 0.3 \beta_p / \alpha^2$	$2 / \beta_p^{0.25}$
$\sigma_x < 0$ or $\sigma_y < 0$	1.0	2.0

5.2.2.2 Reference degree of slenderness

The reference degree of slenderness is to be taken as:

$$\lambda = \sqrt{\frac{R_{eH_P}}{K \sigma_E}}$$

where: K —Buckling factor, as defined in Table 5.2.2.3 and Table 5.2.2.6.

5.2.2.3 Ultimate buckling stresses

The ultimate buckling stresses of plate panels, in N/mm², are to be taken as:

$$\sigma_{cx} = C_x R_{eH_P}$$

$$\sigma_{cy} = C_y R_{eH_P}$$

The ultimate buckling stress of plate panels subject to shear, in N/mm², is to be taken as:

$$\tau_c = C_\tau \frac{R_{eH_P}}{\sqrt{3}}$$

where: C_x, C_y, C_r — Reduction factors, as defined in Table 5.2.2.3.

For the 1st Equation of [5.2.2.1], when $\sigma_x < 0$ or $\sigma_y < 0$, the reduction factors are to be taken as :

$$C_x = C_y = C_r = 1$$

For other cases:

(1) For SP-A and UP-A, C_y is calculated according to Table 5.2.2.3 by using

$$c_1 = \left(1 - \frac{1}{\alpha}\right) \geq 0$$

(2) For SP-B and UP-B, C_y is calculated according to Table 5.2.2.3 by using

$$c_1 = 1$$

(3) For vertically stiffened single side skin of bulk carrier, C_y is calculated according to Table 5.2.2.3 by using

$$c_1 = \left(1 - \frac{1}{\alpha}\right) \geq 0$$

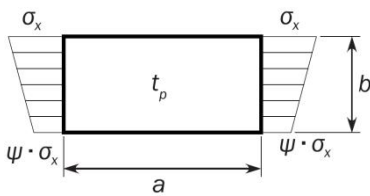
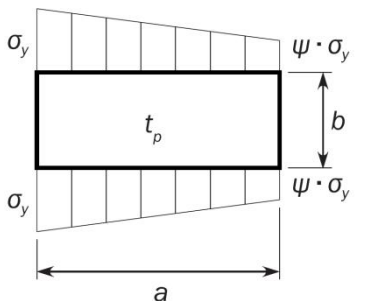
(4) For corrugation of corrugated bulkheads, C_y is calculated according to Table 5.2.2.3 by using

$$c_1 = \left(1 - \frac{1}{\alpha}\right) \geq 0$$

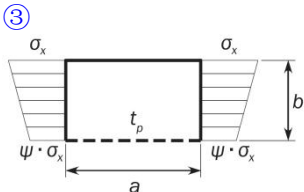
The boundary conditions for plates are to be considered as simply supported, see cases in ①, ② and ⑮ of Table 5.2.2.3. If the boundary conditions differ significantly from simple support, a more appropriate boundary condition can be applied according to the different cases of Table 5.2.2.3 with the consent of CCS.

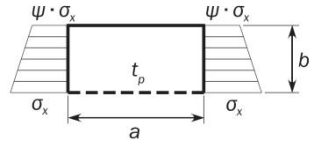
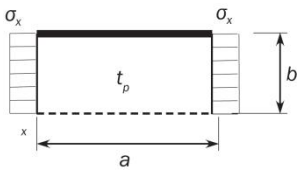
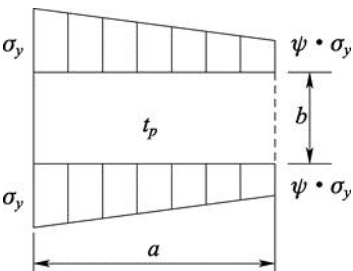
Buckling factor and reduction factor plane plate panels

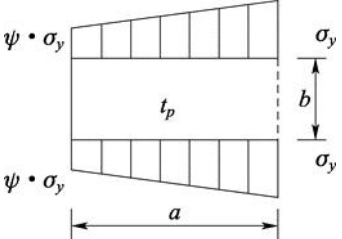
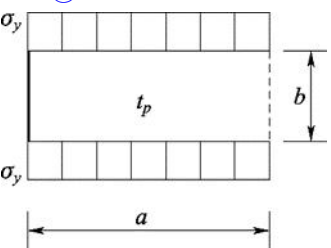
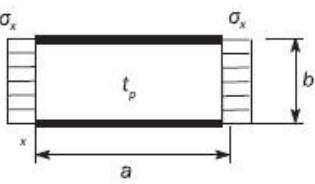
Table 5.2.2.3

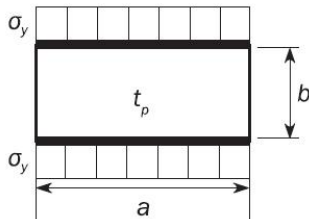
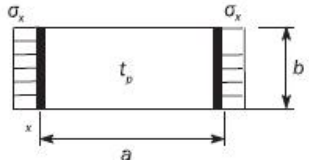
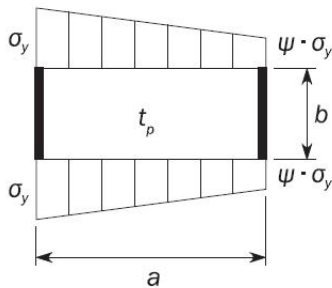
Case	Stress ratio ψ	Aspect ratio α	Buckling factor K	Reduction factor C
① 	$1 \geq \psi \geq 0$	$K_x = F_{long} \frac{8.4}{\psi + 1.1}$		When $\sigma_x \leq 0$, $C_x = 1$;
	$0 > \psi > -1$	$K_x = F_{long} [7.63 - \psi(6.26 - 10 \psi)]$		When $\sigma_x > 0$,
	$\psi \leq -1$	$K_x = F_{long} [5.975(1 - \psi)^2]$		$C_x = 1$ for $\lambda \leq \lambda_c$ $C_x = c \left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2} \right)$ for $\lambda > \lambda_c$ where: $c = (1.25 - 0.12\psi) \leq 1.25$ $\lambda_c = \frac{c}{2} \left(1 + \sqrt{1 - \frac{0.88}{c}} \right)$
② 	$1 \geq \psi \geq 0$	$K_y = F_{tran} \frac{2 \left(1 + \frac{1}{\alpha^2} \right)^2}{1 + \psi + \frac{(1 - \psi)}{100} \left(\frac{2.4}{\alpha^2} + 6.9 f_1 \right)}$		When $\sigma_y \leq 0$, $C_y = 1$;
		$\alpha \leq 6$	$f_1 = (1 - \psi)(\alpha - 1)$	When $\sigma_y > 0$:
		$\alpha > 6$	$f_1 = 0.6(1 - \frac{6\psi}{\alpha})(\alpha + \frac{14}{\alpha})$ but not greater than $14.5 - \frac{0.35}{\alpha^2}$	$C_y = c \left(\frac{1}{\lambda} - \frac{R + F^2(H - R)}{\lambda^2} \right)$ where: $c = (1.25 - 0.12\psi) \leq 1.25$ $R = \lambda \left(1 - \frac{\lambda}{c} \right)$ for $\lambda < \lambda_c$ $R = 0.22$ for $\lambda \geq \lambda_c$

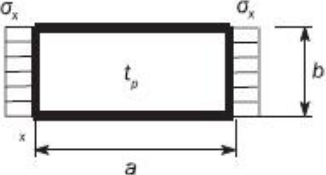
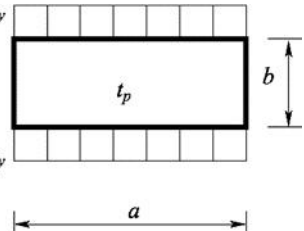
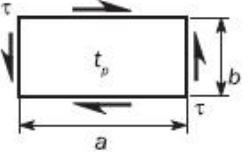
	$1 - \frac{4\alpha}{3} \leq \psi < 0$	$K_y = \frac{200F_{tran}(1+\beta^2)^2}{(1-f_3)(100+2.4\beta^2+6.9f_1+23f_2)}$		$\lambda_c = 0.5c(1+\sqrt{1-0.88/c})$ $F = \left(1 - \left(\frac{K}{0.91} - 1\right) / \lambda_p^2\right) c_1 \geq 0$ $\lambda_p^2 = \lambda^2 - 0.5 \text{ for } 1 \leq \lambda_p^2 \leq 3$ c_1 as defined in 5.1.1.3. $H = \lambda - \frac{2\lambda}{c(T+\sqrt{T^2-4})} \geq R$ $T = \lambda + \frac{14}{15\lambda} + \frac{1}{3}$
		$\alpha > 6(1-\psi)$	$f_1 = 0.6\left(\frac{1}{\beta} + 14\beta\right)$ but not greater than $14.5 - 0.35\beta^2$ $f_2 = f_3 = 0$	
		$3(1-\psi) \leq \alpha \leq 6(1-\psi)$	$f_1 = \frac{1}{\beta} - 1$ $f_2 = f_3 = 0$	
		$1.5(1-\psi) \leq \alpha < 3(1-\psi)$	$f_1 = \frac{1}{\beta} - (2 - \omega\beta)^4 - 9(\omega\beta - 1)\left(\frac{2}{3} - \beta\right)$ $f_2 = f_3 = 0$	
		$1 - \psi \leq \alpha < 1.5(1 - \psi)$	For $\alpha > 1.5$, $f_1 = 2\left(\frac{1}{\beta} - 16\left(1 - \frac{\omega}{3}\right)^4\right)\left(\frac{1}{\beta} - 1\right)$ $f_2 = 3\beta - 2$; $f_3 = 0$ For $\alpha \leq 1.5$, $f_1 = 2\left(\frac{1.5}{1-\psi} - 1\right)\left(\frac{1}{\beta} - 1\right)$	

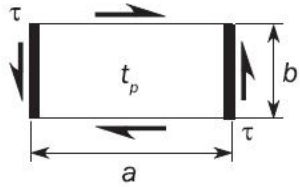
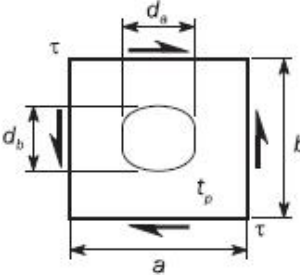
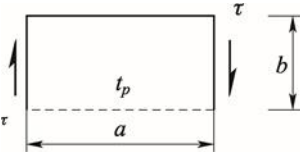
			$f_2 = \frac{\psi(1-16f_4^2)}{1-\alpha} \quad ; \quad f_3 = 0$ $f_4 = [1.5 - Min(1.5;\alpha)]^2$	
			$f_1 = 0$ $f_2 = 1 + 2.31(\beta - 1) - 48\left(\frac{4}{3} - \beta\right)f_4^2$ $f_3 = 3f_4(\beta - 1)\left(\frac{f_4}{1.81} - \frac{\alpha - 1}{1.31}\right)$ $f_4 = [1.5 - Min(1.5;\alpha)]^2$	
	$0.75(1-\psi) \leq \alpha < (1-\psi)$			
	$\psi < 1 - \frac{4\alpha}{3}$	$K_y = 5.972F_{tran} \frac{\beta^2}{1-f_3}$ where, $f_3 = f_5 \left(\frac{f_5}{1.81} + \frac{1+3\psi}{5.24} \right)$ $f_5 = \frac{9}{16} [1 + Max(-1;\psi)]^2$		
③	$1 \geq \psi \geq 0$	$K_x = \frac{4(0.425 + 1/\alpha^2)}{3\psi + 1}$	For UP-A: $C_x = 1$ for $\lambda \leq 0.75$ $C_x = \frac{0.75}{\lambda}$ for $\lambda > 0.75$	
	$0 > \psi > -1$	$K_x = 4(0.425 + 1/\alpha^2)(1 + \psi) - 5\psi(1 - 3.42\psi)$	For UP-B:	

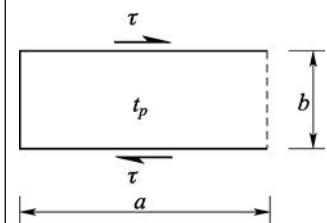
④ 	$1 \geq \psi \geq -1$	$K_x = \left(0.425 + \frac{1}{\alpha^2}\right) \frac{3-\psi}{2}$		$C_x = 1$ for $\lambda \leq 0.7$ $C_x = \frac{1}{\lambda^2+0.51}$ for $\lambda > 0.7$
⑤ 	-	$\alpha \geq 1.64$	$K_x = 1.28$	
		$\alpha < 1.64$	$K_x = \frac{1}{\alpha^2} + 0.56 + 0.13\alpha^2$	
⑥ 	$1 \geq \psi \geq 0$	$K_y = \frac{4(0.425 + \alpha^2)}{(3\psi + 1)\alpha^2}$		For UP-A: $C_y = 1$ for $\lambda \leq 0.75$ $C_y = \frac{0.75}{\lambda}$ for $\lambda > 0.75$
	$0 > \psi \geq -1$	$K_y = 4\left(0.425 + \alpha^2\right)(1+\psi)\frac{1}{\alpha^2} - 5\psi(1-3.42\psi)\frac{1}{\alpha^2}$		For UP-B: $C_y = 1$ for $\lambda \leq 0.7$ $C_y = \frac{1}{\lambda^2+0.51}$ for $\lambda > 0.7$

⑦ 	$1 \geq \psi \geq -1$	$K_y = (0.425 + \alpha^2) \frac{3 - \psi}{2\alpha^2}$	
⑧ 	--	$K_y = 1 + \frac{0.56}{\alpha^2} + \frac{0.13}{\alpha^4}$	
⑨ 	—	$K_x = 6.97$	$C_x = 1$ for $\lambda \leq 0.83$ $C_x = 1.13 \left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2} \right)$ for $\lambda > 0.83$
⑩	—	$K_y = 4 + \frac{2.07}{\alpha^2} + \frac{0.67}{\alpha^4}$	$C_y = 1$ for $\lambda \leq 0.83$ $C_y = 1.13 \left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2} \right)$ for $\lambda > 0.83$

				
⑪ 	—	$\alpha \geq 4$	$K_x = 4$	$C_x = 1$ for $\lambda \leq 0.83$
		$\alpha < 4$	$K_x = 4 + 2.74 \left[\frac{4 - \alpha}{3} \right]^4$	$C_x = 1.13 \left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2} \right)$ for $\lambda > 0.83$
⑫ 	-	$K_y = K_y$ determined as per case ②		For $\alpha < 2$, $C_y = C_{y2}$; For $\alpha \geq 2$, $C_y = \left(1.06 + \frac{1}{10\alpha} \right) C_{y2} ;$ where, $C_{y2} : C_y \text{ determined as per case ②}$

⑬ 	—	$\alpha \geq 4$	$K_x = 6.97$	$C_x = 1$ for $\lambda \leq 0.83$ $C_x = 1.13 \left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2} \right)$ for $\lambda > 0.83$
		$\alpha < 4$	$K_x = 6.97 + 3.1 \left[\frac{4 - \alpha}{3} \right]^4$	
⑭ 	—	$K_y = \frac{6.97}{\alpha^2} + \frac{3.1}{\alpha^4} \left(\frac{4 - 1/\alpha}{3} \right)^4$		$C_y = 1$ for $\lambda \leq 0.83$ $C_y = 1.13 \left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2} \right)$ for $\lambda > 0.83$
⑮ 	—	$K_\tau = \sqrt{3} \left[5.34 + \frac{4}{\alpha^2} \right]$		$C_\tau = 1$ for $\lambda \leq 0.84$
⑯	—	$K_\tau = \sqrt{3} \left[5.34 + \text{Max} \left[\frac{4}{\alpha^2}; \frac{7.15}{\alpha^{2.5}} \right] \right]$		$C_\tau = \frac{0.84}{\lambda}$ for $\lambda > 0.84$

			
⑰ 	—	$K_\tau = K_{\tau case 15} r$ $K_{\tau case 15}$: K_τ according to case ⑮ r = opening reduction factor taken as $r = \left(1 - \frac{d_a}{a}\right) \left(1 - \frac{d_b}{b}\right)$ with $\frac{d_a}{a} \leq 0.7 \text{ and } \frac{d_b}{b} \leq 0.7$	
⑱ 	—	$K_\tau = \sqrt{3} \left(0.6 + \frac{4}{\alpha^2}\right)$	$C_\tau = 1 \text{ for } \lambda \leq 0.84$
⑲	—	$K_\tau = 8$	$C_\tau = \frac{0.84}{\lambda} \text{ for } \lambda > 0.84$

			
Edge boundary conditions: ----- Plate edge free; —————Plate edge simply supported; ————— Plate edge clamped.			
Note (1): Cases listed are general cases. Each stress component (σ_x, σ_y) is to be understood in local coordinates.			

5.2.2.4 Correction factor F_{long}

The correction factor F_{long} depending on the edge stiffener types on the longer side of the buckling panel is defined in Table 5.2.2.4. An average value of F_{long} is to be used for plate panels having different edge stiffeners. For stiffener types other than those mentioned in Table 5.2.2.4, the value of c is to be agreed by CCS. In such a case, value of c higher than those mentioned in Table 5.2.2.4 can be used, provided it is verified by buckling strength check of panel using non-linear FE analysis and deemed appropriate by CCS.

Correction factor F_{long}

Table 5.2.2.4

Structural element types			F_{long}	c
Unstiffened Panel			1.0	N/A
Stiffened Panel	Stiffener not fixed at both ends		1.0	N/A
	Stiffener fixed at both ends	Flat bar ⁽¹⁾	$F_{long} = c + 1 \text{ for } \frac{t_w}{t_p} > 1$	0.10
		Bulb profile		0.30
		Angle profile	$F_{long} = c \left(\frac{t_w}{t_p} \right)^3 + 1 \text{ for } \frac{t_w}{t_p} \leq 1$	0.40
		T profile		0.30
		Girder of high rigidity (e.g. bottom transverse)	1.4	N/A
	U-type profile fitted on hatch cover ⁽²⁾	(1) Plate on which the U-type profile is fitted, including EPP b_1 and EPP b_2: • For $b_2 < b_1$: $F_{long}=1$; • For $b_2 \geq b_1$: $F_{long} = \left(1.55 - 0.55 \frac{b_1}{b_2} \right) \left[1 + c \left(\frac{t_w}{t_p} \right)^3 \right]$ (2)Other plates of the U-type profile: $F_{long}=1$	0.2	

Notes:

(1) t_w is the net web thickness, in mm, without the correction defined in [5.4.3.5] of this Section.

(2) b_1 , b_2 and t_w are defined in Section 1, Figure 1.2.3.2(2).

5.2.2.5 Correction factor F_{tran}

The correction factor F_{tran} is to be taken as:

(1) For transversely frame EPP of single side skin bulk carrier, between the hopper and top wing tank:

- ① $F_{tran} = 1.25$ when the two adjacent frames are supported by one tripping bracket fitted in way of the adjacent plate panels;
- ② $F_{tran} = 1.33$ when the two adjacent frames are supported by two tripping brackets each fitted in way of the adjacent plate panels.
- ③ $F_{tran} = 1.15$ elsewhere.

(2) For the attached plate of a U-type stiffener fitted on a hatch cover:

$$F_{tran} = \text{Max}(3 - 0.08(F_{tran0} - 6)^2, 1.0) \leq 2.25$$

where:

$$F_{tran0} = \text{Min}\left(\frac{b_2}{b_1} + \frac{6b_2^2}{\pi^2 h_w (b_1 + b_2)} \left(\frac{t_w}{t_p}\right)^3, 6\right) \quad \text{for EPP } b_2;$$

$$F_{tran0} = \text{Min}\left(\frac{b_1}{b_2} + \frac{6b_1^2}{\pi^2 h_w (b_2 + b_1)} \left(\frac{t_w}{t_p}\right)^3, 6\right) \quad \text{for EPP } b_1.$$

with b_1 , b_2 and h_w as defined in Figure 1.2.3.2(2) of this Section.

Coefficient F defined in Case 2 of Table 5.2.2.3 is to be replaced by the following formula:

$$F = \left[1 - \left(\frac{K_y}{0.91 F_{tran}} - 1 \right) / \lambda_p^2 \right] c_1 \geq 0$$

(3) For other cases, the correction factor F_{tran} is to be taken as 1.0.

5.2.2.6 Curved plate panels

This requirement for curved plate limit state is applicable when $R/t_p \leq 2500$. Otherwise, the requirement for plate limit state given in [5.2.2.1] of this Section is applicable.

The curved plate limit state is based on the following interaction formula:

$$\left(\frac{\gamma_c \sigma_{ax} S}{C_{ax} R_{eH_P}} \right)^{1.25} - 0.5 \cdot \left(\frac{\gamma_c \sigma_{ax} S}{C_{ax} R_{eH_P}} \right) \left(\frac{\gamma_c \sigma_{tg} S}{C_{tg} R_{eH_P}} \right) + \left(\frac{\gamma_c \sigma_{tg} S}{C_{tg} R_{eH_P}} \right)^{1.25} + \left(\frac{\gamma_c \tau \sqrt{3} S}{C_{\tau} R_{eH_P}} \right)^2 = 1.0$$

With the corresponding buckling utilisation factor defined as:

$$\eta_{curved_plate} = \frac{1}{\gamma_c}$$

where:

σ_{ax} — Applied axial stress to the cylinder corresponding to the curved plate panel, in N/mm². In case of tensile axial stresses, $\sigma_{ax} = 0$;

σ_{tg} — Applied tangential stress to the cylinder corresponding to the curved plate panel, in N/mm². In case of tensile tangential stresses, $\sigma_{tg} = 0$;

C_{ax} , C_{tg} , C_{τ} — Buckling reduction factor of the curved plate panel, as defined in Table 5.2.2.6.

The stress multiplier factor, γ_c , of the curved plate panel need not be taken less than the stress multiplier factor, γ_c , for the expanded plane panel according to [5.3.1.1] of this Section.

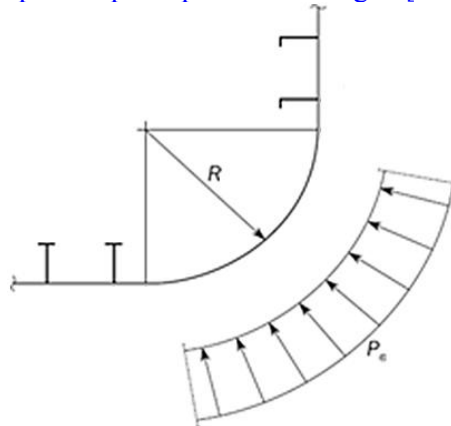
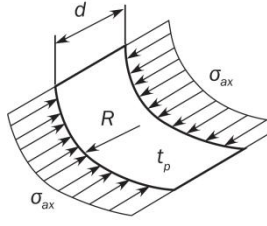
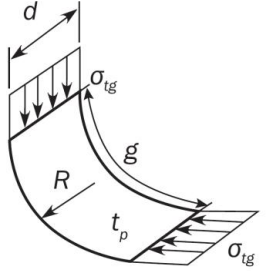
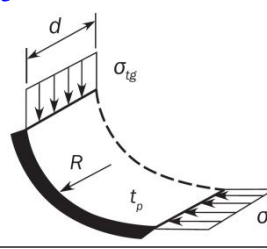
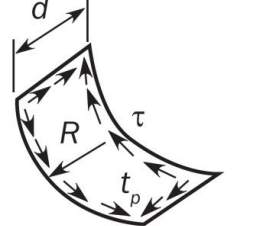


Figure 5.2.2.6 Transverse stiffened bilge plating

Buckling factor and reduction factor for curved plate panel with $R/t_p \leq 2500$

Table 5.2.2.6

Case	Aspect ratio	Buckling factor K	Reduction factor C
1 	$\frac{d}{R} \leq 0.5 \sqrt{\frac{R}{t_p}}$	$K = 1 + \frac{2}{3} \frac{d^2}{R t_p}$	For general application $C_{ax} = 1$ for $\lambda \leq 0.25$ $C_{ax} = 1.233 - 0.933\lambda$ for $0.25 < \lambda \leq 1$ $C_{ax} = 0.3 / \lambda^2$ for $1 < \lambda \leq 1.5$ $C_{ax} = 0.2 / \lambda^2$ for $\lambda > 1.5$ For curved single fields, e.g. bilge strake, which are bounded by plane panels as shown in Figure 5.3.1.6: $C_{ax} = \frac{0.65}{\lambda^2} \leq 1.0$
	$\frac{d}{R} > 0.5 \sqrt{\frac{R}{t_p}}$	$K = 0.267 \frac{d^2}{R t_p} \left[3 - \frac{d}{R} \sqrt{\frac{t_p}{R}} \right]$ $\geq 0.4 \frac{d^2}{R t_p}$	
2 	$\frac{d}{R} \leq 1.63 \sqrt{\frac{R}{t_p}}$	$K = \frac{d}{\sqrt{R t_p}} + 3 \frac{(R t_p)^{0.175}}{d^{0.35}}$	For general application: $C_{tg} = 1$ for $\lambda \leq 0.4$ $C_{tg} = 1.274 - 0.686\lambda$ for $0.4 < \lambda \leq 1.2$ $C_{tg} = \frac{0.65}{\lambda^2}$ for $\lambda > 1.2$ For curved single fields, e.g. bilge strake, which are bounded by plane panels as shown in Figure 5.3.1.6: $C_{tg} = \frac{0.8}{\lambda^2} \leq 1.0$
	$\frac{d}{R} > 1.63 \sqrt{\frac{R}{t_p}}$	$K = 0.3 \frac{d^2}{R^2} + 2.25 \left(\frac{R^2}{d t_p} \right)^2$	
3 	$\frac{d}{R} \leq \sqrt{\frac{R}{t_p}}$	$K = \frac{0.6d}{\sqrt{R t_p}} + \frac{\sqrt{R t_p}}{d} - 0.3 \frac{R t_p}{d^2}$	As in load case 2
	$\frac{d}{R} > \sqrt{\frac{R}{t_p}}$	$K = 0.3 \frac{d^2}{R^2} + 0.291 \left(\frac{R^2}{d t_p} \right)^2$	
4 	$\frac{d}{R} \leq 8.7 \sqrt{\frac{R}{t_p}}$	$K = \sqrt{3} \sqrt{28.3 + \frac{0.67 d^3}{R^{1.5} t_p^{1.5}}}$	$C_\tau = 1$ for $\lambda \leq 0.4$; $C_\tau = 1.274 - 0.686\lambda$, for $0.4 < \lambda \leq 1.2$; $C_\tau = \frac{0.65}{\lambda^2}$ for $\lambda > 1.2$
	$\frac{d}{R} > 8.7 \sqrt{\frac{R}{t_p}}$	$K = \sqrt{3} \frac{0.28 d^2}{R \sqrt{R t_p}}$	
Explanations for boundary conditions ----- Plate edge free; _____ Plate edge simply supported; ■ Plate edge clamped.			

5.2.2.7 Applied normal and shear stresses to plate panels

The normal stress, σ_x and σ_y , in N/mm², to be applied for the overall stiffened panel capacity and the plate panel capacity calculations as given in [5.2.1.1] and [5.2.2.1] respectively, are to be taken as follows:

- (1) For FE analysis, the reference stresses as defined in Section 4, [4.2.4];
- (2) For prescriptive assessment of the overall stiffened panel capacity and the plate panel capacity, the axial or transverse compressive stresses calculated according to the Relevant UR-S, at load calculation points of the considered stiffener or the considered elementary plate panel, as defined in (1) and (2) of Section 3, [3.1.2.1] respectively. However, in case of transverse stiffening arrangement, the transverse compressive stress used for the assessment of the overall stiffened

panel capacity is to be taken as the compressive stress calculated at load calculation points of the stiffener attached plating, as defined in (1) of Section 3, [3.1.2.1].

(3) For grillage analysis where the stresses are obtained based on beam theory, the stresses taken as:

$$\sigma_x = \frac{\sigma_{xb} + \nu\sigma_{yb}}{1 - \nu^2}$$

$$\sigma_y = \frac{\sigma_{yb} + \nu\sigma_{xb}}{1 - \nu^2}$$

where:

σ_{xb}, σ_{yb} — Stress, in N/mm², from grillage beam analysis respectively along x and y axis of the plate attached to the PSN web.

The shear stress, τ , in N/mm², to be applied for the overall stiffened panel capacity and the plate panel capacity calculations as given in [5.2.1.1] and [5.2.2.1] respectively, are to be taken as follows:

- ① For FE analysis, the reference shear stresses as defined in Section 4, [4.2.4];
- ② For prescriptive assessment of the plate panel buckling capacity, the shear stresses calculated according to the Relevant UR-S, at load calculation points of the considered elementary plate panel, as defined in (1) of Section 3, [3.1.2.1];
- ③ For prescriptive assessment of the overall elastic stiffened panel buckling capacity, the shear stresses calculated according to the Relevant UR-S, at the following load calculation point:
 - (a) At the middle of the full span, l , of the considered stiffener;
 - (b) At the intersection point between the stiffener and its attached plating.
- (4) For grillage beam analysis, $\tau = 0$ in the plate attached to the PSM web.

5.2.3 Stiffeners

5.2.3.1 Buckling modes

The following buckling modes are to be checked:

- (1) Stiffener induced failure (*SI*);
- (2) Associated plate induced failure (*PI*).

5.2.3.2 Web thickness of flat bar

For accounting the decrease of the stiffness due to local lateral deformation, the effective web thickness of flat bat stiffener, in mm, is to be used in [5.2.1] and [5.2.3.4] for the calculation of the net sectional area, A_s , the net section modulus, Z , and the moment of inertia, I , of the stiffener and is taken as:

$$t_{w_red} = t_w \left(1 - \frac{2\pi^2}{3} \left(\frac{h_w}{s} \right)^2 \left(1 - \frac{b_{eff1}}{s} \right) \right)$$

5.2.3.3 Idealisation of bulb profile

Bulb profiles are to be considered as equivalent angle profiles. The net dimensions of the equivalent built-up section are to be obtained from the following formulae:

$$h_w = h'_w - \frac{h'_w}{9.2} + 2$$

$$b_f = \alpha \left(t'_w + \frac{h'_w}{6.7} - 2 \right)$$

$$t_f = \frac{h'_w}{9.2} - 2$$

$$t_w = t'_w$$

where: h'_w, t'_w — Net height and thickness of a bulb section, in mm, as shown in

Figure 5.2.3.3;

α — Coefficient equal to:

$$\alpha = 1.1 + \frac{(120 - h'_w)^2}{3000} \text{ for } h'_w \leq 120$$

$$\alpha = 1.0 \text{ for } h'_w > 120.$$

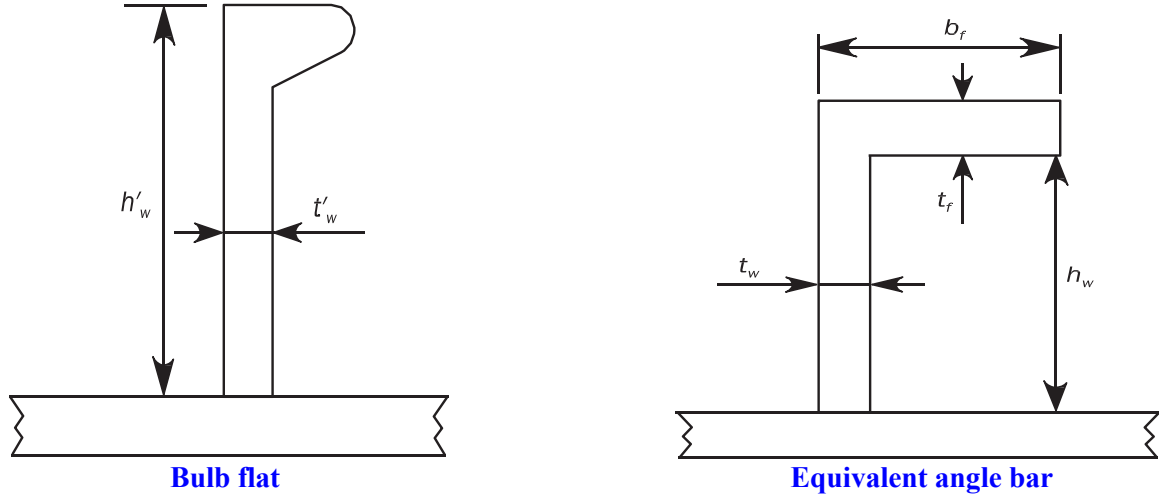


Figure 5.2.3.3 Idealisation of bulb stiffener

5.2.3.4 Ultimate buckling capacity

When $\sigma_a + \sigma_b + \sigma_w > 0$ while initially setting $\gamma = 1$, the ultimate buckling capacity for stiffeners is to be checked according to the following interaction formula:

$$\frac{\gamma_c \sigma_a + \sigma_b + \sigma_w}{R_{eH}} S = 1$$

with the corresponding buckling utilisation factor defined as:

$$\eta_{stiffener} = \frac{1}{\gamma_c}$$

where:

σ_a — Effective axial stress, in N/mm², at mid span of the stiffener, acting on the stiffener with its attached plating

$$\sigma_a = \sigma_x \frac{st_p + A_s}{b_{eff1}t_p + A_s}.$$

σ_x — Nominal axial stress, in N/mm², acting on the stiffener with its attached plating:

- (1) For FE analysis, σ_x is the FE corrected stress as defined in [5.2.3.6] in the attached plating in the direction of the stiffener axis;
- (2) For prescriptive assessment, σ_x is the axial stress, in N/mm², calculated according to Section 3, [3.2.2.1] at load calculation point of the stiffener, as defined in Section 3, [3.1.2.1];
- (3) For grillage beam analysis, σ_x is the stress acting along the x -axis of the attached buckling panel.

R_{eH} — Specified minimum yield stress of the material, in N/mm²:

- (1) $R_{eH} = R_{eH,S}$ for stiffener induced failure (SI);
- (2) $R_{eH} = R_{eH,P}$ for plate induced failure (PI).

σ_b — Bending stress in the stiffeners, in N/mm²:

$$\sigma_b = \frac{M_0 + M_1 + M_2}{1000Z}.$$

Z — Net section modulus of stiffener, including effective width of attached plating according to [5.2.3.5], to be taken as:

- (1) The section modulus calculated at the top of stiffener flange for stiffener

- induced failure (*SI*);
- (2) The section modulus calculated at the bottom of attached plating for plate induced failure (*PI*).
- M_2 — Bending moment, in N·mm, due to eccentricity of sniped stiffeners, to be taken as:
- (1) $M_2 = 0$ for continuous stiffeners;
- (2) $M_2 = C_{snip} w_{na} \gamma \sigma_x (A_p + A_s)$ for stiffeners sniped at one or both ends.
- C_{snip} — Coefficient to account for the end effect of the stiffener sniped at one or both ends, to be taken as:
- (1) $C_{snip} = -1.2$ for stiffener induced failure (*SI*);
- (2) $C_{snip} = 1.2$ for plate induced failure (*PI*).
- σ_w — Stress due to torsion, in N/mm², as defined in [5.4.4.4].
- M_I — Bending moment, in N·mm, due to the lateral load, P , taken as follows:
- (1) $M_I = C_i \frac{|P|sl^2}{24 \times 10^3}$ for continuous stiffener;
- (2) $M_I = C_i \frac{|P|sl^2}{8 \times 10^3}$ for sniped stiffener at both ends;
- (3) $M_I = C_i \frac{|P|sl^2}{14.2 \times 10^3}$ for stiffener sniped at one end and continuous at the other end.
- P — Lateral load, in kN/m²:
- (1) For FE analysis, P is the average pressure as defined in Section 4, [4.2.5.2] in the attached plating;
- (2) For prescriptive assessment, P is the static pressure calculated at load calculation point of the stiffener, as defined in Section 3, [3.1.2.1].
- C_i — Pressure coefficient:
- (1) $C_i = C_{SI}$ for stiffener induced failure (*SI*);
- (2) $C_i = C_{PI}$ for plate induced failure (*PI*).
- C_{PI} — Plate induced failure pressure coefficient:
- (1) $C_{PI} = 1$ if the lateral pressure is applied on the side opposite to the stiffener;
- (2) $C_{PI} = -1$ if the lateral pressure is applied on the same side as the stiffener.
- C_{SI} — Stiffener induced failure pressure coefficient:
- (1) $C_{SI} = -1$ if the lateral pressure is applied on the side opposite to the stiffener;
- (2) $C_{SI} = 1$ if the lateral pressure is applied on the same side as the stiffener.
- M_0 — Bending moment, in Nmm, due to the lateral deformation w of stiffener:
- $$M_0 = F_E C_{sl} \frac{\gamma}{\gamma_{GEB} - \gamma} w_0 \text{ with precondition } \gamma_{GEB} - \gamma > 0.$$
- γ_{GEB} — Stress multiplier factor of global elastic buckling capacity as defined in [5.2.1].
- F_E — Ideal elastic buckling force of the stiffener, in N:
- $$F_E = \left(\frac{\pi}{l}\right)^2 EI \times 10^4.$$
- I — Moment of inertia, in cm⁴, of the stiffener including effective width of attached plating. I is to comply with the following requirement:
- $$I \geq \frac{st_p^3}{12 \times 10^4}.$$
- t_p — Net thickness of plate, in mm, to be taken as:
- (1) For prescriptive requirements: the mean thickness of the two attached plating panels;
- (2) For FE analysis, the thickness of the considered EPP on one side of the stiffener.
- C_{sl} — Deformation reduction factor to account for global slenderness, to be taken as:
- (1) $C_{sl} = 1 - \frac{1}{12} \lambda_G^4$ for $\lambda_G \leq 1.56$;
- (2) $C_{sl} = 3 / \lambda_G^4$ for $\lambda_G > 1.56$.
- λ_G — The reference degree of global slenderness of the stiffened panel, to be taken as:
- $$\lambda_G = \sqrt{\frac{\gamma_{ReH}}{\gamma_{GEB}}}$$

- where: $\gamma_{ReH} = \frac{\text{Min}(R_{eH,P}, R_{eH,S})}{\sqrt{\sigma_{x,av}^2 + \sigma_y^2 - \sigma_{x,av}\sigma_y + 3\tau^2}}$.
- $\sigma_{x,av}$ — Average stress for both plate and stiffener as defined in [5.2.1.2].
- σ_y — Applied transverse stress to the plate panel as defined in [5.2.1.1].
- τ — Applied shear stress to the plate panel as defined in [5.2.1.1].
- w_0 — Assumed imperfection, in mm, to be taken as:
 $w_0 = l/1000$;
- σ_w — Stress due to torsional deformation, in N/mm², to be taken as:
 (1) For stiffener induce failure (SI)
 ① For $\sigma_a > 0$:

$$\sigma_w = E\gamma_w e_f \Phi_0 \left(\frac{m_{tor}\pi}{l_{tor}} \right)^2 \left(\frac{1}{1 - \frac{\gamma\sigma_a}{\sigma_{ET}}} - 1 \right)$$
 with precondition $\sigma_{ET} - \gamma\sigma_a > 0$
 ② For $\sigma_a \leq 0$:
 $\sigma_w = 0$
 (2) For plate induced failure (PI)
 $\sigma_w = 0$
- y_w — Distance, in mm, from centroid of stiffener cross section to the free edge of stiffener flange, to be taken as:
 (1) $y_w = \frac{t_w}{2}$ for flat bar;
 (2) $y_w = b_f - \frac{h_w t_w^2 + t_f b_f^2}{2A_s}$ for angle and bulb profiles;
 (3) $y_w = b_{f-out} + 0.5t_w - \frac{h_w t_w^2 + t_f (b_f^2 - 2b_f d_f)}{2A_s}$ for L2 profile;
 (4) $y_w = \frac{b_f}{2}$ for T profile.
- Φ_0 — Coefficient taken as:

$$\Phi_0 = \frac{l_{tor}}{m_{tor} h_w} \times 10^{-4}.$$
- σ_{ET} — Reference stress for torsional buckling, in N/mm², to be taken as:

$$\sigma_{ET} = \frac{E}{I_p} \left[\left(\frac{m_{tor}\pi}{l_{tor}} \right)^2 I_\omega \times 10^2 + \frac{1}{2(1+\nu)} I_T + \left(\frac{l_{tor}}{m_{tor}\pi} \right)^2 \varepsilon \times 10^{-4} \right].$$
- I_p — Net polar moment of inertia of the stiffener defined in Table 5.4.4.4, in cm⁴, about point C as shown in Section 1 Figure 1.2.3.2, as defined in Table 5.2.3.4.
- I_T — Net St. Venant's moment of inertia of the stiffener, in cm⁴, as defined in Table 5.2.3.4.
- I_ω — Net sectional moment of inertia of the stiffener, in cm⁶, about point C as shown in Section 1, Figure 1.2.3.2(1), as shown in Table 5.2.3.4.
- l_{tor} — Stiffener span, in mm, distance equal to spacing between primary supporting members, i.e. $l_{tor} = l$. When the stiffener is supported by tripping brackets, l_{tor} is to be taken as the maximum spacing between the adjacent primary supporting members and fitted tripping brackets.
- m_{tor} — Number of half waves taken as a positive integer so as to give smallest reference stress for torsional buckling.
- ε — Degree of fixation, to be taken as:

$$\varepsilon = \left(\frac{3b}{t_p^3} + \frac{2h_w}{t_w^3} \right)^{-1} \quad \text{for bulb, angle, L2 and T profiles;}$$

$$\varepsilon = \left(\frac{t_p^3}{3b} \right) \quad \text{for flat bars.}$$
- A_w — Net web area, in mm²;
- A_f — Net flange area, in mm².

Cross section characteristics	Moment of inertia	
	Flat bars	Bulb, angle, L2 and T profiles

I_p	$\frac{h_w^3 t_w}{3 \times 10^4}$	$\left(\frac{A_w(e_f - 0.5t_f)^2}{3} + A_f e_f^2 \right) \times 10^{-4}$
I_T	$\frac{h_w t_w^3}{3 \times 10^4} \left(1 - 0.63 \frac{t_w}{h_w} \right)$	$\frac{(e_f - 0.5t_f)t_w^3}{3 \times 10^4} \left(1 - 0.63 \frac{t_w}{e_f - 0.5t_f} \right) + \frac{b_f t_f^3}{3 \times 10^4} \left(1 - 0.63 \frac{t_f}{b_f} \right)$
I_ω	$\frac{h_w^3 t_w^3}{36 \times 10^6}$	For bulb, angle and L2 profiles: $\frac{A_f^3 + A_w^3}{36 \times 10^6} + \frac{e_f^2}{10^6} \left(\frac{A_f b_f^2 + A_w t_w^2}{3} - \frac{(A_f b_f + A_w t_w)^2}{4(A_f + A_w)} \right)$ For T profile: $\frac{b_f^3 t_f e_f^3}{12 \times 10^6}$
Notes: (1) t_w is the net web thickness, in mm. t_{w_red} as defined in [5.2.3.2] is not to be used in this Table; (2) d_f is to be taken as 0 for bulb and angle profiles.		

5.2.3.5 Effective width of attached plating

The effective width of attached plating of stiffeners, b_{eff} in mm, is to be taken as:

(1) For $\sigma_x > 0$:

① For FE analysis,

$$b_{eff} = \text{Min}(C_x b, \chi_s s)$$

② For prescriptive assessment,

$$b_{eff} = \text{Min}\left(\frac{C_{x1} b_1 + C_{x2} b_2}{2}, \chi_s s\right)$$

(2) For $\sigma_x \leq 0$:

$$b_{eff} = \chi_s s$$

where: χ_s — Effective width coefficient to be taken as:

$$\textcircled{1} \chi_s = \frac{1.12}{1 + \frac{1.75}{\left(\frac{\ell_{eff}}{s}\right)^{1.6}}} \leq 1.0 \text{ for } \frac{\ell_{eff}}{s} \geq 1$$

$$\textcircled{2} \chi_s = 0.407 \frac{\ell_{eff}}{s} \text{ for } \frac{\ell_{eff}}{s} < 1.$$

ℓ_{eff} — Effective length of the stiffener, in mm, taken as:

(1) $\ell_{eff} = \frac{l}{\sqrt{3}}$ for stiffener fixed at both ends;

(2) $\ell_{eff} = 0.75l$ for stiffener simply supported at one end and fixed at the other.

(3) $\ell_{eff} = l$ for stiffener simply supported at both ends.

5.2.3.6 FE corrected stresses for stiffener capacity

When the reference stresses σ_x and σ_y obtained by FE analysis according to Section 4, [4.2.4] are both compressive, σ_x is to be corrected according to the following formulae:

(1) If $\sigma_x < \nu \sigma_y$

$$\sigma_{xcor} = 0$$

(2) If $\sigma_x \geq \nu \sigma_y$

$$\sigma_{xcor} = \sigma_x - \nu \sigma_y$$

5.2.4 Primary Supporting Members

5.2.4.1 Web plate in way of openings

The web plate of primary supporting members with openings is to be assessed for buckling based on the combined axial compressive and shear stresses.

The web plate adjacent to the opening on both sides is to be considered as individual unstiffened plate panels as shown in Table 5.2.4.1.

The interaction formulae of [5.2.2.1] are to be used with:

$$\sigma_x = \sigma_{av}$$

$$\sigma_y = 0$$

$$\tau = \tau_{av}$$

where: σ_{av} — Weighted average compressive stress, in N/mm², in the area of web plate being considered, i.e. *P1*, *P2* and *P3* as shown in Table 5.2.4.1.

For the application of Table 5.2.4.1, the weighted average shear stress is to be taken as:

(1) Opening modelled in primary supporting members:

τ_{av} — Weighted average compressive stress, in N/mm², in the area of web plate being considered, i.e. *P1*, *P2* and *P3* as shown in Table 5.2.4.1.

(2) Opening not modelled in primary supporting members:

τ_{av} — Weighted average shear stress, in N/mm², given in Table 5.2.4.1.

Buckling reduction factors of web plate in way of openings

Table 5.2.4.1

Configuration ⁽¹⁾		C_x, C_y	C_τ	
			Opening modelled in PSM	Opening not modelled in PSM
(a) Without edge reinforcements ⁽²⁾		Separate reduction factors are to be applied to areas <i>P1</i> and <i>P2</i> using case ③ or case ⑥ in Table 5.2.2.3, with edge stress ratio: $\psi = 1.0$	Separate reduction factors are to be applied to areas <i>P1</i> and <i>P2</i> using case ⑱ or case ⑲ in Table 5.2.2.3.	When case ⑰ of Table 5.2.2.3 is applicable: A common reduction factor is to be applied to areas <i>P1</i> and <i>P2</i> using case ⑰ with: $\tau_{av} = \tau_{av}(web)$; When case ⑰ of Table 5.2.2.3 is not applicable: Separate reduction factors are to be applied to areas <i>P1</i> and <i>P2</i> using case ⑱ or case ⑲ with: $\tau_{av} = \tau_{av}(web)h / (h - h_0)$
(b) With edge reinforcement		Separate reduction factors are to be applied for areas <i>P1</i> and <i>P2</i> using C_x for case ① or C_y for case ② in Table 5.2.2.3 with stress ratio: $\psi = 1.0$.	Separate reduction factors are to be applied for areas <i>P1</i> and <i>P2</i> using case ⑮ in Table 5.2.2.3.	Separate reduction factors are to be applied to areas <i>P1</i> and <i>P2</i> using case ⑮ in Table 5.2.2.3 with: $\tau_{av} = \tau_{av}(web)h / (h - h_0)$
(c) Example of hole in web		Panels <i>P1</i> and <i>P2</i> are to be evaluated in accordance with (a). Panel <i>P3</i> is to be evaluated in accordance with (b).		

where:

h — Height, in m, of the web of the primary supporting member in way of the opening;

h_0 — Height, in m, of the opening measured in the depth of the web;

$\tau_{av}(web)$ — Weighted average shear stress, in N/mm², over the web height of the primary supporting member.

Note (1) Web panels to be considered for buckling in way of openings are shown shaded and numbered *P1*, *P2*, etc.

Note (2) For a PSM web panel with opening and without edge reinforcements as shown in configuration (a), the applicable buckling

Configuration ⁽¹⁾	C_x, C_y	C_τ	
		Opening modelled in PSM	Opening not modelled in PSM
assessment method depends on its specific boundary conditions. If one of the long edges along the face plate or along the attached plating is not subject to "inline support", i.e. the edge is free to pull in, Method B should be applied. In other cases, typically such as when the short plate edge is attached to the plate flanges, Method A is applicable.			

5.2.4.2 Reduction factors of web plate in way of openings

The reduction factors, C_x or C_y in combination with C_τ of the plate panel(s) of the web adjacent to the opening is to be taken as shown in Table 5.2.4.1.

5.2.4.3 The equivalent plate panel of web plate of primary supporting members crossed by perpendicular stiffeners is to be idealised as shown in Figure 5.2.4.3.

The correction of panel breadth is applicable also for other slot configurations provided that the web or collar plate is attached to at least one side of the passing stiffener.

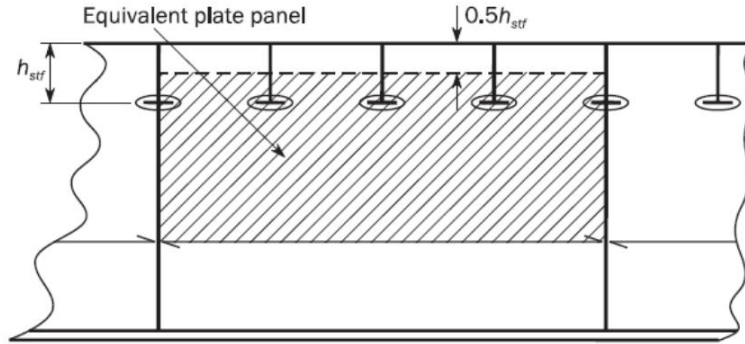


Figure 5.2.4.3 PMS web plate idealisation

5.2.5 Stiffened Panels with U-type Stiffeners

5.2.5.1 Local plate buckling

For stiffened panels with U-type stiffeners, local plate buckling is to be checked for each of the plate panels EPP b_1, b_2, b_f and h_w (see Section 1, Figure 1.2.3.2(2)) separately as follows:

(1) The attached plate panels EPP b_1, b_2 are to be assessed using SP-A model, where in the calculation of buckling factors K_x as defined in Case ① of Table 5.2.2.3, the correction factor F_{long} for U-type stiffeners as defined in Table 5.2.2.4 is to be used; and in the calculation of K_y as defined in Case ② of Table, the F_{tran} for U-type stiffeners as defined in [5.2.2.5] is to be used.

(2) The face plate and web plate panels EPP b_f and h_w are to be assessed using UP-B model with $F_{long} = 1$ and $F_{tran} = 1$.

5.2.5.2 Overall stiffened panel buckling and stiffener buckling

For a stiffened panel with U-type stiffeners, the overall buckling capacity and ultimate capacity of the stiffeners are to be checked with warping stress $\sigma_w = 0$, and with bending moment of inertia including effective width of attached plating being calculated based on the following assumptions:

(1) The two web panels of a U-type stiffener are to be taken as perpendicular to the attached plate with thickness equal to t_w and height equal to the distance between the attached plate and the face plate of the stiffener.

(2) Effective width of the attached plating b_{eff} , taken as the sum of the b_{eff} calculated for EPP, b_1 and b_2 respectively according to SP-A model.

(3) Effective width of the attached plating of a stiffener without shear lag effect, b_{eff1} , taken as the sum of the b_{eff1} calculated for the EPP, b_1 and b_2 respectively.

5.3 Buckling capacity of column structures

5.3.1 Column Buckling of Corrugations

5.3.1.1 Buckling utilisation factor

The column buckling utilisation factor, η , for axially compressed corrugations is to be taken as:

$$\eta_{column} = \frac{\sigma_{av}}{\sigma_{cr}}$$

where: σ_{av} — Average axial compressive stress in the member, in N/mm²;

σ_{cr} — Minimum critical buckling stress, in N/mm², taken as:

$$\textcircled{1} \sigma_{cr} = \sigma_E \text{ for } \sigma_E \leq 0.5R_{eH_S}$$

$$\textcircled{2} \sigma_{cr} = \left(1 - \frac{R_{eH_S}}{4\sigma_E}\right) R_{eH_S} \text{ for } \sigma_E > 0.5R_{eH_S} ;$$

σ_E — Elastic column compressive buckling stress, in N/mm², according to [5.3.1.2];

R_{eH_S} — Specified minimum yield stress of the considered member, in N/mm². For built-up members, the lowest specified minimum yield stress is to be used.

5.3.1.2 Elastic column buckling stress

The elastic compressive column buckling stress, σ_E , in N/mm² of members subject to axial compression is to be taken as:

$$\sigma_E = \pi^2 E f_{end} \frac{I}{Al_{pill}^2} \times 10^{-4}$$

where: I — Net moment of inertia about the weakest axis of the cross section, in cm⁴;

A — Net cross-sectional area of the member, in cm²;

l_{pill} — Unsupported length of the member, in m;

f_{end} — End constraint factor, corresponding to simply supported ends is to be applied except for fixed end support to be used in way of stool with width exceeding 2 times the depth of the corrugation, taken as:

- $f_{end} = 1.0$ where both ends are simply supported;
- $f_{end} = 2.0$ where one end is simply supported and the other end is fixed;
- $f_{end} = 4.0$ where both ends are fixed.

SECTION 6 STRESS BASED REFERENCE STRESSES

Symbols

- a — Length, in mm, of the longer side of the plate panel as defined in Section 5;
- b — Length, in mm, of the shorter side of the plate panel as defined in Section 5;
- A_i — Area, in mm², of the i -th plate element of the buckling panel;
- n — Number of plate elements in the buckling panel;
- σ_{xi} — Actual stress, in N/mm², at the centroid of the i -th plate element in x direction, applied along the shorter edge of the buckling panel;
- σ_{yi} — Actual stress, in N/mm², at the centroid of the i -th plate element in y direction, applied along the longer edge of the buckling panel;
- ψ — Edge stress ratio as defined in Section 5;
- τ_i — Actual membrane shear stress, in N/mm², at the centroid of the i -th plate element of the buckling panel.

6.1 Stress Based Method

6.1.1 Introduction

6.1.1.1 This Section provides a method to determine stress distribution along edges of the considered buckling panel by second-order polynomial curve, by linear distribution using least square method and by weighted average approach. The reference stress is the stress components at centre of plate element transferred into the local system of the considered buckling panel.

6.1.1.2 Definition

A regular panel is a plate panel of rectangular shape. An irregular panel is plate panel which is not regular, as detailed in Section 4, [4.2.3.1].

6.1.2 Stress Application

6.1.2.1 Regular panel

The reference stresses are to be taken as defined in [6.2.1] for a regular panel when the following conditions are satisfied:

- At least, one plate element centre is located in each third part of the long edge a of a regular panel; and
- This element center is located at a distance in the panel local x direction not less than $a/4$ to at least one of the element centers in the adjacent third part of the panel.

Otherwise, the reference stresses are to be taken as defined in [6.2.2] for an irregular panel.

6.1.2.2 Irregular panel and curved panel

The reference stresses of an irregular panel or of a curved panel are to be taken as defined in [6.2.2].

6.2 Reference Stresses

6.2.1 Regular Panel

6.2.1.1 Longitudinal stress

The longitudinal stress σ_x applied on the shorter edge of the buckling panel is to be calculated as follows:

For plate buckling assessment, the distribution of $\sigma_x(x)$ is assumed as second order polynomial curve as:

$$\sigma_x = Cx^2 + Dx + E$$

The best fitting curve $\sigma_x(x)$ is to be obtained by minimising the square error Π considering the area of each element as a weighting factor:

$$\Pi = \sum_{i=1}^n A_i [\sigma_{xi} - (Cx_i^2 + Dx_i + E)]^2$$

The unknown coefficients C , D and E is yield zero first derivatives, $\partial \Pi$ with respect to C , D and E , respectively.

$$\begin{cases} \frac{\partial \Pi}{\partial C} = 2 \sum_{i=1}^n A_i x_i^2 [\sigma_{xi} - (Cx_i^2 + Dx_i + E)] = 0 \\ \frac{\partial \Pi}{\partial D} = 2 \sum_{i=1}^n A_i x_i [\sigma_{xi} - (Cx_i^2 + Dx_i + E)] = 0 \\ \frac{\partial \Pi}{\partial E} = 2 \sum_{i=1}^n A_i [\sigma_{xi} - (Cx_i^2 + Dx_i + E)] = 0 \end{cases}$$

The unknown coefficients C , D and E can be obtained by solving the 3 above equations.

$$\sigma_{x1} = \frac{1}{b} \int_0^b \sigma_x(x) dx = \frac{b^2}{3} C + \frac{b}{2} D + E$$

$$\sigma_{x2} = \frac{1}{b} \int_{a-b}^a \sigma_x(x) dx = \left(a^2 - ab + \frac{b^2}{3} \right) C + \left(a - \frac{b}{2} \right) D + E$$

If $-\frac{D}{2C} < \frac{b}{2}$ or $-\frac{D}{2C} > a - \frac{b}{2}$, σ_{x3} is to be ignored. Otherwise, σ_{x3} is taken as:

$$\sigma_{x3} = \frac{1}{b} \int_{x_{min}}^{x_{max}} \sigma_x(x) dx = \frac{b^2}{12} C - \frac{D^2}{4C} + E$$

where: $x_{min} = -\frac{b}{2} - \frac{D}{2C}$

$$x_{max} = \frac{b}{2} - \frac{D}{2C}$$

The longitudinal stress is to be taken as:

$$\sigma_x = \text{Max}(\sigma_{x1}, \sigma_{x2}, \sigma_{x3}) ;$$

The edge stress ratio is to be taken as:

$$\psi_x = 1$$

For overall stiffened panel buckling and stiffener buckling assessments, the longitudinal stress σ_x applied on the shorter edge of the attached plate is to be taken as:

$$\sigma_x = \frac{\sum_{i=1}^n A_i \sigma_{xi}}{\sum_{i=1}^n A_i}$$

The edge stress ratio ψ_x for the stress σ_x is equal to 1.0.

6.2.1.2 Transverse stress

The transverse stress σ_y applied along the longer edges of the buckling panel is to be calculated by extrapolation of the transverse stresses of all elements up to the shorter edges of the considered buckling panel.

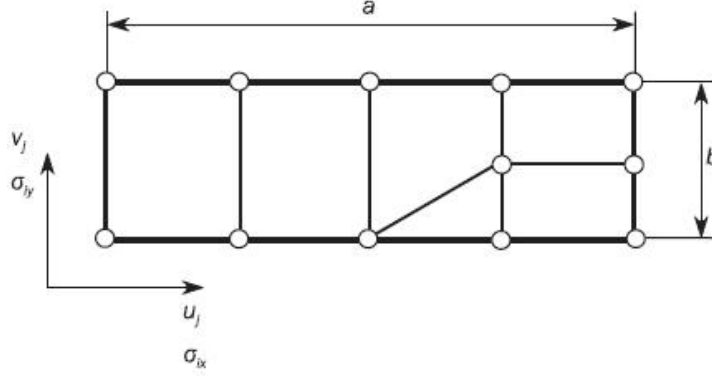


Figure 6.2.1.2 Buckling panel

The distribution of $\sigma_y(x)$ is assumed as straight line. Therefore:

$$\sigma_y(x) = A + Bx$$

The best fitting curve $\sigma_y(x)$ is to be obtained by the least square method minimising the square error Π considering area of each element as a weighting factor.

$$\Pi = \sum_{i=1}^n A_i [\sigma_{yi} - (A + Bx_i)]^2$$

The unknown coefficients A and B are to be yield zero first partial derivatives, $\partial \Pi$ with respect to A and B , respectively.

$$\frac{\partial \Pi}{\partial A} = 2 \sum_{i=1}^n A_i [\sigma_{yi} - (A + Bx_i)] = 0$$

$$\frac{\partial \Pi}{\partial B} = 2 \sum_{i=1}^n A_i x_i [\sigma_{yi} - (A + Bx_i)] = 0$$

The unknown coefficients A and B are obtained by solving the 2 above equations and are given as follow:

$$A = \frac{(\sum_{i=1}^n A_i \sigma_{yi})(\sum_{i=1}^n A_i x_i^2) - (\sum_{i=1}^n A_i x_i)(\sum_{i=1}^n A_i x_i \sigma_{yi})}{(\sum_{i=1}^n A_i)(\sum_{i=1}^n A_i x_i^2) - (\sum_{i=1}^n A_i x_i)^2}$$

$$B = \frac{(\sum_{i=1}^n A_i)(\sum_{i=1}^n A_i x_i \sigma_{yi}) - (\sum_{i=1}^n A_i x_i)(\sum_{i=1}^n A_i \sigma_{yi})}{(\sum_{i=1}^n A_i)(\sum_{i=1}^n A_i x_i^2) - (\sum_{i=1}^n A_i x_i)^2}$$

The transverse stress is to be taken as:

$$\sigma_y = \max(A, A + Ba)$$

The edge stress ratio is to be taken as:

$$\psi_y = \frac{\min(A, A + Ba)}{\max(A, A + Ba)} \text{ for } \sigma_y > 0$$

$$\psi_y = 1 \text{ for } \sigma_y \leq 0.$$

6.2.1.3 Shear stress

The shear stress τ is to be calculated using a weighted average approach, and is to be taken as:

$$\tau = \frac{\sum_{i=1}^n A_i \tau_i}{\sum_{i=1}^n A_i}$$

6.2.2 Irregular Panel and Curved Panel

6.2.2.1 Reference stresses

The longitudinal, transverse and shear stresses are to be calculated using a weighted average approach. They are to be taken as:

$$\sigma_x = \frac{\sum_{i=1}^n A_i \sigma_{xi}}{\sum_{i=1}^n A_i}$$

$$\sigma_y = \frac{\sum_{i=1}^n A_i \sigma_{yi}}{\sum_{i=1}^n A_i}$$

$$\tau = \frac{\sum_{i=1}^n A_i \tau_i}{\sum_{i=1}^n A_i}$$

The edge stress ratios are to be taken as:

$$\psi_x = 1;$$

$$\psi_y = 1.$$

CHAPTER 3 EQUIPMENT AND OUTFITS

Section 1 RUDDERS

3.1.1 General requirements

3.1.1.1 Basic assumptions

(1) This Section applies to ordinary profile rudders, and to some enhanced profile rudders with special arrangements for increasing the rudder force. Rudders not conforming to the profile types included in this Section will be subject to special consideration.

(2) This section applies to rudders made of steel. Rudders made of material different from steel will be subject to special consideration.

3.1.1.2 Design considerations

(1) Effective means are to be provided for supporting the weight of the rudder without excessive bearing pressure, e.g. by a rudder carrier attached to the upper part of the rudder stock. The hull structure in way of the rudder carrier is to be suitably strengthened.

(2) Suitable arrangements are to be provided to prevent the rudder from lifting.

(3) In rudder trunks which are open to the sea, a seal or stuffing box is to be fitted above the deepest load waterline, to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier. If the top of the rudder trunk is below the deepest waterline waterline at scantling draught (without trim), two separate watertight seals /stuffing boxes are to be provided.

3.1.1.4 Welding and design details

(3) Welds in the rudder side plating subjected to significant stresses from rudder bending and welds between plates and heavy pieces (solid parts in forged or cast steel or very thick plating) are to be made as full penetration welds. In way of highly stressed areas e.g. cut-out of semi-spade rudder and upper part of spade rudder, cast or welding on ribs is to be arranged. Two sided full penetration welding is normally to be arranged. Where back welding is impossible welding is to be performed against ceramic backing bars or equivalent. Steel backing bars may be used and are to be continuously welded on one side to the heavy piece bevelled edge, see Figure 3.1.1.4(3). The bevel angle is to be at least 15° for one sided welding.

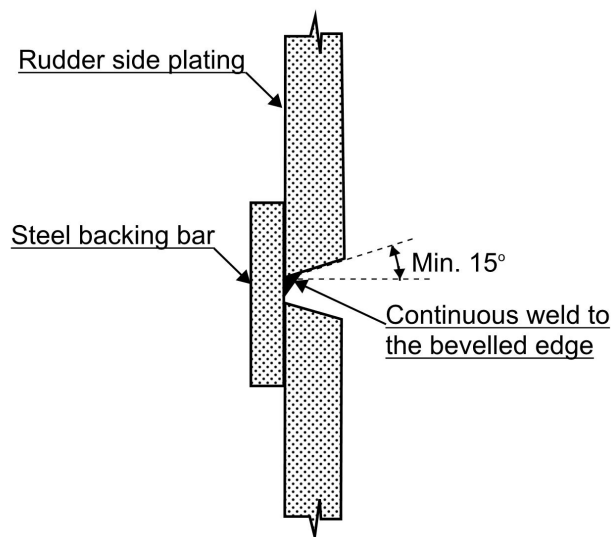


Figure 3.1.1.4(3) Use of steel backing bar in way of full penetration welding of rudder side plating

3.1.2 Rudder force and rudder torque

3.1.2.1 Rudder blades without cut-outs

(1) The rudder force C_R upon which the rudder scantlings are to be based is to be determined from

the following formula:

$$C_R = 132 K_1 K_2 K_3 A V^2 \quad \text{N}$$

where: C_R — rudder force, in N;
 A — area of rudder blade, in m^2 ;
 V — maximum service speed (knots). When the speed is less than 10 knots, V is to be replaced by the following:
 $V_{\min} = (V + 20) / 3$
For the astern condition the maximum astern speed V_{astern} [\(the greatest speed which the ship is designed to maintain in service at sea at the deepest sea-going draught\)](#) is to be used, however, in no case less than:
 $V_{\text{astern}} = 0.5 V$;

3.1.4 Rudder stock scantlings

3.1.4.2 Rudder stock scantlings due to combined loads

If the rudder stock is subjected to combined torque and bending, the equivalent stress in the rudder stock is not to exceed $118 / K \text{ N/mm}^2$.

K — material factor for the rudder stock as given in 3.1.1.3(5).

The equivalent stress σ_e is to be determined by the formula:

$$\sigma_e = \sqrt{\sigma_b^2 + 3\tau_t^2} \quad \text{N/mm}^2$$

where: bending stress: $\sigma_b = \frac{10.2M}{d_c^3} \times 10^3 \quad \text{N/mm}^2$;

torsional stress: $\tau_t = \frac{5.1Q_R}{d_c^3} \times 10^3 \quad \text{N/mm}^2$.

The rudder stock diameter d_c is therefore not to be less than:

$$d_c = d_t \sqrt[6]{1 + \frac{4 \left(\frac{M}{Q_R} \right)^2}{3}} \quad \text{mm}$$

where: M — bending moment, in $\text{N}\cdot\text{m}$, at the station of the rudder stock considered.

[For a spade rudder with trunk extending inside the rudder, the rudder stock scantlings are to be checked against the two cases defined in 2.2, Appendix 1 of this Chapter.](#)

3.1.5 Rudder blade

3.1.5.2 Rudder plating

The thickness t of the rudder side, top and bottom plating is not to be less than:

$$t = 5.5 s \beta \sqrt{K} \sqrt{d + C_R 10^{-4} / A + 2.5} \quad \text{mm}$$

where: d — [summer loadline scantling](#) draught, in m;
 C_R — rudder force, in N, according to 3.1.2.1 of this Section;
 A — rudder area, in m^2 ;

$$\beta = \sqrt{1.1 - 0.5 \left(\frac{s}{b} \right)^2} \quad \text{max. } 1.00 \text{ if } \frac{b}{s} \geq 2.5;$$

s — smallest unsupported width of plating, in m;

b — greatest unsupported width of plating, in m;

K — material factor for the rudder plating as given in 3.1.1.3(2).

3.1.6 Rudder stock couplings

3.1.6.4 Cone couplings with special arrangements for mounting and dismounting the couplings

(2) Push-up pressure

The push-up pressure is not to be less than the greater of the two following values:

$$p_{\text{req1}} = \frac{2Q_F \times 10^3}{d_m^2 l \pi \mu_0} \quad \text{N/mm}$$

$$^2 p_{req2} = \frac{6M_c \times 10^3}{l^2 d_m} \text{ N/mm}^2$$

where: Q_F — design yield moment of rudder stock, as defined in-3.1.6.3(2) of this Section, in N·m;

d_m — mean cone diameter, in mm, see Figure 3.1.6.3(a);

l — coupling length, in mm;

μ_0 — frictional coefficient, equal to 0.15;

M_b M_e — bending moment in rudder stock at the top of the cone coupling (e.g. in case of spade rudders), in N·m.

For spade rudder with trunk extending inside the rudder, the coupling is to be checked against the two cases defined in 2.2, Appendix 1 of this Chapter

It has to be proved by the designer that the push-up pressure does not exceed the permissible surface pressure in the cone. The permissible surface pressure p_{perm} , in N/mm², is to be determined by the following formula:

$$p_{perm} = \frac{0.95 R_{eH} (1 - \alpha^2)}{\sqrt{3 + \alpha^4}} - p_b \text{ N/mm}^2 \text{ N/mm}^2$$

where: $p_b = \frac{3.5 M_c \times 10^3}{d_m l^2} \text{ N/mm}^2$;

R_{eH} — specified minimum yield stress of the material of the gudgeon, in N/mm²;

$$\alpha = \frac{d_m}{d_a};$$

d_m — diameter, in mm, see Figure 3.1.6.3(a);

d_a — outer diameter of the gudgeon, see Figure 3.1.6.3(a), in mm, to be not less than 1.25 d_0 , see Figure 3.1.6.3(a) and Figure 3.1.6.3(b)(the least diameter is to be considered).

3.1.7 Pintles

3.1.7.2 Couplings

(2) Push-up pressure for pintle

The required push-up pressure for pintle in case of dry fitting, in N/mm², is to be determined by p_{req1} as given below.

The required push-up pressure for pintle in case of oil injection fitting, in N/mm², is to be determined by the maximum pressure of p_{req1} and p_{req2} as given below:

The required push-up pressure for pintle p_{req} , in N/mm², is to be determined by the following formula:

$$p_{req} = 0.4 \frac{B_1 d_0}{d_m^2 l} \text{ N/mm}^2$$

$$p_{req2} = \frac{6 M_{bp} \times 10^3}{l^2 d_m} \text{ N/mm}^2$$

where: B_1 — Supporting force in the pintle, in N;

d_0 — Pintle diameter, in mm, see Figure 3.1.6.3(a).

M_{bp} — bending moment in the pintle cone coupling to be determined by:

$$M_{bp} = B l_a \text{ Nm}$$

l_a — length between middle of pintle-bearing and top of contact surface between cone coupling and pintle, see Figure 3.1.7.2.

The push up length Δl_1 is to be calculated similarly as in 3.1.6.4(3) of this Section, using required push-up pressure and properties for the pintle.

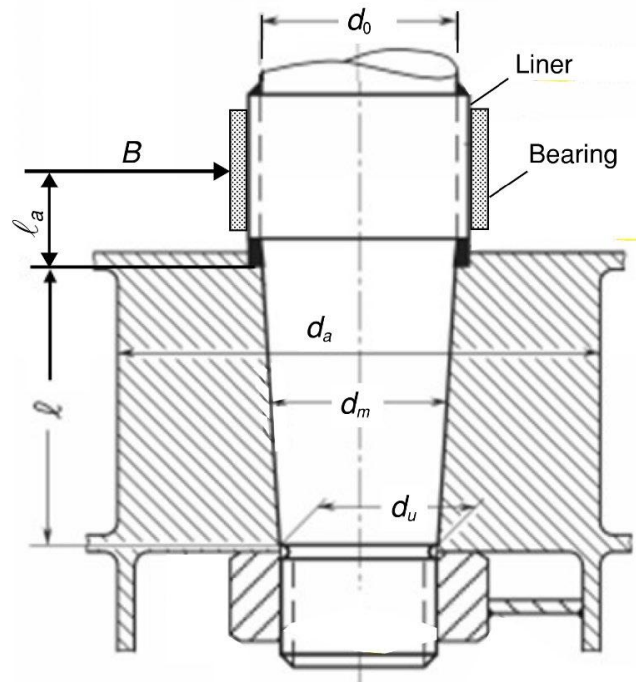


Figure 3.1.7.2 pintle cone coupling indicating l_a

3.1.8 Rudder stock bearing, rudder shaft bearing and pintle bearing

3.1.8.1 Liners and bushes

(1) Rudder stock bearing

Liners and bushes are to be fitted in way of bearings. For rudder stocks and pintles having diameter less than 200 mm, liners in way of bushes may be provided optionally. The minimum thickness of liners and bushes t_{min} is to be equal to:

- $t_{min} = 8$ mm for metallic materials and synthetic material;
- $t_{min} = 22$ mm for lignum material.

(2) Pintle bearing

The thickness of any liner or bush t , in mm, is not to be less than the minimum thickness defined in 3.1.8.1(1) and the following value:

$$t = 0.01\sqrt{B}$$

where: B —relevant bearing force, in N.

3.1.9 Strength of rudder horns and rudder trunk

3.1.9.2 Rudder trunk

The requirements in this paragraph apply to trunk configurations which are extended below stern frame and arranged in such a way that the trunk is stressed by forces due to rudder action.

(1) Materials, welding and connection to hull

The steel used for the rudder trunk is to be of weldable quality, with a carbon content not exceeding 0.23% on ladle analysis or a carbon equivalent C_{EQ} not exceeding 0.41%.

Plating materials for rudder trunks are in general not to be of lower grades than corresponding to class II as defined in Section 3, Chapter 1 of this PART.

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

For rudder trunks extending below shell or skeg, the The fillet shoulder radius r , in mm (see Figure 3.1.9.2) is to be as large as practicable and to comply with the following formulae:

$$r = 0.1d_c / K, \text{ without being less than:}$$

$$r = 60 \text{ mm} \quad \text{when } \sigma = 40 / K \text{ N/mm}^2$$

$$r = 30 \text{ mm} \quad \text{when } \sigma < 40/K \text{ N/mm}^2$$

where: d_c — rudder stock diameter axis as defined in 3.1.4.2;

σ — bending stress in the rudder trunk, in N/mm²;

K — material factor [for the rudder trunk](#) as given in 3.1.1.3(2) or 3.1.1.3(5) of this Section.

The radius may be obtained by grinding. If disk grinding is carried out, score marks are to be avoided in the direction of the weld. The radius is to be checked with a template for accuracy. Four profiles at least are to be checked. A report is to be submitted to the Surveyor.

Rudder trunks comprising of materials other than steel are to be specially considered by CCS.

Section 2 ANCHORING AND MOORING EQUIPMENT

3.2.1 Equipment number

3.2.1.1 The anchoring equipment for sea-going ships are to be provided in accordance with Tables 3.2.1.1(1) and 3.2.1.1(2), based on the ship type and service area as well as the equipment number derived from 3.2.1.2 of this Section. Requirements of this Section for the number, length and breaking loads of towlines and mooring lines are only as guidance.

For non-self-propelled ships engaged in special work, of which an increased mass of anchors is required by the owner and anchoring operations are carried out by means of other appliances, chain cables may be provided in accordance with the rule requirements for the mass of anchors only.

The requirement for the anchoring equipment in this Section is intended for temporary mooring of a vessel within a harbour or sheltered area when the vessel is awaiting berth, tide, etc.

The equipment is therefore not designed to hold a ship off fully exposed coasts in rough weather or to stop a ship which is moving or drifting. In this condition the loads on the anchoring equipment increase to such a degree that its components may be damaged or lost owing to the high energy forces generated, particularly in large ships.

The anchoring equipment presently required in this Section is designed to hold a ship in good holding ground in conditions such as to avoid dragging of the anchor. In poor holding ground the holding power of the anchors will be significantly reduced.

The Equipment Numeral (EN) formula for anchoring equipment required in this Section is based on an assumed maximum current speed of 2.5 m/sec, maximum wind speed of 25 m/sec and a minimum scope of chain cable between 6 and 10, the scope being the ratio between length of chain paid out and water depth. For ships with an equipment length greater than 135 m, alternatively the required anchoring equipment can be considered applicable to a maximum current speed of 1.54 m/s, a maximum wind speed of 11 m/s and waves with maximum significant height of 2 m.

It is assumed that under normal circumstances a ship will use only one bow anchor and chain cable at a time.

Manufacture of anchors and anchor chain cables is to be in accordance with the relevant requirements of CCS Rules for Materials and Welding.

The bower anchor is to be connected with its chain cable, arranged onboard the ship and ready for use.

[In addition to planned anchoring for normal operations, anchoring equipment is also important for ship safety in emergency situations such as loss of maneuverability, unscheduled repairs and other unexpected situations.](#)

3.2.1.2 The equipment number N is to be obtained from the following formula:

$$N = \Delta^{\frac{2}{3}} + 2(Bh + S_{fun}) + \frac{A}{10}$$

where: Δ — moulded displacement, in t, to the summer load waterline;

B — moulded breadth, in m;

h — effective height, in m, from the summer load waterline to the top of the uppermost house, i.e.:

$$h = a + \sum h_i$$

where: a — vertical distance at hull side, in m, measured from the summer load waterline amidships to the upper deck;

h_i — height at the centreline, in m, of each tier of houses having a breadth greater than $B/4$; for the lowest tier h_1 is to be measured at centreline from the upper deck or from a notional deck line where there is local discontinuity in the upper deck, see Figure 3.2.1.1(1);

A — area, in m^2 , in profile view of the hull, within the length of the vessel, and of superstructures and deckhouses and funnels above the summer load waterline, which are within the length of the vessel, and also having a breadth greater than $B/4$. The side projected area of the funnel is considered in A when A_{FS} is greater than zero. In this case, the side projected area of the funnel should be calculated between the upper deck, or notional deck line where there is local discontinuity in the upper deck, and the effective height h_F ;

S_{fun} — effective front projected area of the funnel, in m^2 , defined as:

$$S_{fun} = A_{FS} - S_{shield}$$

where: A_{FS} — front projected area of the funnel, in m^2 , calculated between the upper deck at centreline, or notional deck line where there is local discontinuity in the upper deck, and the effective height h_F . A_{FS} is taken equal to zero if the funnel breadth is less than or equal to $B/4$ at all elevations along the funnel height;

h_F — effective height of the funnel, in m, measured from the upper deck at centreline, or notional deck line where there is local discontinuity in the upper deck, and the top of the funnel. The top of the funnel may be taken at the level where the funnel breadth reaches $B/4$;

S_{shield} — the section of front projected area A_{FS} , in m^2 , which is shielded by all deck houses having breadth greater than $B/4$. If there are more than one shielded section, the individual shielded sections i.e $S_{shield1}$, $S_{shield2}$ etc as shown in Figure 3.2.1.2(3) to be added together. To determine S_{shield} , the deckhouse breadth is assumed B for all deck houses having breadth greater than $B/4$ as shown for $S_{shield1}$, $S_{shield2}$ in Figure 3.2.1.2(3).

When several funnels are fitted on the ship, the above parameters are taken as follows:

h_F — effective height of the funnel, in m, measured from the upper deck, or notional deck line where there is local discontinuity in the upper deck, and the top of the highest funnel. The top of the highest funnel may be taken at the level where the sum of each funnel breadth reaches $B/4$;

A_{FS} — sum of the front projected area of each funnel, in m^2 , calculated between the upper deck, or notional deck line where there is local discontinuity in the upper deck, and the effective height h_F . A_{FS} is to be taken equal to zero if the sum of each funnel breadth is less than or equal to $B/4$ at all elevations along the funnels height;

A — Side projected area, in m^2 , of the hull, superstructures, houses and funnels above the Summer Load waterline which are within the length of the ship. The total side projected area of the funnels is to be considered in the side projected area of the ship, A , when A_{FS} is greater than zero. The shielding effect of funnels in transverse direction may be considered in the total side projected area, i.e., when the side projected

areas of two or more funnels fully or partially overlap, the overlapped area needs only to be counted once.

The equipment number of tugs is to be determined by the following formula:

$$N = \Delta^{\frac{2}{3}} + 2(aB + \sum b_i h_i) + \frac{A}{10}$$

where: a , B and h_i — same as defined above;

b_i — breadth, in m, of superstructures or of deckhouses of each tier having a breadth greater than $B/4$.

[For tugs under 45 m in length intended for towing service only, one anchor may be used onboard provided that the second anchor and its relevant chain cable holds readily available to be installed. In case of loss of anchor, the tug is to remain in port until replace anchor equipment is installed onboard.](#)

In the calculation of h and A , sheer and trim are to be ignored, i.e. h is the sum of freeboard amidships plus the height (at centreline) of each tier of houses having a breadth greater than $B/4$. Screens and bulwarks more than 1.5 m in height are to be regarded as parts of superstructures or deckhouses.

Screens and bulwarks more than 1.5 m in height are to be regarded as parts of superstructures or deckhouses.

If a house having a breadth greater than $B/4$ is above a house with a breadth of $B/4$ or less then the wide house is to be included but the narrow house ignored.

The height of the hatch coamings and that of any deck cargo, such as containers, may be disregarded when determining h and A . With regard to determining A , when a bulwark is more than 1.5 m high, the area shown as A_2 in Figure 3.2.1.2(2) is to be included in A . The total length of chain given in Table 3.2.1.1(2) is to be divided in approximately equal parts between the two bower anchors.

[For ships of length less than 90 m, alternative methodology using direct force calculation for anchoring equipment described in appendix 3 of this Chapter may be used.](#)

Equipment Required

Table 3.2.1.1(1)

Ship type	Required equipment
Cargo ships, bulk carriers, oil tankers, trailing suction dredgers, ferries, etc.	Using N
Tugs	Using N
Offshore supply ships	Using N , but the chain cables are to be selected 2 grades above N
Manned barges	Using N
Unmanned barges	Using N , but only one bower anchor is required, and 0.5 times the length of chain cables required for N may be provided
Floating cranes, floating pile drivers or other similar workboats	Using N , but side projections of the crane, pile driver, etc., are to be considered for N . If the anchors used comply with the requirements of this Table, they may be used in lieu of bower anchors. Where wires are substituted for chain cables (irrespective of ship length), anchor weight is at least to be increased by 25%, the length of the wires is not to be less than 1.5 times that of the required chain cables and the breaking strength of the wires is to be equal to that of the required chain cables. Anchor winches used as an alternative to windlasses are to satisfy the requirements of Section 2, Chapter 13, PART THREE of the Rules (except for requirements for cable lifters and chain stoppers). For the arrangement of winches, rope guides are to be provided and testing is to be carried out in accordance with the requirements of 13.2.6, Chapter 13, PART THREE of the Rules. A short length of chain cables is to be fitted between the anchor and the wire, having a length of 12.5 m or equal to the distance from the anchor in the stowed position to the winch, whichever is the lesser, and a swivel is to be fitted at the connection between the wire and the chain cable

3.2.3 Chain cables

3.2.3.1 For ships with N less than 90, chain cables may be substituted by studless chains of equivalent proof-load.

3.2.3.2 Wire rope may be used in place of chain cable on ships ~~with less than 40 m in length and~~ subject to the following conditions:

(1) with less than 90 m in length and which will need an anchor for emergency purposes, i.e., not intended to use their anchor in normal temporary anchoring operation, or

(2) with the anchoring equipment used for positioning with a minimum of 4 points anchoring, e.g., for cable or pipe laying.

(3) for anchors used for operation of floating cranes, floating pile drivers or other similar workboats as specified in Table 3.2.1.1(1).

3.2.3.3 Use of wire rope is subject to the following conditions:

(1) The wire ropes are to have a total length equal to 1.5 times the corresponding length of stud link chain cables required in Table 3.2.1.1(2), and a minimum breaking load equal to that given for the corresponding stud link chain cable of Grade CCS 1.

(2) The anchor weight shall be increased by 25 % compared to anchor associated with chain cable according to Table 3.2.1.1(2).

(3) A short length of chain cable is to be fitted between the wire rope and the anchor, having a length equal to 12.5 m or the distance from the anchor in the stowed position to the winch, whichever is the lesser.

(34) All surfaces being in contact with the wire need to be rounded with a radius of not less than 10 times the wire rope diameter (including stem).

(5) Steel wire shall be selected to fit for purpose based on the manufacturer recommendation and shall be provided with guidance for maintenance and inspection.

3.2.3.34 A swivel is to be provided to the chain cables at the outboard end to which the anchor is connected.

3.2.3.45 The inboard end of the chain cables is to be secured to the hull structure and so arranged that they will be capable of being immediately released from a position easily accessible outside the chain locker.

3.2.3.56 Grade CCS 1 material having a tensile stress of less than 400 N/mm² is not to be used in association with high holding power anchors. Grade CCS 3 material is to be used only for chains of 20.5 mm or more in diameter.

3.2.3.67 The total length of chain given in Table 3.2.1.1(2) is to be divided in approximately equal parts between the two bower anchors.

3.2.4 Towlines and mooring lines

3.2.4.1 The number, length and breaking loads of mooring lines are to be marked on the mooring arrangement plan of the ship. The towlines listed in Table 3.2.1.1(2) are provided on board for the tug or for the use by other ships towing the ship. The lateral projected area of deck cargoes as given ~~in the loading manual~~ by the ship nominal capacity condition is to be taken into account during the calculation of equipment number for selection of towing lines. As an alternative method to 3.2.4, the number and strength of mooring lines may be determined by means of direct mooring analysis of Appendix 2 of this Chapter.

Appendix 1 GUIDELINES FOR CALCULATION OF BENDING MOMENT AND SHEAR FORCE DISTRIBUTION

2 The Forces on Rudder–Rudder Stock

2.1 Spade rudder

Data for the analysis

$l_{10} - l_{30}$ = lengths of the individual girders of the system, in m;

$I_{10} - I_{30}$ = moments of inertia of these girders, in cm⁴.

Load of rudder body P_R :

$$P_R = C_R / (l_{10} 10^3) \quad \text{kN/m}$$

Moments and forces

The moments and forces may be determined by the following formulae:

$$M_b = C_R (l_{20} + (l_{10} (2c_1 + c_2) / 3(c_1 + c_2))) \quad \text{Nm}$$

$$B_3 = \frac{M_b}{l_{30}} \quad \text{N}$$

$$B_2 = C_R + B_3 \quad \text{N}$$

where: C_R — rudder force, in N.

The maximum moment, M_c , in top of the cone coupling as shown in Figure 2.1 is applicable for the connection between the rudder and the rudder stock.

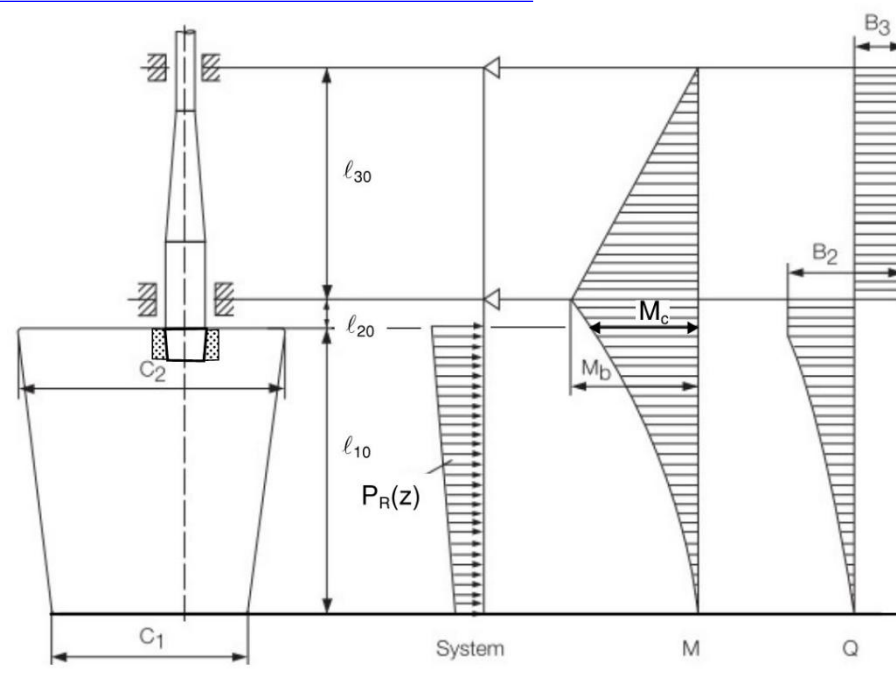


Figure 2.1 Spade rudder

2.2 Spade rudder with trunk

Data for the analysis

$l_{10} - l_{30}$ = lengths of the individual girders of the system, in m;

$I_{10} - I_{30}$ = moments of inertia of these girders, in cm^4 .

Load of rudder body P_R :

$$P_R = C_R / ((l_{10} + l_{20}) 10^3) \quad \text{kN/m}$$

Moments and forces

For a spade rudders with rudders trunks the moments with trunk extending inside the rudder, in N-m, and forces, in N, may be determined by the following formulae: the strength is be checked against the following two cases, and the moments and forces for the two cases defined above may be determined according to Figure 2.2(1) and 2.2(2), respectively.

(1) pressure applied on the entire rudder area;

Full rudder force $C_R = C_{R1} + C_{R2}$

total rudder torque $Q_R = Q_{R1} + Q_{R2}$

rudders stock bending moment $M_b = M_{CR2} - M_{CR1}$

(2) pressure applied only on rudder area below the middle of neck bearing.

Rudder force C_{R2} corresponding to rudder torque Q_{R2} acting at rudder blade area A_2 with rudders stock bending moment $M_b = M_{CR2}$

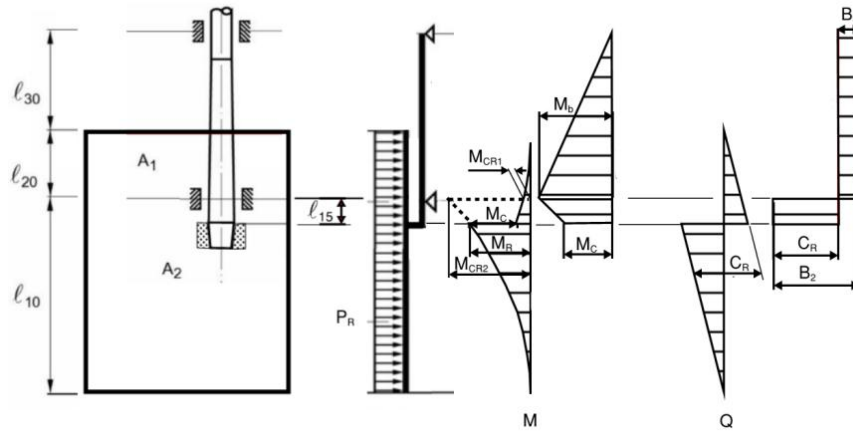


Figure 2.2(1)

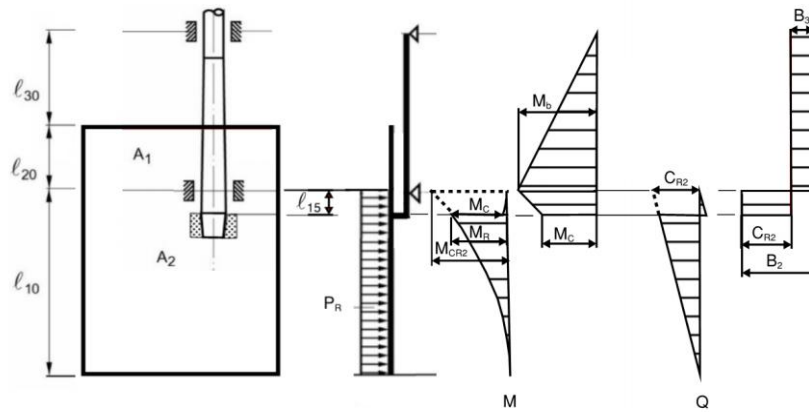


Figure 2.2(2)

M_R is the greatest of the following values:

$$M_{CR1} = C_{R1}(CG_{1Z} - l_{10}) \quad \text{Nm}$$

$$M_{CR2} = C_{R2}(l_{10} - CG_{2Z}) \quad \text{Nm}$$

where: C_{R1} : rudder force over the rudder blade area A_1 ;

C_{R2} : rudder force over the rudder blade area A_2 ;

CG_{1Z} : vertical position of the centre of gravity of the rudder blade area A_1 ;

CG_{2Z} : vertical position of the centre of gravity of the rudder blade area A_2 ;

$$C_R = C_{R1} + C_{R2} \quad \text{N}$$

$$B_3 = (M_{CR2} - M_{CR1}) / (l_{20} + l_{30}) \quad \text{N}$$

$$B_2 = C_R + B_3 \quad \text{N}$$



Appendix 3 DIRECT FORCE CALCULATION FOR ANCHORING EQUIPMENT

1.1 As an alternative to the prescriptive approach described in 3.2.1.2 of this Chapter direct force calculation may be performed to determine the necessary anchoring equipment for monohull ships with length less than 90m.

2.1 The total force (static + dynamic) F_{EN} , in kN, induced by wind and current acting on monohull in anchoring condition as defined in A1.1 may be calculated as follows:

where: F_{SLPH} ——Static force on wetted part of the hull due to current;

F_{SH} ——Static force on hull due to wind;

F_{ss} ——Static force on superstructures due to wind.

Static force on wetted part of the hull due to current F_{SLPH} , in kN, is defined according to the following formula:

where: ρ — Water density, equal to 1025kg/m³;

C_f ——Coefficient equal to:

$$C_f = (1+k) \frac{0.075}{(\log R_s - 2)^2}$$

where: R_e —Reynolds number equal to:

$$R_e = \frac{(V_e L_{WL})}{1.054 \cdot 10^{-6}}$$

k — Coefficient equal to:

$$k = 0.017 + 20 \frac{C_{bWL}}{L_{WL}^2 T^{-0.5} B_{WL}^{-1.5}}$$

C_{bWL} — block coefficient at waterline equal to:

$$C_{bWL} = \frac{\Delta}{1.025 L_{WL} B_{WL} T}$$

where: Δ — Moulded displacement at waterline, in m^3 ;

S_m — Total wetted surface of the part of the hull under draught, in m^2 .

The value of S_m is to be given by the Designer. When this value is not available, S_m may be taken equal to $6 \cdot \Delta^{2/3}$;

V_e — Speed of the current, in m/s.

2.1.2 Calculation of F_{SH}

Static force on hull due to wind F_{SH} , in kN, is defined according to the following formula:

$$F_{SH} = \frac{1}{2} \rho (C_{hfr} S_{hfr} + 0.02 S_{hlat}) V_w^2 10^{-3}$$

where: ρ — Air density, equal to 1.22 kg/m^3 ;

V_w — Speed of the wind, in m/s;

S_{hfr} — Front surface of hull and bulwark if any, in m^2 , projected on a vertical plane of the ship situated aft of the aft end of the ship and perpendicular to the longitudinal axis of the ship;

S_{hlat} — Partial lateral surface of one single side of the hull and bulwark if any, in m^2 , through the overall length of the ship, projected on a vertical plane parallel to the longitudinal axis of the ship and delimited according to Figure 2.1.2. In Figure 2.1.2, B is the breadth of the hull, in m.

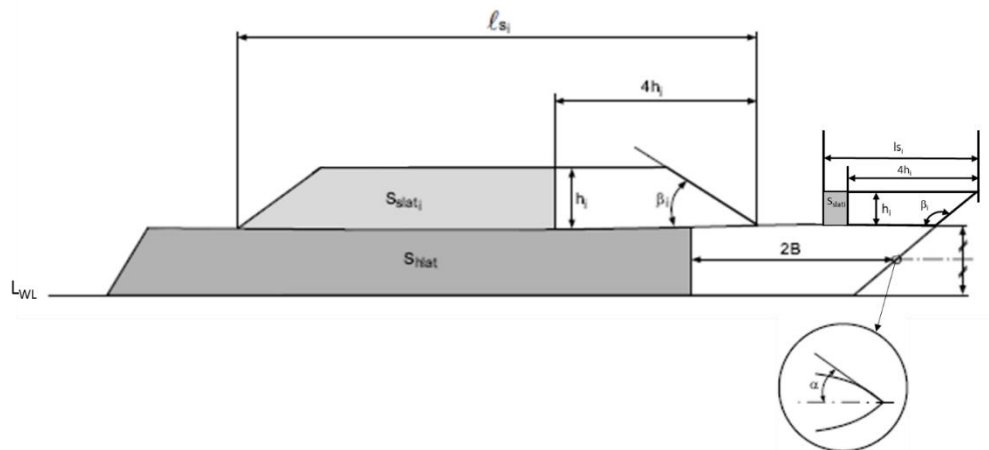


Figure 2.1.2

C_{hfr} — Coefficient equal to $0.8 \sin \alpha$, with α defined in Figure 2.1.2;

The upper part of the hull is the part extending from side to side to the uppermost continuous deck extending over the ship length.

2.1.3 Calculation of F_{SS}

(1) General case

Static force on superstructures and deckhouses due to wind F_{SS} , in kN, is defined according to the following formula:

$$F_{SS} = \frac{1}{2} \rho \sum (C_{sfr_i} S_{sfr_i} + 0.08 S_{slat_i}) V_W^2 10^{-3}$$

where: ρ — Air density, equal to 1.22 kg/m^3 ;

V_W — Speed of the wind, in m/s;

S_{sfr_i} — Front surface of tier i (superstructure or deckhouse, including bulwark if any), in m^2 , projected on a vertical plane of the ship situated aft of the aft end of the ship and perpendicular to the longitudinal axis of the ship;

S_{slat_i} — Partial lateral surface of one single side of tier i (superstructure or deckhouse, including bulwark if any), in m^2 , projected on a vertical plane parallel to the longitudinal axis of the ship and delimited according to Figure 2.1.2. When $4h_i \geq l_{si}$, S_{slat_i} is to be taken equal to 0;

C_{sfr_i} — Coefficient equal to $0.8 \sin \beta_i$, with β_i defined in Figure 2.1.2 without being greater than 90° ;

(2) Superstructures in the forward part of the ship

When superstructures are located in the front of the hull with front and side walls of superstructures in the continuity of the side shell, the static force induced by wind applied on these superstructures F_{SS} , in kN, is defined as the sum of the forces applied to each superstructure tier according to the following formula:

$$F_{SS} = \frac{1}{2} \rho \sum (C_{hfr_i} S_{hfr_i} + 0.08 S_{slat_i}) V_W^2 10^{-3}$$

where: S_{hfr_i} — Front surface of tier i of the superstructure, in m^2 , projected on a vertical plane of the ship situated aft of the aft end of the ship and perpendicular to the longitudinal axis of the ship

C_{hfr_i} — Coefficient equal to $0.8 \sin \alpha_s$, with α_s defined in Figure 2.1.2 and measured at mid height of the superstructure tier located in the front of the hull.

The static force is to be added to the static force calculated for the other superstructures and deckhouses according to 2.1.3(1) of this Appendix.

3 Anchor weight

3.1 The individual mass of anchor, in kg, is to be at least equal to:

for ordinary anchor: $P = (F_{EN} / 7) \cdot 10^2$

for high holding power anchor: $P = (F_{EN} / 10) \cdot 10^2$

for very high holding power: $P = (F_{EN} / 15) \cdot 10^2$

4 Chain cable

4.1 Stud link chain cable scantling

Chain cable diameters are to be based on the minimum breaking load BL and proof load PL of steel grades.

	<u>CCS</u> <u>Grade 1</u>	<u>CCS</u> <u>Grade 2</u>	<u>CCS</u> <u>Grade 3</u>
<u>BL</u>	<u>$6F_{EN}$</u>	<u>$6.8F_{EN}$</u>	<u>$7.5F_{EN}$</u>
<u>PL</u>	<u>$0.7BL$</u>		

The chain cable scantling is to be consistent with the mass of the associated anchor. In case the anchor on board is heavier by more than 7% from the mass calculated in 3.1 of this Appendix, the value of F_{EN} to take into account for the calculation of BL and PL is to be deduced from the actual mass of the anchor according to the formulae in 3.1 of this Appendix.

4.2 Length of individual chain cable

The length of chain cable L_{ee} , in m, linked to each anchor is to be at least equal to:

when $P < 180$, $L_{ee} = 30 \ln(P) - 42$

when $P \geq 180$, L_{ee} to be selected according to Table 3.2.1.1(2) of this Chapter.

where: P: Anchor weight, in kg, defined in 3.1 of this Appendix for an ordinary anchor according to the considered case.

CHAPTER 8 BULK CARRIERS

Section 1 GENERAL PROVISIONS

8.1.1 Application

8.1.1.1 Bulk carriers are ships [provided with single deck, double bottom, topside tank and hopper tank, and](#) intended primarily to carry dry cargo in bulk, not including ore carriers.

8.1.3 Direct strength calculation and fatigue strength assessment for hull structure

8.1.3.1 For bulk carriers of 150 m or over in length, direct calculation is to be carried out for the strength of primary structural members (both longitudinal and transverse) within cargo area in accordance with the requirements of Appendix 1 of this Chapter.

8.1.3.2 For bulk carriers of 150 m or over in length, the fatigue strength check is to be carried out for the following structural members in the cargo area in accordance with CCS Guidelines for Fatigue Strength of Ship Structure:

- (1) connections of longitudinals (bottom, side, deck and inner shell) to transverse web frames;
- (2) connections of longitudinals (bottom, side, deck and inner shell) to transverse bulkheads;
- (3) connections of hopper tanks or inner shell to inner bottoms;
- (4) connections of inner bottoms to lower stool [sloping side](#) plates;
- (5) connections of corrugated transverse bulkheads to lower stool top plates;
- (6) connections of corrugated transverse bulkheads to upper stool sloping plates;
- (7) connections of frames to top side tanks and hopper tanks of single hull bulk carriers.

Section 8 is amended as follows:

Section 8 EVALUATION OF SCANTLINGS OF HATCH COVERS OF CARGO HOLDS

[8.8.1 General requirements](#)

[8.8.1.1 This Section applies to bulk carriers, ore carriers and combination carriers. If hatch covers of cargo holds are to comply with the relevant requirements of Section 20, Chapter 2 of this PART.](#)

Section 9 DOUBLE SIDE STRUCTURES

8.9.1 General requirements

8.9.1.1 This Section applies to the double side skin construction within the cargo area of bulk carriers.

8.9.1.2 Manholes are to be provided in transverse webs and horizontal girders. The manholes may either be round or elliptical. The long axis of an elliptical manhole is to be vertical to or along the length of the ship. Except access openings, the holes in upper and lower adjacent horizontal

girders are not to be on the same vertical line. The manhole edges are to be strengthened.

8.9.2 Structural arrangements of double side skin

8.9.2.1 ~~Where Double~~ double side skin is ~~to be~~ provided ~~throughout in~~ the cargo area, ~~and~~ the inner shell is to extend as far forward and aft as practicable at the fore and aft ends of the cargo hold and is to be effectively connected and tapered to the structures there. Supporting members within the inner shell are to be provided in double side skin instead of one side of the cargo hold.

CHAPTER 9 ROLL ON-ROLL OFF SHIPS, PASSENGER SHIPS, RO-RO PASSENGER SHIPS AND FERRIES

Section 1 GENERAL PROVISIONS

9.1.1 Application

9.1.1.1 This Chapter applies to roll on-roll off ships, passenger ships, ro-ro passenger ships and ferries defined as follows:

- (1) A roll on-roll off ship is a ship specially designed and constructed for the carriage of vehicles, and cargo in pallet form or in containers, and loaded/unloaded by wheeled vehicles;
- (2) A passenger ship is a ship which carries more than twelve passengers;
- (3) Ro-ro passenger ship means a passenger ship with ro-ro cargo spaces or special category spaces;
- (4) Ferries are the ships specially designed for the carriage of passengers (without sleeping berths) and/or vehicles engaged on regular voyages between two sides of straits or islands. [Ferries carrying more than 12 passengers are ferry passenger ships.](#)

Section 2 HULL STRUCTURE

9.2.1 General requirements

9.2.1.1 The structural arrangements of hull are to comply with the relevant requirements of Section ~~428~~, Chapter 1 of this PART.

A new Section 8 is added as follows:

Section 8 EXTERNAL GLASS BALUSTRADES

9.8.1 General

9.8.1.1 The requirements of this Section apply solely to external glass balustrades. External glass balustrades are barriers constructed with glass that are used on exposed decks.

9.8.1.2 Glass balustrades, in lieu of bulwark or guard rails (see Section 19, Chapter 2 of this PART), may be accepted on exposed decks above position 2 specified in 1.1.2.22, Section 1, Chapter 1 of this PART, except on mooring deck and in way of lifeboats and life rafts and embarkation stations.

9.8.1.3 Glass is to be manufactured in accordance with a recognised National or International Standard.

9.8.1.4 The detailed arrangement, applicable loads and structural strength calculations are to be submitted to CCS.

9.8.2 Arrangement requirements

9.8.2.1 External glass balustrades are to be not less than 1 m in height.

9.8.2.2 In general, openings (e.g. the gaps between panels or the gap between the deck and the bottom of a panel) are not to be greater than 76 mm unless required for water freeing.

9.8.2.3 If a well is formed, the necessary drainage port is to be provided. Openings for water freeing are not to be greater than 230 mm.

9.8.3 Design pressure

9.8.3.1 For the lowest weather deck, the minimum design pressure P_w of glass balustrades is to be calculated as follows:

$$P_w = 9.81h, \text{ kN/m}^2$$

where: h —head in 2.17.2, Section 17, Chapter 2 of this PART.

9.8.3.2 For higher exposed decks, the minimum design pressure P_w of glass balustrades is to be calculated as follows:

(1) Below 1.7C m above the scantling draught, $P_w = 5 \text{ kN/m}^2$, where C is the coefficient as specified in 2.2.3.1, Section 2, Chapter 2 of this PART;

(2) For other locations, $P_w = 2.5 \text{ kN/m}^2$.

9.8.4 Minimum scantling requirements

9.8.4.1 External glass balustrades using monolithic glass are to comply with the following requirements:

(1) Minimum thickness of glass is not to be less than 6.0 mm;

(2) Top rail is required, with a minimum section modulus of 17 cm^3 ;

(3) Stanchions is to be fitted, not more than 1.5 m apart, with minimum section modulus of 20 cm^3 .

9.8.4.2 External glass balustrades using laminated glass are to comply with the following requirements:

(1) Minimum thickness for each glass pane is not to be less than 4 mm;

(2) Top rail is required, with a minimum section modulus of 17 cm^3 ;

(3) Stanchions is to be fitted, not more than 1.5 m apart, with minimum section modulus of 20 cm^3 .

9.8.4.3 The section modulus requirements in 9.8.4.1 and 9.8.4.2 above are based on steel. For other metallic materials, equivalent section modulus is to be calculated.

9.8.4.4 The glass panes are to be supported at minimum two opposite sides by metallic mounting frames. The glass panes can be fixed to the metal frame by mechanical means or adhesive. If the metal mounting frames are connected to the stanchion by bolts, there is to be no less than two force bolts on one side.

9.8.4.5 The overlap between the glass panes and metallic frames is not to be less than 10 mm or $b/75$ mm, whichever is greater, but not more than 20 mm, b is the breadth of the glass pane, in mm.

9.8.4.6 In public areas, laminated glass panes are required for external glass balustrades.

9.8.5 Glass thickness

9.8.5.1 For monolithic toughened glass, the thickness is to be less than the value obtained from the following formula:

$$t = b\sqrt{\beta P} / 200 \text{ mm}$$

where: b —length of the shorter side of the glass, in mm;

P —load for calculation, $P = 0.5P_w$, in kN/m²;

P_w —design pressure, in kN/m², see 9.8.3 of this Section;

β —coefficient, to be taken as follows:

1) glass with firm support on all sides:

$$\beta = 0.54A_R - 0.078A_R^2 - 0.17 \text{ for } A_R \leq 3.6$$

$$\beta = 0.7645 \text{ for } A_R > 3.6$$

2) glass with firm support on two sides only:

$$\beta = 0.7645$$

where: A_R —aspect ratio of rectangle window, to be taken as follows

$$A_R = a / b$$

a —length of the longer side of the glass, in mm;

b —length of the shorter side of the glass, in mm.

9.8.5.2 For laminated toughened glass, the equivalent thickness is to be less than the value obtained from 9.8.5.1. The equivalent thickness is calculated according to the following formula:

$$t_e = \sqrt{\sum_{i=1}^n t_i^2} \text{ mm}$$

where: n —number of glass layers;

t_i —thickness of the i^{th} layer glass.

9.8.6 Balustrade stanchions

9.8.6.1 For balustrade stanchions below 1.7C m above the scantling draught, the section modulus W at the bottom is not to be less than:

$$W = 655 \frac{P S l^2}{R_{eH}} \text{ cm}^3$$

where: S —distance between stanchions, in m;

l —height of the stanchion, in m;

P —load for calculation, $P = P_w$, in kN/m²;

P_w —design pressure, in kN/m², see 9.8.3 of this Section;

R_{eH} —yield stress of material, in N/mm².

9.8.6.2 For balustrade stanchions below 1.7C m above the scantling draught, the shear area A at the bottom is not to be less than:

$$A = 22.7 \frac{P S l}{R_{eH}} \text{ cm}^2$$

where: S —distance between stanchions, in m;

l — height of the stanchion, in m;
 P — load for calculation, $P = P_w$, in kN/m²;
 R_{eH} — yield stress of material, in N/mm².

CHAPTER 12 BARGES

Section 1 GENERAL PROVISIONS

12.1.1 Application

12.1.1.1 The barges defined in this Chapter are non-self-propelled ships pushed or towed by other ships and divided into the following types:

- (1) Barges carrying general dry cargo in cargo holds;
- (2) Barges carrying cargo oil in cargo tanks;
- (3) Shipborne barges carrying general dry cargo in cargo holds and carried on board a barge carrier;
- (4) Specially designed pontoons for the carriage of cargo on deck;
- (5) Barges dedicated to transporting marine engineering jacket structure and landing jacket into water by the stern for launching of jacket;

[\(6\) Barges carrying chemicals in cargo tanks;](#)

[\(7\) Barges carrying liquefied gas in cargo tanks.](#)

12.1.1.2 Where not covered by this Chapter, barges carrying cargo oil in bulk in cargo tanks are to comply with the relevant requirements of Chapter 5 or 6 of this PART according to its structural configuration; [barges carrying chemicals in cargo tanks are to comply with the relevant requirements of Chapter A4, PART TWO of CCS Rules for Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk;](#) [barges carrying liquefied gas in cargo tanks are to comply with the relevant requirements of Appendices 1 and 2, PART TWO of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gas in Bulk](#) and other barges are to comply with the relevant requirements of Chapter 2 of this PART.

12.1.1.3 For pontoons regarded as one of offshore floating facilities, the structure may be in accordance with the requirements of this Chapter for pontoon barges.



CHINA CLASSIFICATION SOCIETY

RULES FOR CONSTRUCTION OF SEA-GOING SHIPS ENGAGED ON DOMESTIC VOYAGES

AMENDMENTS

2024

PART THREE MACHINERY INSTALLATIONS

CONTENTS

CHAPTER 2	PUMPING AND PIPING SYSTEMS	3-1
Section 6	PUMPS, VALVES AND FITTINGS	3-1
Section 8	ARRANGEMENT	3-1
CHAPTER 5	PIPING SYSTEM FOR OIL TANKERS	3-2
Section 1	GENERAL PROVISIONS	3-2
CHAPTER 12	SHAFT VIBRATION AND ALIGNMENT	3-3
Section 2	TORSIONAL VIBRATION	3-3
Section 3	AXIAL VIBRATION	3-3

CHAPTER 2 PUMPING AND PIPING SYSTEMS

Section 6 PUMPS, VALVES AND FITTINGS

2.6.2 Valves and fittings

2.6.2.5 Indicators are to be provided to show the open and closing condition of the valves, unless this can be observed in some other way; for remotely controlled valves, the remote control position is also to show the open and closing condition of the valve.

Section 8 ARRANGEMENT

2.8.1 Piping arrangement

2.8.1.3 The pipe piercing the collision bulkhead below the freeboard deck (bulkhead deck for passenger ships) is to be fitted with a screw-down remotely controlled valve, ~~unless the use of other valves are agreed by the Administration,~~ capable of being operated from above the freeboard deck (bulkhead deck for passenger ships), ~~and the valve chest is to be secured at the bulkhead inside the forepeak and means being provided for indicating whether the valve is open or shut.~~ The valve is to be normally closed. If the remote control system should fail during operation of the valve, the valve is to close automatically or be capable of being closed manually from a position above the freeboard deck (bulkhead deck for passenger ships).

~~For cargo ships, the above pipes may be provided with butterfly valves capable of being operated from above freeboard decks, supported as appropriate by valve seats or flanges.~~

The above-mentioned valves may be fitted on the forward or after side of the collision bulkhead provided that ~~the valves are readily accessible under all service conditions and~~ the space in which they are located is not a cargo space, ~~and it is not necessary to fit an operating device above the freeboard deck.~~

All valves are to be of steel, bronze or other approved ductile material. Valves of ordinary cast iron or similar material are not acceptable.

CHAPTER 5 PIPING SYSTEM FOR OIL TANKERS

Section 1 GENERAL PROVISIONS

5.1.7 Earthing of cargo oil pipes

5.1.7.1 Earthing and bonding of cargo tanks and piping systems for the control of static electricity is to comply with the requirements in 1.3.4.1[12](#) of PART FOUR of the Rules.

CHAPTER 12 SHAFT VIBRATION AND ALIGNMENT

Section 2 TORSIONAL VIBRATION

12.2.4 Additional requirements for generators

12.2.4.1 In the case of alternating current generators, the resultant vibration amplitudes at the rotor are not to exceed 3.5° electrical degrees under rated load working conditions. [Where the inverter provided with rectification can ensure the output of stable power supply to the grid for normal use, the electrical degree is not limited to \$3.5^{\circ}\$.](#)

Section 3 AXIAL VIBRATION

12.3.1 General requirements

12.3.1.2 Documents of axial vibration characteristics of the [large-sized](#) slow-speed two-stroke diesel engine [direct](#) propulsion shafting systems and of the turbine propulsion shafting systems are to be submitted for approval.



CHINA CLASSIFICATION SOCIETY

**RULES FOR CONSTRUCTION OF
SEA-GOING SHIPS ENGAGED ON
DOMESTIC VOYAGES**

AMENDMENTS

2024

**PART FOUR ELECTRICAL
INSTALLATIONS**

CONTENTS

CHAPTER 2 ELECTRICAL INSTALLATIONS IN SHIPS	4-1
Section 17 ADDITIONAL REQUIREMENTS FOR SHIPS CARRYING VEHICLES WITH FUEL IN THEIR TANKS FOR THEIR OWN PROPULSION	4-1
Section 18 ADDITIONAL REQUIREMENTS FOR SHIPS CARRYING DANGEROUS GOODS	4-1

CHAPTER 2 ELECTRICAL INSTALLATIONS IN SHIPS

Section 17 ADDITIONAL REQUIREMENTS FOR SHIPS CARRYING VEHICLES WITH FUEL IN THEIR TANKS FOR THEIR OWN PROPULSION

2.17.2 Carriage of vehicles in special category spaces above the bulkhead deck of passenger ships and in closed ro-ro spaces and closed vehicle spaces (with not less than 10 air changes per hour) of passenger ships and cargo ships

2.17.3 Carriage of vehicles in special category spaces below the bulkhead deck of passenger ships and in closed ro-ro spaces and closed vehicle spaces (with less than 10 air changes per hour) of passenger ships and cargo ships

2.17.4 Carriage of vehicles in cargo spaces of passenger ships and cargo ships in cargo spaces other than vehicle, special category or ro-ro spaces

~~2.17.4.1 Where vehicles are carried in cargo spaces of passenger ships, the electrical equipment fitted within such spaces and their exhaust ventilation trunking are to be of certified safe type. On all ships, when vehicles with fuel in their tanks for their own propulsion are carried in cargo spaces other than vehicle, special category or ro-ro spaces, the requirements of SOLAS regulation II-2/20.2.1.2 are to be complied with.~~

~~2.17.4.2 Where vehicles are carried in cargo spaces of cargo ships, the electrical equipment fitted within such spaces and their exhaust ventilation trunking are to be of certified safe type. For spaces with not less than 10 air changes per hour and other than those within a height of 450 mm above the vehicle deck or vehicle platform, where electrical equipment other than that of certified safe type is fitted, the enclosure of which is to be of at least IP55 type.~~

2.17.5.1 For the electrical equipment fitted in the area, the degrees of protection by enclosures are to comply with the relevant requirements of Table 1.3.2.2 of this PART.

Section 18 ADDITIONAL REQUIREMENTS FOR SHIPS CARRYING DANGEROUS GOODS

2.18.3.4 Where ammonium nitrate (UN1942) and ammonium nitrate fertilizer (UN2067) of class 5.1, ammonium nitrate fertilizer (UN2071) of class 9, ammonium nitrate-based fertilizer and ammonium nitrate-based fertilizer MHB (non-hazardous) are to be carried, all electrical equipment, other than that of intrinsically certified safe type, in hazardous areas are to be electrically disconnected from the power source in accordance with the requirements of 2.18.8.1.

2.18.5.1 Where solid dangerous goods in bulk (solid dangerous goods capable of creating explosive gas atmosphere) and MHB are to be carried, electrical equipment of certified safe type installed in hazardous areas are to be in compliance with the minimum requirements of Table 2.18.5.1.

Characteristics of Electrical Equipment for Use in Hazardous Areas (Example)

Table 2.18.5.1

Dangerous goods	IMO class	Dominant risk ^①	Protection against explosive dust atmosphere	Protection against explosive gas atmosphere	
			Degree of protection	Explosion group	Temperature class
Aluminium ferrosilicon powder UN1395	4.3	H ₂	—	IIC	T2
Aluminium silicon powder uncoated UN1398	4.3	H ₂	—	IIC	T2

Dangerous goods	IMO class	Dominant risk ^①	Protection against explosive dust atmosphere	Protection against explosive gas atmosphere	
			Degree of protection	Explosion group	Temperature class
Aluminium smelting by-products or Aluminium remelting by-products UN3170	4.3	H2	—	IIC	T2
Aluminium smelting/remelting by-products, processed	MHB(WF and/or WT and/or CR)	H2	—	IIC	T1
Ammonium nitrate UN1942	5.1	Combustible	—	Intrinsically safe equipment	T4
Ammonium nitrate based fertilizer UN2067	5.1	Combustible	—	Intrinsically safe equipment	T4
Ammonium nitrate based fertilizer UN2071	9	=	—	Intrinsically safe equipment	T4
Ammonium nitrate based fertilizer (non-hazardous)	-	=	—	Intrinsically safe equipment	T4
Ammonium nitrate-based fertilizer MHB	MHB(OH)	=	=		T4
Brown coal briquettes	MHB (CB and/or SH)	Dust, methane	IP55	IIA	T4
Coal	MHB (CB and/or SH and/or WF and/or CR)	Dust, methane	IP55	IIA	T4
Direct reduced iron (A)	MHB (SH and/or WF)	H ₂	—	IIC	T2
Direct reduced iron (B)	MHB (SH and/or WF)	H ₂	—	IIC	T2
Direct reduced iron (C)	MHB (SH and/or WF)	H ₂	—	IIC	T2
Ferrophosphorus (including briquettes)	MHB (WF and/or WT)	H ₂	—	IIC	T1
Ferrosilicon, with at least 25% but less than 30% silicon, or 90% or more silicon (including briquettes)	MHB (WF and/or WT)	H ₂	—	IIC	T1
Ferrosilicon UN1408, with 30% or more but less than 90% silicon (including briquettes)	4.3	H ₂	—	IIC	T1
Iron oxide, spent or sponge iron, spent UN1376	4.2	Dust	IP55	IIA	T2
Seed cake, containing vegetable oil UN1386	4.2	Hexane	—	IIA	T3
Seed cake UN2217	4.2	Hexane	—	IIA	T3
Seed cakes and other residues of processed oily vegetables	MHB (SH)	Dust	IP55	IIA	T3
Silicomanganese (low-carbon)	MHB(WF and/or WT and/or TX)	H ₂	—	IIC	T1
Solidified fuels recycled from paper and plastics	MHB (SH)	Combustible	IP55	—	T3
Sugarcane biomass pellets	MHB(CB and/or WF and/or WT and/or OH)	Combustible, dust	IP55	IIA	T3

Dangerous goods	IMO class	Dominant risk ^①	Protection against explosive dust atmosphere	Protection against explosive gas atmosphere	
			Degree of protection	Explosion group	Temperature class
Sulphur UN1350 (crushed lump and coarse grained)	4.1	Combustible, dust	IP55	—	T4
Zinc Ashes UN1435	4.3	H ₂	—	IIC	T2
Wood torrefied	MHB(CB and/or SH and/or CR)	Combustible, dust	IP55	—	T3
Wood pellets, containing additives and/or binders	MHB(WF)	Dust	IP55	—	T3
Wood pellets, not containing any additives and/or binders	MHB(OH)	Dust	IP55	—	T3

Note: ① The term “risk” relates only to the risk of explosion due to dangerous goods and electrical appliances.