# Contents

# Part 2 SHIP TYPES

# Chapter 1 BULK CARRIERS

## Section 1 GENERAL ARRANGEMENT DESIGN

### 1. Forecastle

#### 1.1 General

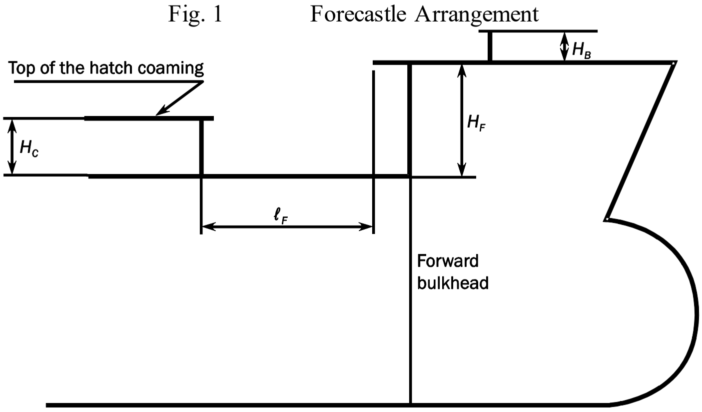
1.1.1

An enclosed forecastle is to be fitted on the freeboard deck.

The aft bulkhead of the enclosed forecastle is to be fitted in way or aft of the forward bulkhead of the foremost hold, as shown in **Fig. 1**.

However, if this requirement hinders hatch cover operation, the aft bulkhead of forecastle may be fitted forward of the forward bulkhead of the foremost cargo hold provided the forecastle length is not less than 7% of ship length for freeboard as specified in **Pt 1**, **Ch 1**, **Sec 4**, **3.1.2** abaft the fore side of stem.

Fig. 1 Forecastle Arrangement




1.1.2

The forecastle height, $H_F$ above the main deck is not to be less than the greater of the following values:

- The standard height of a superstructure as specified in **Pt 1**, **Ch 1**, **Sec 4**, **3.3**.
- $H_C + 0.5\ m$, where $H_C$ is the height of the forward transverse hatch coaming of the foremost cargo hold, i.e. cargo hold No. 1.

1.1.3

All points of the aft edge of the forecastle deck are to be located at a distance less than or equal to $\ell_F$, taken as:

$$\ell_F = 5\sqrt{H_F - H_C}$$

from the hatch coaming plate.

1.1.4

A breakwater is not to be fitted on the forecastle deck with the purpose of protecting the hatch coaming or hatch covers. If fitted for other purposes, it is to be located such that its upper edge at centreline is not less than $H_B / tan\ 20°$ forward of the aft edge of the forecastle deck, where $H_B$ is the height of the breakwater above the forecastle, see **Fig.1**.

## 2. Access Arrangements

### 2.1 Special arrangements for bulk carriers

2.1.1

Where a duct keel or pipe tunnel is fitted, provision is to be made for at least two exits to the open deck arranged at a maximum distance from each other.

The aft access may lead from the engine room to the duct keel. Where an aft access is provided from the engine room to the duct keel, the access opening to the duct keel is to be provided with watertight hatch cover, cover plate or door.

Ventilation may be aided by the use of mechanical means as required.

2.1.2

Where a watertight door is fitted for access to the duct keel, the scantlings of the watertight door are to comply with the requirements of the individual Society.

# Section 2 STRUCTURAL DESIGN PRINCIPLES

**Symbols**

For symbols not defined in this section, refer to **Pt 1**, **Ch 1**, **Sec 4**.

## 1. Application

### 1.1

1.1.1

This section applies to structures in all parts of bulk carriers, in addition to requirements given in **Pt 1**, **Ch 3**, **Sec 6**.

## 2. Corrosion Protection

### 2.1 General

2.1.1 Void double side skin spaces

Void double side skin spaces are to have a corrosion protective system fitted in accordance with **2.2**.

2.1.2 Cargo holds and ballast holds

Cargo holds and ballast holds are to have a corrosion protective system fitted in accordance with **2.3**.

### 2.2 Protection of Void Double Side Skin Spaces

2.2.1

Void double side skin spaces in the cargo area for ships having a freeboard length $L_{LL}$ of not less than 150 *m* are to have an efficient corrosion prevention system, such as hard protective coatings or equivalent.

### 2.3 Protection of Cargo Hold Spaces

2.3.1 Coating

It is the responsibility of the builder and of the owner to choose coatings suitable for the intended cargoes, in particular for the compatibility with the cargo.

2.3.2 Application

All internal and external surfaces of hatch coamings and hatch covers, and all internal surfaces of cargo holds (side and transverse bulkheads), excluding the inner bottom area and part of the hopper tank sloping plate and lower stool sloping plate, are to have an efficient protective coating, of an epoxy type or equivalent, applied in accordance with the manufacturer's recommendation.

The side and transverse bulkhead areas to be coated are specified in **2.3.3** and **2.3.4** respectively.

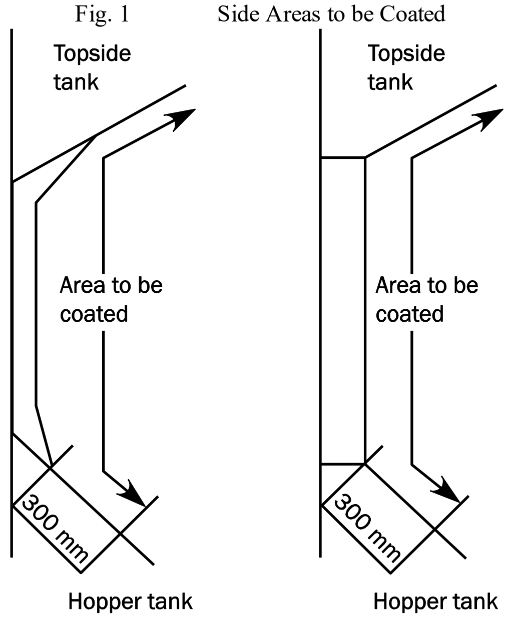
2.3.3 Side areas to be coated

The areas to be coated are the internal surfaces of:

- The inner side plating.
- The internal surfaces of the topside tank sloping plates.
- The internal surfaces of the hopper tank sloping plates for a distance of 300 *mm* below the frame end bracket for holds of single side skin construction, or below the hopper tank upper end for holds of double side skin construction.

These areas are shown in **Fig. 1**

Fig. 1 Side Areas to be Coated




2.3.4 Transverse bulkhead areas to be coated

The areas of transverse bulkheads to be coated are all the areas located above an horizontal level located at a distance of 300 *mm* below the frame end bracket for holds of single side skin construction or below the hopper tank upper end for holds of double side skin construction.

## 3. Structural Detail Principles

### 3.1 Double Bottom Structure

3.1.1 Application

In addition to the requirements provided in **Pt 1**, **Ch 2**, **Sec 3**, **2**, the requirements of this sub-article are applicable to the following ships:

- All bulk carriers with freeboard length $L_{LL}$ less than 150 *m*,
- Bulk carriers having a freeboard length $L_{LL}$ of 150 *m* or above, with one or more cargo holds arranged for carriage of water ballast.

3.1.2 Double bottom height

Height of double bottom in cargo area, $d_{DB}$, in *m*, measured from keel line at mid-length of each cargo hold is not to be less than:

$$d_{DB} = 0.032B + 0.19\sqrt{T_{SC}}$$

A lower double bottom height may be accepted, provided all of the following requirements are satisfied:

- The spacing of adjacent girders is not to be greater than 4.6 *m* or 5 times the spacing of bottom or inner bottom stiffeners, whichever is the smaller.
- The spacing of floors is not to be greater than 3.5 *m* or 4 times the side frame spacing, whichever is the smaller. Where side frames are not transverse, the nominal frame spacing as specified by the designer is to be used.

3.1.3 Girder spacing

The spacing of adjacent girders is generally not to be greater than 4.6 *m* or 5 times the spacing of bottom or inner bottom stiffeners, whichever is the smaller.

3.1.4 Floor spacing

The spacing of floors is generally not to be greater than 3.5 *m* or 4 times the side frame spacing, whichever is the smaller. Where side frames are not transverse, the nominal frame spacing as specified by the designer is to be used.

### 3.2 Single Side Structure

3.2.1 Application

This article applies to the single side structure with transverse framing of single side bulk carrier.

If single side structure is supported by transverse or longitudinal primary supporting members, the requirements in **Pt 1**, **Ch 3**, **Sec 6**, **8** apply to these primary supporting members as regarded to ones in double side skin.

3.2.2 General arrangement

Side frames are to be arranged at every frame space.

If air pipes are passing through the cargo hold, they are to be protected by appropriate measures to avoid a mechanical damage.

3.2.3 Side frames

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

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

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

where:

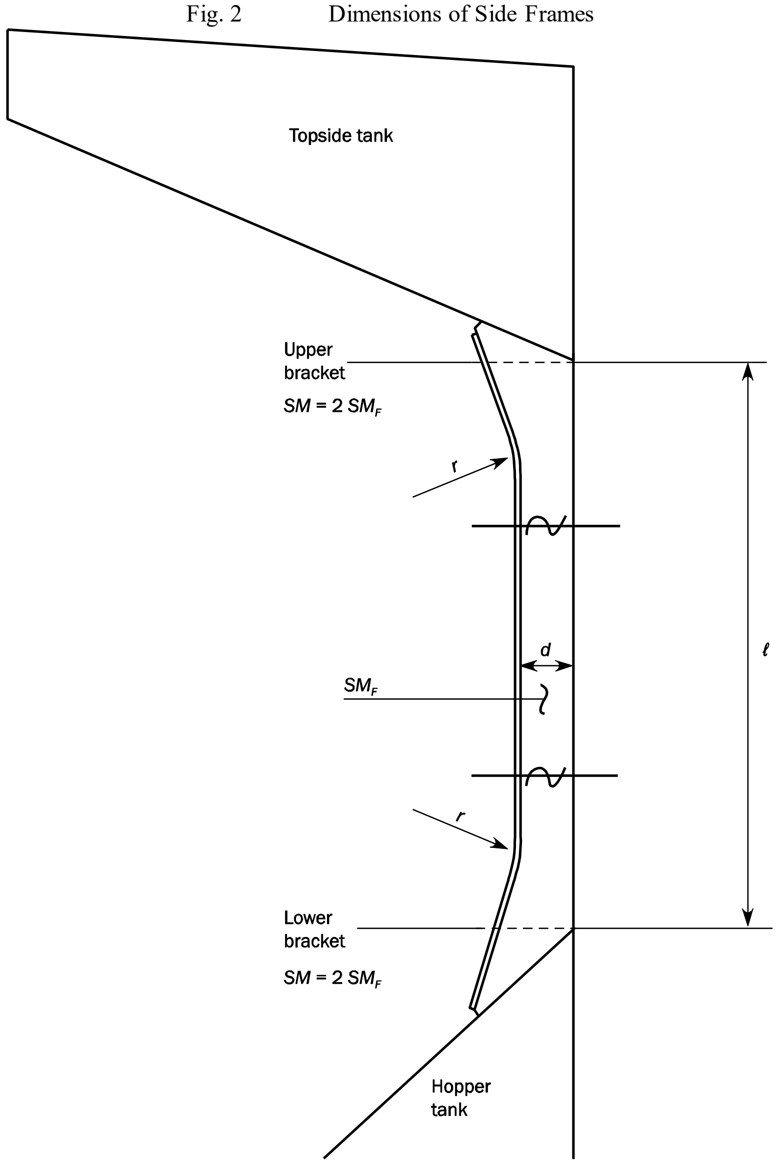
$t_c$ : Corrosion addition, in mm, specified in **Pt 1**, **Ch 3**, **Sec 3**.

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

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

The dimensions of side frames are defined in **Fig. 2**.

Fig. 2 Dimensions of Side Frames

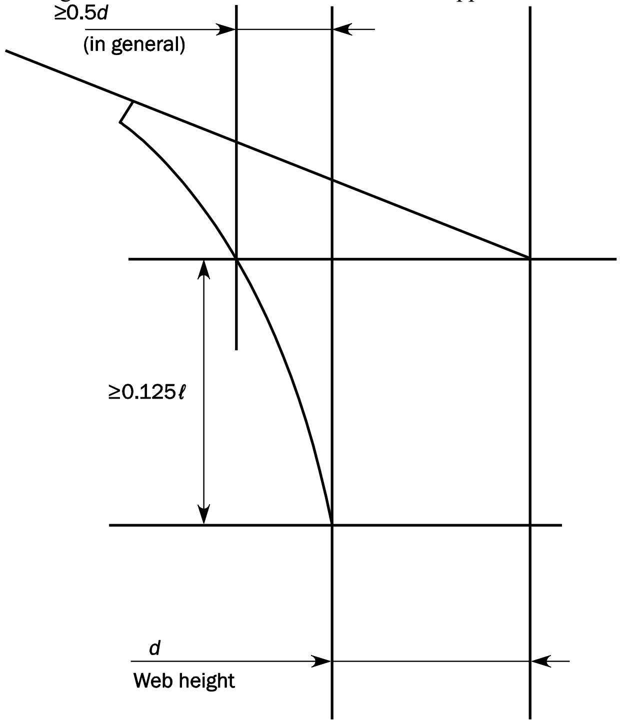


3.2.4 Upper and lower brackets

The face plates or flange of the brackets is to be sniped at both ends. Brackets are to be arranged with soft toes. The as-built thickness of the brackets is not to be less than the as-built thickness of the side frame webs to which they are connected.

The dimensions (in particular the height and length) of the lower brackets and upper brackets are not to be less than those shown in **Fig. 3**.

Fig. 3 Dimensions of Lower and Upper Brackets



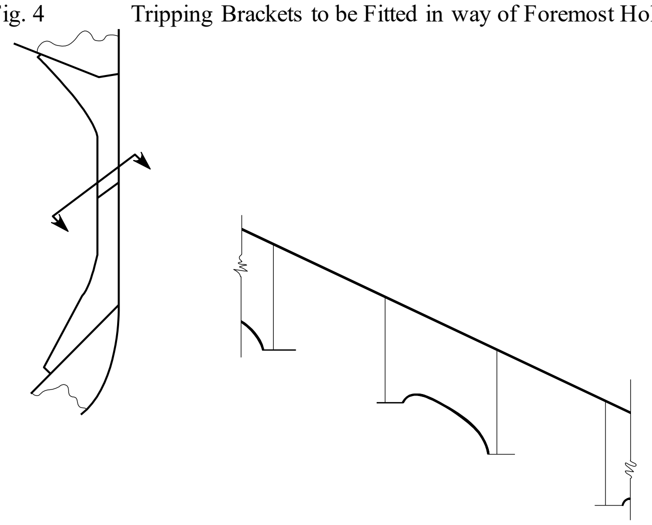

3.2.5 Tripping brackets

In way of the foremost hold and in the holds of *BC-A* ships, side frames of asymmetrical section are to be fitted with tripping brackets at every two frames, as shown in **Fig. 4**.

The as-built thickness of the tripping brackets is not to be less than the as-built thickness of the side frame webs to which they are connected.

Double continuous welding is to be adopted for the connections of tripping brackets with side shell frames and plating.

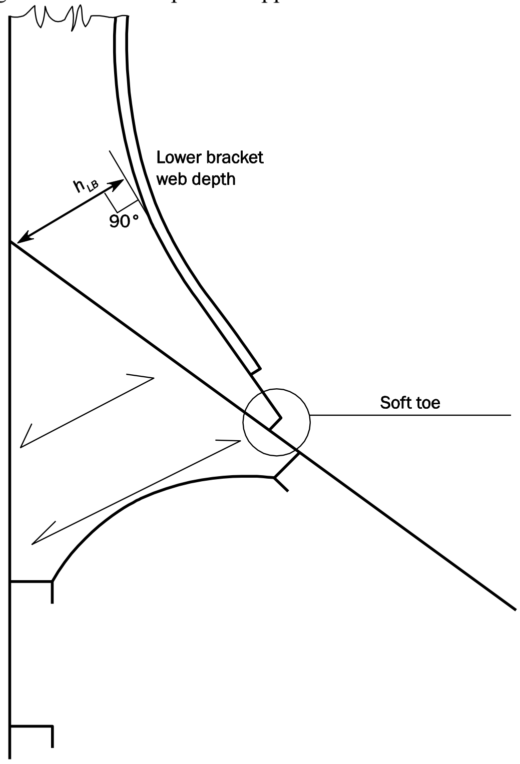
Fig. 4 Tripping Brackets to be Fitted in way of Foremost Hold



3.2.6 Support structure

Structural continuity with the lower and upper end connections of side frames is to be ensured within hopper and topside tanks by connecting brackets as shown in **Fig. 5**.

Fig. 5 Example of Support Structure for Lower End




### 3.3 Deck Structures

3.3.1 Web frame spacing in topside tanks

For bulk carriers with freeboard length $L_{LL}$ less than 150 *m*, the spacing of web frames in topside tanks is generally not to be greater than 6 frame spaces.

3.3.2 Cross deck between hatches of bulk carriers

Inside the line of openings, where a transversely framed structure is adopted for the cross deck structures, hatch end beams and cross deck beams are to be adequately supported by girders and extended outward to the second longitudinal from the hatch side girders towards the deck side. Where the extension of girders outward is impracticable, intercostal stiffeners are to be fitted between the hatch side girder and the second longitudinal and checks of the structure are to be performed in compliance with the requirements in **Pt 1**, **Ch 7** or by means deemed appropriate by the Society.

The transverse primary members supporting the cross deck are to be supported by side or topside tank primary supporting members.

Smooth connection of the strength deck at side with the transversely framed cross deck is to be ensured by a plate of intermediate thickness.

3.3.3 Topside tank structures

The topside tank sloping plates are to be longitudinally framed.

Topside tank structures, where fitted, are to extend as far as possible within the machinery space and are to be adequately tapered.

Where a double side primary supporting member is fitted outside the plane of the topside tank web frame, special attention is to be paid to structural continuity.

3.3.4 Openings in strength deck - Corner of hatchways

(a) Within the cargo hold region

For cargo hatchways located within the cargo hold region, insert plates, the thicknesses of which are to be determined according to the formula given after, are to be fitted in way of corners where the plating cut-out has a circular profile.

The radius of circular corners is not to be less than 5% of the hatch width, where a continuous longitudinal deck girder is fitted below the hatch coaming.

Corner radius, in the case of the arrangement of two or more hatchways athwartship, is considered by the Society on a case-by-case basis.

For hatchways located within the cargo hold region, insert plates are, in general, not required in way of corners where the plating cut-out has an elliptical or parabolic profile and the half axes of elliptical openings, or the half lengths of the parabolic arch, are not less than:

- 1/20 of the hatchway width or 600 $mm$, whichever is the lesser, in the transverse direction.
- Twice the transverse dimension, in the fore and aft direction.

Where insert plates are required, their net thickness is to be obtained, in $mm$, from the following formula:

$$t_{INS} = \left(0.8 + 0.4\frac{b}{\ell}\right) t_{off}$$

without being taken less than $t_{off}$ or greater than 1.6 $t_{off}$.

where:

$\ell$: Width, in $m$, in way of the corner considered, of the cross deck strip between two consecutive hatchways, measured in the longitudinal direction, see **Pt 1**, **Ch 3**, **Sec 6**, **Fig. 15**.

$b$: Width, in $m$, of the hatchway considered, measured in the transverse direction, see **Pt 1**, **Ch 3**, **Sec 6**, **Fig. 15**.

$t_{off}$: Offered net thickness, in $mm$, of the deck at the side of the hatchways.

For the extreme corners of end hatchways, insert plates are required. The net thickness of these insert plates is to be 60% greater than the net offered thickness of the adjacent deck plating. A lower thickness may be accepted by the Society on the basis of calculations showing that stresses at hatch corners are lower than permissible values.

Where insert plates are required, the arrangement is shown in **Pt 1**, **Ch 9**, **Sec 6**, **Table 15**, in which $d_1$, $d_2$, $d_3$ and $d_4$ are to be greater than the stiffener spacing.

For ships having a freeboard length $L_{LL}$ of 150 $m$ or above, the corner radius, the thickness and the extent of insert plate may be determined by the results of a direct strength assessment according to **Pt 1**, **Ch 7**, including buckling check and fatigue strength assessment of hatch corners according to **Pt 1**, **Ch 8** and **Pt 1**, **Ch 9** respectively. For such type of ships it is recommended to arrange circular hatch corners.

(b) Outside the cargo hold region

For hatchways located outside the cargo hold region, a reduction in the thickness of the insert plates in way of corners may be considered by the Society on a case-by-case basis.

3.3.5 Protection against wire rope

Wire rope grooving in way of cargo holds openings is to be prevented by fitting suitable protection such as half-round bar on the hatch side girders (i.e. upper portion of topside tank plates) and hatch end beams in cargo hold and upper portion of hatch coamings.

3.3.6 Protection of cargo hatch opening corners against mechanical damage

Specific measures are to be arranged to prevent the hatch opening corners from mechanical damage incurred by coming into direct contact with the vertical grab wire under normal operations.

# Section 3 HULL LOCAL SCANTLING

## Symbols

For symbols not defined in this section, refer to **Pt 1**, **Ch 1**, **Sec 4**.

$C_{XG}$, $C_{YS}$, $C_{YR}$, $C_{YG}$, $C_{ZP}$, $C_{ZR}$ : Load combination factors, as defined in **Pt 1**, **Ch 4**, **Sec 2**.

$d_{shr}$ : Effective shear depth of the stiffener as defined in **Pt 1**, **Ch 3**, **Sec 7**, **1.4.3**.

$F_R$ : Resultant force, in *kN*, as defined in **Pt 1**, **Ch 4**, **Sec 6**, **Table 7**.

$F_{sc\text{-}ib\text{-}s}$ : Static load, in *kN*, as defined in **Pt 1**, **Ch 4**, **Sec 6**, **4.3.1**.

$F_{sc\text{-}ib}$ : Total load, in *kN*, as defined in **Pt 1**, **Ch 4**, **Sec 6**, **4.2.1**.

$F_{sc\text{-}hs\text{-}s}$ : Static load, in *kN*, as defined in **Pt 1**, **Ch 4**, **Sec 6**, **4.3.2**.

$F_{sc\text{-}hs}$ : Total load, in *kN*, as defined in **Pt 1**, **Ch 4**, **Sec 6**, **4.2.2**.

$\ell$ : Distance, in *m*, as defined in **Pt 1**, **Ch 4**, **Sec 6**.

$\ell_{bdg}$ : Effective bending span, in *m*, as defined in **Pt 1**, **Ch 3, Sec 7, 1.1.2**.

$\ell_{lp}$ : Distance, in *m*, as defined in **Pt 1**, **Ch 4**, **Sec 6**.

$\ell_{SF}$ : Side frame span $\ell$, in *m*, as defined in **Ch 1**, **Sec 2**, **Fig. 2**, not to be taken less than 0.25 *D*.

$P$ : Design pressure in $kN/m^2$, for the design load set being considered according to **Pt 1**, **Ch 6**, **Sec 2**, **2** and calculated at the load calculation point defined in **Pt 1**, **Ch 3**, **Sec 7**, **3.2**.

$P_R$ : Resultant pressure, in $kN/m^2$, as defined in **Pt 1**, **Ch 4**, **Sec 6**, **Table 7**.

$s_{CW}$ : Plate width, in *mm*, taken as the width of the corrugation flange $b_{f-cg}$ or the web $b_{w-cg}$, whichever is greater, see **Pt 1**, **Ch 3**, **Sec 6**, **Fig. 21**.

$s_{cg}$ : Half pitch, in *mm*, of the corrugation flange as defined in **Pt 1**, **Ch 3**, **Sec 6**, **Fig. 21**.

## 1. Cargo Hold Side Frames of Single Side Bulk Carriers

### 1.1 Strength Criteria

1.1.1 Net section modulus and net shear sectional area

The net section modulus $Z$, in $cm^3$, and the net shear sectional area $A_{shr}$, in $cm^2$, in the mid-span area of side frames subjected to lateral pressure are not to be taken less than:

$$Z = 1.125\,\alpha_m \frac{P\,s\,\ell_{SF}^2}{f_{bdg}\,C_s\,R_{eH}}$$

$$A_{shr} = 5.0\,\alpha_S \frac{P\,s\,\ell_{SF}}{C_t\,\tau_{eH}} \left(\frac{\ell_{SF} - 2\ell_B}{\ell_{SF}}\right) 10^{-3}$$

where:

$\alpha_m$: Coefficient taken as:

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

$\alpha_m = 0.36$ for other ships.

$f_{bdg}$: Bending coefficient taken as 10.

$C_s$: Permissible bending stress coefficient for the design load set being considered taken as:

$Cs = 0.75$ for acceptance criteria set *AC-S*.

$Cs = 0.90$ for acceptance criteria set *AC-SD*.

$\alpha_S$: Coefficient taken as:

$\alpha_s = 1.1$ for side frames of empty holds in alternate condition of *BC-A* ships.

$\alpha_s = 1.0$ for other side frames.

$\ell_B$: Lower bracket length, in $m$, as defined in **Fig. 1**.

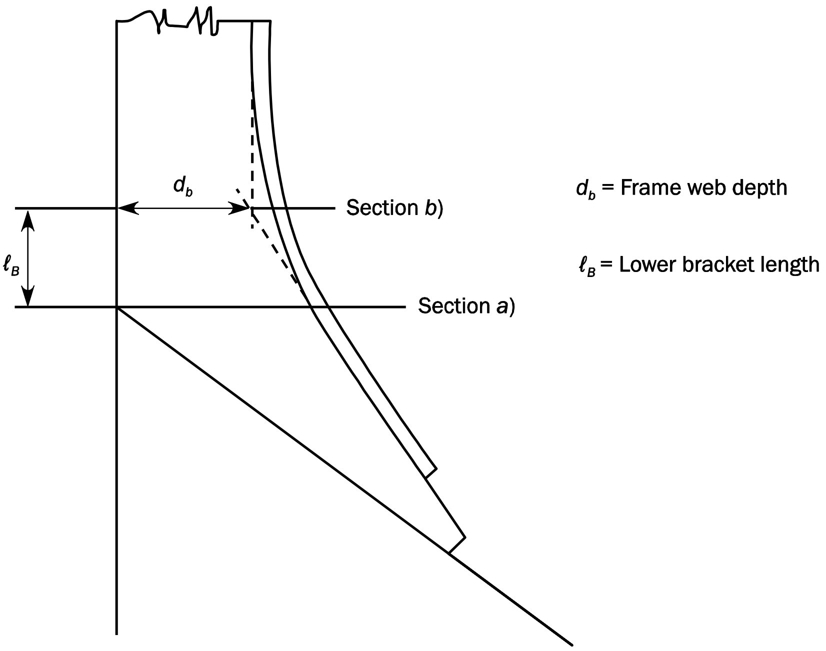
*P*: Design pressures, in $kN/m^2$, for design load sets as defined in **Pt 1**, **Ch 6**, **Sec 2**, **Table 1**.

$C_t$: Permissible shear stress coefficient for the design load set being considered, taken as:

$C_t = 0.75$ for acceptance criteria set *AC-S*.

$C_t = 0.90$ for acceptance criteria set *AC-SD*.

Fig. 1 Side Frame Lower Bracket Length




1.1.2 Side frames in ballast holds

In addition to **1.1.1**, for side frames in cargo holds designed to carry ballast water in heavy ballast condition, the net section modulus *Z*, in $cm^3$, and the net web thickness, $t_w$, in *mm*, all along the span are to be in accordance with **Pt 1**, **Ch 6**, **Sec 5** where the span of the side frame is $\ell$ as defined in **Pt 1**, **Ch 3**, **Sec 7**, **1.1** with consideration to brackets at ends.

1.1.3 Additional strength requirements

The net moment of inertia *I*, in $cm^4$, of the three side frames located immediately abaft the collision bulkhead is not to be taken less than:

$$I = 0.18 \frac{P \ell_{SF}^4}{n}$$

where:

*n* : Frame number of considered side frame counted from the collision bulkhead to the frame in question, taken equal to 1, 2 or 3.

As an alternative, supporting structures, such as horizontal stringers, are to be fitted between the collision bulkhead and a side frame which is in line with transverse webs fitted in both the topside tank and hopper tank, maintaining the continuity of the forepeak stringers within the foremost hold.

### 1.2 Lower Bracket of Side Frame

1.2.1

At the level of the lower bracket as shown in **Ch 1**, **Sec 2**, **Fig. 2**, the net section modulus of the frame and bracket, or integral bracket, with associated shell plating, is not to be taken less than twice the required net section modulus *Z*, in $cm^3$,for the frame mid-span area obtained from **1.1.1**.

1.2.2

For holds intended to carry ballast water in heavy ballast condition, the net section modulus *Z*, in $cm^3$, at the level of the lower bracket is not to be taken less than twice the greater of the required net section moduli given in **1.1.1** and **1.1.2**.

1.2.3

The net thickness $t_{LB}$, in *mm*, of the lower bracket is not to be taken less than:

$$t_{LB} = t_w + 1.5$$

where $t_w$ is the net thickness of the side frame web, in $mm$.

1.2.4

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

- For symmetrically flanged frames:

$$\frac{h_{LB}}{t_{LB}} \leq 87\sqrt{k}$$

- For asymmetrically flanged frames:

$$\frac{h_{LB}}{t_{LB}} \leq 73\sqrt{k}$$

The web depth $h_{LB}$ of lower bracket is to be measured from the intersection between the hopper tank sloping plating and the side shell plate, perpendicularly to the face plate of the lower bracket as shown in **Ch 1**, **Sec 2**, **Fig. 5**.

For the three side frames located immediately abaft the collision bulkhead, where the frames are strengthened in accordance with **1.1.3** and the offered $t_{LB}$ is greater than 1.73 $t_w$, the $t_{LB}$ applied in **1.2.4** may be taken as $t'_{LB}$ given by:

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

where $t_w$ is the net thickness of the side frame web, in $mm$, corresponding to $A_{shr}$ determined in accordance to **1.1.1**.

### 1.3 Upper Bracket of Side Frame

1.3.1

At the level of the upper bracket as shown in **Ch 1**, **Sec 2**, **Fig. 2** the net section modulus of the frame and bracket, or integral bracket, with associated shell plating, is not to be taken less than twice the net section modulus $Z$ required for the frame mid-span area obtained from **1.1.1**.

1.3.2

For holds intended to carry ballast water in heavy ballast condition, the net section modulus $Z$, in $cm^3$, at the level of the upper bracket is not to be taken less than twice the greater of the required net sections modulus obtained from **1.1.1** and **1.1.2**.

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

### 1.4 Provided Support at Upper and Lower Connections of Side Frames

1.4.1 Net section modulus

The net section modulus of the:

- Side shell and hopper tank longitudinals supporting the lower connecting brackets.
- Side shell and topside tank longitudinals supporting the upper connecting brackets.

is to comply with the following formula:

$$\sum_n Z_{pl\,i}\, d_i \geq \alpha_T \frac{P\, \ell_{SF}^2\, \ell_1^2}{16 R_{eH}}$$

where:

$n$ : Number of the longitudinal stiffeners on the side shell and hopper/topside tank supporting the lower/upper end connecting bracket of the side frame, as applicable.

$Z_{pl\,i}$: Net plastic section modulus, in $cm^3$, of the $i$-th longitudinal stiffener on the side shell or hopper/topside tank supporting the lower/upper end connecting bracket of the side frame, as applicable.

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

$\ell_1$ : Spacing, in $m$, of transverse supporting webs in hopper/topside tank, as applicable.

$R_{eH}$: Lowest value of specified yield stress, in $N/mm^2$, among the materials of the longitudinal stiffeners of side shell and hopper/topside tanks that support the lower/upper end connecting bracket of the side frame.

$\alpha_T$ :Coefficient taken as:

$\alpha_T = 150$ for the longitudinal stiffeners supporting the lower connecting brackets.

$\alpha_T = 75$ for the longitudinal stiffeners supporting the upper connecting brackets.

1.4.2 Net connection area of brackets

The net connection area of the lower or upper connecting bracket to the supporting longitudinal stiffener is to comply with the following formula:

$$\sum_i A_i d_i R_{eH,bkt-i} \geq 0.02\alpha_T P s \ell_{SF}^2 10^{-3}$$

where:

$A_i$ : The offered net connection area of the bracket connecting with the $i$-th longitudinal stiffener, in $cm^2$.

$d_i$, $\alpha_T$: As defined in **1.4.1.**

$R_{eH,bkt-i}$: The specified minimum yield stress of the bracket connecting with the $i$-th longitudinal stiffener, in $N/mm^2$,

$s$ : The space of the side frame, in $mm$.

## 2. Structure Loaded by Steel Coils on Wooden Dunnage

### 2.1 General

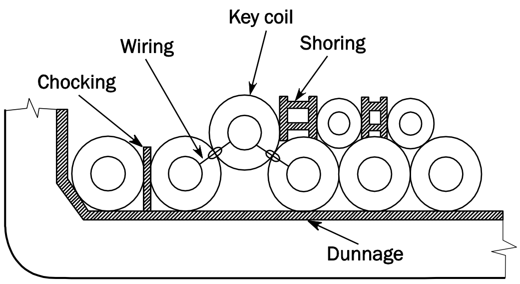
2.1.1

The net thickness of inner bottom plating, hopper side plating and inner hull plating for ships intended to carry steel coils is to comply with **2.3.1** and **2.4.1** up to a height not less than the one corresponding to the top of upper tier in touch with hopper or inner hull plating.

The net section modulus and the net shear sectional area of longitudinal stiffeners on inner bottom, hopper tank top and inner hull for ships intended to carry steel coils are to comply with **2.3.2** and **2.4.2** up to a height not less than the one corresponding to the top of upper tier in touch with hopper or inner hull plating.

Standard terminology and means for securing of steel coils is described in **Fig. 2**.

Fig. 2 Inner Bottom Loaded by Steel Coils




### 2.2 Load Application

2.2.1 Design load sets

The static and dynamic load components are to be determined in accordance with **Pt 1**, **Ch 4**, **Sec 7**, **Table 1**.

Radius of gyration, $k_r$, and metacentric height, $GM$, are to be in accordance with **Pt 1**, **Ch 4**, **Sec 3**, **Table 2** for the considered loading condition specified in the design load set. The design load sets for steel coil loading is given in **Table 1**.

Table 1 Design Load Sets

| Item | Design load set | Load component | Draught | Design load | Loading condition |
|---|---|---|---|---|---|
| Inner bottom, hopper sloping plate and inner hull | *BC-9* | $F_{sc-ib-s}$ or $F_{sc-hs-s}$ | $T_{SC}$ | *S* | Steel Coil condition |
| Inner bottom, hopper sloping plate and inner hull | *BC-10* | $F_{sc-ib}$ or $F_{sc-hs}$ | $T_{SC}$ | *S+D* | Steel Coil condition |

## 2.3 Inner Bottom

### 2.3.1 Inner bottom plating

The net thickness $t$, in $mm$, of plating of longitudinally framed inner bottom is not to be taken less than:

$$t = K_1\sqrt{\frac{F_{sc-ib-s}\,10^3}{C_a R_{eH}}}$$ for design load set *BC-9*

$$t = K_1\sqrt{\frac{F_{sc-ib}\,10^3}{C_a R_{eH}}}$$ for design load set *BC-10*

where:

$K_1$ : Coefficient taken as:

$$K_1 = \sqrt{\frac{1.7\frac{s}{1000}\ell K_2 - 0.73\left(\frac{s}{1000}\right)^2 K_2^2 - (\ell - \ell_{lp})^2}{2\ell_{lp}\left(2\frac{s}{1000} + 2\ell K_2\right)}}$$

$K_2$ : Coefficient taken as:

$$K_2 = -\frac{s}{1000\ell} + \sqrt{\left(\frac{s}{1000\ell}\right)^2 + 1.37\left(\frac{1000\ell}{s}\right)^2\left(1 - \frac{\ell_{lp}}{\ell}\right)^2 + 2.33}$$

$C_a$ : Permissible bending stress coefficient, as defined in **Pt 1**, **Ch 6**, **Sec 4**, **1.1.1**.

### 2.3.2 Stiffeners of inner bottom plating

The net section modulus $Z$, in $cm^3$, and the net web thickness, $t_w$, in $mm$, of single span stiffeners located on inner bottom plating are not to be taken less than:

$$Z = K_3\frac{F_{sc-ib-s}}{8C_s R_{eH}}10^3 \text{ and } t_w = \frac{0.5F_{sc-ib-s}}{d_{shr}C_t\tau_{eH}}10^3$$, for design load set *BC-9*.

$$Z = K_3\frac{F_{sc-ib}}{8C_s R_{eH}}10^3 \text{ and } t_w = \frac{0.5F_{sc-ib}}{d_{shr}C_t\tau_{eH}}10^3$$, for design load set *BC-10*.

where:

$K_3$ : Coefficient as defined in **Table 2**.

$K_3 = 2\ell_{bdg}/3$, when $n_2 > 10$.

$C_s$ : Permissible bending stress coefficient, as defined in **Pt 1**, **Ch 6**, **Sec 5**, **1.1.2**.

$C_t$ : Permissible shear stress coefficient for the design load set being considered, to be taken as:

$C_t = 0.85$ for acceptance criteria set *AC-S*.

$C_t = 1.00$ for acceptance criteria set *AC-SD*.

$n_2$ : Number of load points per *EPP* of the inner bottom, see **Pt 1**, **Ch 4**, **Sec 6**, **4.1.3**.

Table 2 Coefficient $K_3$

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

## 2.4 Hopper Tank and Inner Hull

### 2.4.1 Hopper sloping plating and inner hull plating

The net thickness $t$, in $mm$, of plating of longitudinally framed bilge hopper sloping plate and inner hull is not to be taken less than:

$$t = K_1\sqrt{\frac{F_{sc-hs-s}}{C_a R_{eH}}10^3}$$, applicable for design load set *BC-9*.

$$t = K_1\sqrt{\frac{F_{sc-hs}}{C_a R_{eH}}10^3}$$, applicable for design load set *BC-10*.

where:

$K_1$ : Coefficient as defined in **2.3.1**.

$C_a$ : As defined in **2.3.1**.

2.4.2 Stiffeners of hopper sloping plating and inner hull plating

The net section modulus $Z$, in $cm^3$, and the net web thickness, $t_w$, in $mm$, of single span ordinary stiffeners located on bilge hopper sloping plate and inner hull plate are not to be taken less than:

$$Z = K_3 \frac{F_{sc-hs-s}}{8C_s R_{eH}} 10^3 \text{ and } t_w = \frac{0.5F_{sc-hs-s}}{d_{shr} C_t \tau_{eH}} 10^3$$, applicable for design load set *BC-9*.

$$Z = K_3 \frac{F_{sc-hs}}{8C_s R_{eH}} 10^3 \text{ and } t_w = \frac{0.5F_{sc-hs}}{d_{shr} C_t \tau_{eH}} 10^3$$, applicable for design load set *BC-10*.

where:

$K_3$ :Coefficient as defined in **Table 2**.

$K_3 = 2\ell_{bdg}/3$ when $n_2 > 10$.

$C_s$, $C_t$ : As defined in **2.3.2**.

# 3. Transverse Vertically Corrugated Watertight Bulkheads Separating Cargo Holds in Flooded Condition

## 3.1 Net Thickness of Corrugation

3.1.1 Cold formed corrugation

The net plate thickness $t$, in $mm$, of transverse vertically corrugated watertight bulkheads separating cargo holds is not to be taken less than:

$$t = 14.9 \cdot 10^{-3} s_{CW} \sqrt{\frac{1.05P_R}{R_{eH}}}$$

The net thicknesses is also to comply with the requirements given in **Pt 1**, **Ch 6**, **Sec 4**, **1.2.1**.

3.1.2 Built-up corrugation

Where the thicknesses of the flange and web of built-up corrugations of transverse vertically corrugated watertight bulkheads separating cargo holds are different, the net plate thicknesses are not to be taken less than that obtained from the following formula.

The net thickness $t_N$, in $mm$, of the narrower plating is not to be taken less than:

$$t_N = 14.9 \cdot 10^{-3} s_N \sqrt{\frac{1.05P_R}{R_{eH}}}$$

$s_N$: Plate width, in $mm$, of the narrower plating.

The net thickness $t_W$, in $mm$, of the wider plating is not to be taken less than the greater of the following formulae:

$$t_W = 14.9 \cdot 10^{-3} s_{CW} \sqrt{\frac{1.05P_R}{R_{eH}}}$$

$$t_W = \sqrt{\frac{4.62 s_{CW}^2 P_R}{R_{eH} 10^4} - t_{NO}^2}$$

$t_{NO}$ : Net offered thickness of the narrower plating, in $mm$, not to be taken greater than:

$$t_{NO} = 14.9 \cdot 10^{-3} s_{CW} \sqrt{\frac{1.05P_R}{R_{eH}}}$$

The net thicknesses is also to comply with the requirements given in **Pt 1**, **Ch 6**, **Sec 4**, **1.2.2**.

3.1.3 Lower part of corrugation

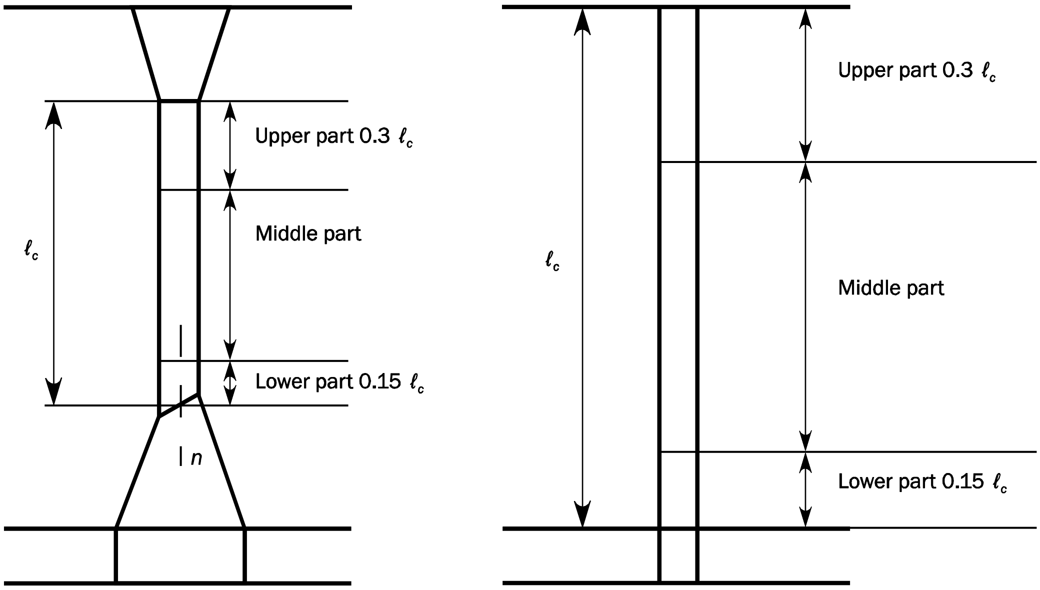
The net thickness of the lower part of corrugations is to be maintained for a distance of not less than 0.15 $\ell_C$ measured from the top of the lower stool, or from the inner bottom where no lower stool is fitted. The span of the corrugations $\ell_C$, in $m$, is to be taken as given in **Pt 1**, **Ch 3**, **Sec 6**, **10.4.5**.

3.1.4 Middle part of corrugation

The net thickness of the middle part of corrugations is to be maintained for a distance not greater than 0.3 $\ell_C$ from the bottom of the upper stool, or from the deck if no upper stool is fitted. The net thickness is also to comply with the requirements in **3.2.1** and

**Pt 1**, **Ch 6**, **Sec 4**, **1.2**.

Fig. 3 Parts of Corrugation




### 3.2 Bending, Shear and Buckling Check

3.2.1 Bending capacity and shear capacity

The bending capacity and the shear capacity of the corrugations of transverse watertight corrugated bulkheads separating cargo holds are to comply with the following formulae:

$$0.5W_{LE} + W_M \geq \frac{M}{0.95R_{eH}}10^3$$

$$\tau \leq \frac{R_{eH}}{2}$$

where:

$M$ : Bending moment in a corrugation, in $kNm$, taken as:

$$M = \frac{F_R \ell_C}{8}$$

$F_R$ : Resultant force, in $kN$, given in **Pt 1**, **Ch 4**, **Sec 6**, **3.1.7**.

$\ell_C$ : Span of the corrugations, in $m$, as given in **Pt 1**, **Ch 3**, **Sec 6**, **10.4.5**.

$W_{LE}$ : Net section modulus, in $cm^3$, of one half pitch corrugation, to be calculated at the lower end of the corrugations according to **3.3**, not to be taken greater than:

$$W_{LE,M} = W_G + \frac{Q\,h_G 10^3 - 0.5h_G^2 s_C P_R}{R_{eH}}$$

$W_G$ : Net section modulus, in $cm^3$, of one half pitch corrugation, to be calculated in way of the upper end of shedder or gusset plates, as applicable, according to **3.3**.

$Q$ : Shear force, in $kN$, at the lower end of a corrugation, to be taken as:

$$Q = 0.8F_R$$

$h_G$ : Height, in $m$, of shedders or gusset plates, as applicable as shown in **Fig. 4** to **Fig. 6**.

$P_R$ : Resultant pressure, in $kN/m^2$, to be calculated in way of the middle of the shedders or gusset plates, as applicable, according to **Pt 1**, **Ch 4**, **Sec 6**, **3.1.7**.

$W_M$ : Net section modulus, in $cm^3$, of one half pitch corrugation, to be calculated at the mid-span of corrugations according to **3.3** without being taken greater than 1.15 $W_{LE}$.

$\tau$ : Shear stress, in $N/mm^2$, in the corrugation to be taken as:

$$\tau = 10\frac{Q}{A_{shr}}$$

$A_{shr}$ : Net shear area, in $cm^2$, of one half pitch corrugation. The calculated net shear area is to consider possible reduced shear efficiency due to non-straight angles between the corrugation webs and flanges. In general, the reduced shear area may be obtained by multiplying the web sectional area by sin $\phi$.

$\phi$ : Angle between the web and the flange, see **Pt 1**, **Ch 3**, **Sec 6**, **Fig. 21**.

The net section modulus of the corrugations in the upper part of the bulkhead, as defined in **Fig. 3**, is not to be taken less than 75% of that of the middle part complying with this requirement and **Pt 1**, **Ch 6**, **Sec 4**, **1.2**, corrected for different minimum yield stresses.

3.2.2 Shear buckling check of the bulkhead corrugation webs

The shear stress $\tau$, calculated according to **3.2.1**, is to comply with the following formula:

$$\tau \leq \tau_C$$

where:

$\tau_C$ : Critical shear buckling stress, in $N/mm^2$, to be taken as:

$$\tau_C = \tau_E \text{ for } \tau_E \leq \frac{R_{eH}}{2\sqrt{3}}$$

$$\tau_C = \frac{R_{eH}}{\sqrt{3}}\left(1 - \frac{R_{eH}}{4\sqrt{3}\tau_E}\right) \text{ for } \tau_E > \frac{R_{eH}}{2\sqrt{3}}$$

$\tau_E$ : Euler shear buckling stress, in $N/mm^2$, to be taken as:

$$\tau_E = 0.9 k_t E \left(\frac{t_w}{b_{w-cg}}\right)^2$$

$k_t$ : Coefficient, to be taken equal to 6.34.

$t_w$ : Net thickness, in *mm*, of the corrugation webs.

$b_{w-cg}$ : Width, in *mm*, of the corrugation webs as shown in **Pt 1**, **Ch 3**, **Sec 6**, **Fig. 21**.

### 3.3 Net Section Modulus of the Corrugations

3.3.1 Effective flange width

The net section modulus of the corrugations is to be calculated with the compression flange having an effective flange width $b_{eff}$ not larger than the following formula:

$$b_{eff} = C_E b_{f-cg}$$

where:

$C_E$ : Coefficient to be taken equal to:

$$C_E = \frac{2.25}{\beta} - \frac{1.25}{\beta^2} \text{ for } \beta > 1.25$$

$$C_E = 1.0 \text{ for } \beta \leq 1.25$$

$\beta$ : Coefficient to be taken equal to:

$$\beta = \frac{b_{f-cg}}{t_f}\sqrt{\frac{R_{eH}}{E}}$$

$b_{f-cg}$ : Width, in *mm*, of the corrugation flange as shown in **Pt 1**, **Ch 3**, **Sec 6**, **Fig. 21**.

$t_f$ : Net flange thickness, in *mm*.

3.3.2 Webs not supported by local brackets

Unless welded to a sloping stool top plate as defined in **3.3.5**, if the corrugation webs are not supported by local brackets below the stool top plate (or below the inner bottom) in the lower part, the section modulus of the corrugations is to be calculated considering the corrugation webs 30% effective.

3.3.3 Effective shedder plates

Provided that effective shedder plates are fitted as shown in **Fig. 4**, when calculating the section modulus at the lower end of the corrugations (Sections '1' in **Fig. 4**), the net area, in $cm^2$, of flange plates may be increased by $I_{SH}$ to be taken as:

$$I_{SH} = 2.5 \cdot 10^{-3} b_{f-cg}\sqrt{t_f t_{SH}} \text{ without being taken greater than } 2.5 b_{f-cg} t_f 10^{-3}$$

where:

$b_{f-cg}$ : Width, in *mm*, of the corrugation flange as shown in **Pt 1**, **Ch 3**, **Sec 6**, **Fig. 21**.

$t_{SH}$ : Net shedder plate thickness, in *mm*.

$t_f$ : Net flange thickness, in *mm*.

Effective shedder plates are those which:

- are not knuckled,
- are welded to the corrugations and the lower stool top plate according to **Pt 1**, **Ch 12**,
- are fitted with a minimum slope of 45 degrees, their lower edge being in line with the lower stool side plating,
- have net thickness not less than 75% of the net required for the corrugation flanges,
- have material properties not less than those required for the flanges.

Fig. 4 Symmetrical and Unsymmetrical Shedder Plates

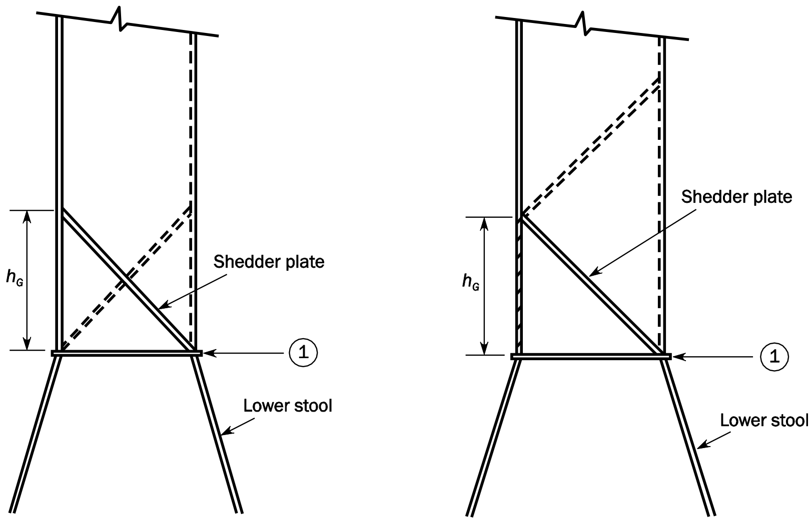



Fig. 5 Symmetrical and Unsymmetrical Gusset / Shedder

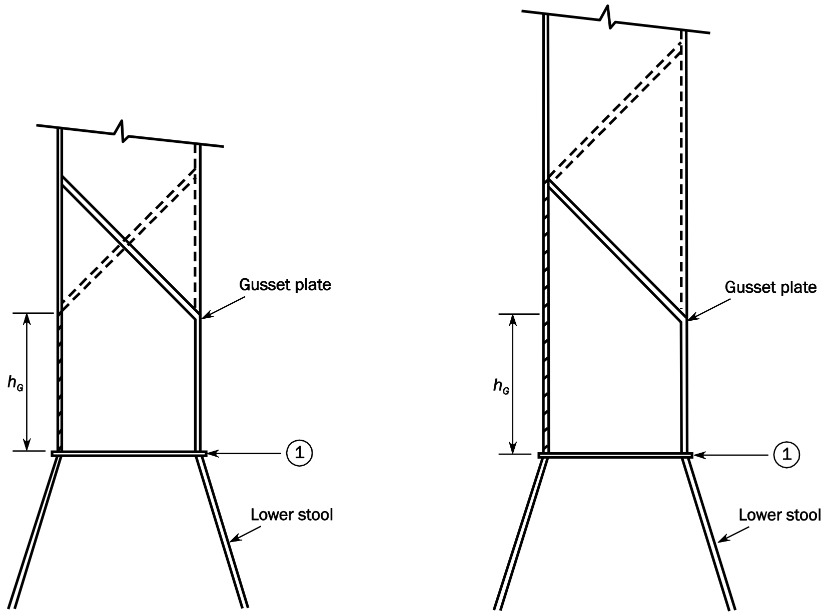
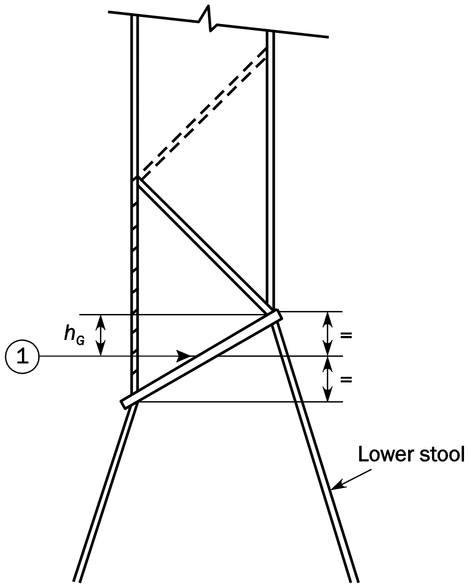


Fig. 6 Asymmetrical Gusset / Shedder Plates




3.3.4 Effective gusset plates

Provided that effective gusset plates are fitted, when calculating the section modulus at the lower end of the corrugations (Sections '1' in **Fig. 5** and **Fig. 6**), the net area, in $cm^2$, of flange plates may be increased by $I_G$ to be taken as:

$$I_G = 7 h_G t_f$$

where:

$h_g$ : Height, in *m*, of gusset plates as shown in **Fig. 5** and **Fig. 6** but not to be taken greater than:

$$\frac{10 S_{GU}}{7}$$

$S_{GU}$: Width, in *m*, of gusset plates.

$t_f$ : Net flange thickness, in *mm*.

Effective gusset plates are those which:

- are in combination with shedder plates having thickness, material properties and welded connections as requested for shedder plates in **3.3.3**,
- have a height not less than half of the flange width,
- are fitted in line with the lower stool side plating,
- are welded to the lower stool top plate, corrugations and shedder plates according to **Pt 1**, **Ch 12**, **Sec 3**, **2.4.6**,
- have net thickness and material properties not less than those net required for the flanges.

3.3.5 Sloping stool top plate

Where the corrugation webs are welded to a sloping stool top plate which has an angle not less than 45 degrees with the horizontal plane, the section modulus at the lower end of the corrugations may be calculated considering the corrugation webs fully effective. For angles less than 45 degrees, the effectiveness of the web may be obtained by linear interpolation between 30% efficient for 0 degrees and 100% efficient for 45 degrees.

Where effective gusset plates are fitted, when calculating the net section modulus of corrugations, the net area of flange plates may be increased as specified in **3.3.4** above. No credit may be given to shedder plates only.

## 4. Allowable Hold Loading for *BC-A* & *BC-B* Ships in Flooded Conditions

### 4.1 Evaluation of Double Bottom Capacity and Allowable Hold Loading

4.1.1 Shear capacity of the double bottom

The shear capacity of the double bottom is to be calculated as the sum of the shear strength at each end of:

- Floors connected to hopper tanks, less one half of the shear strength of the two floors adjacent to each stool, or transverse bulkhead if no stool is fitted as shown in **Fig. 7**. The shear strength of floors is to be calculated according to **4.1.2**.

- Double bottom girders connected to stools, or transverse bulkheads if no stool is fitted. The shear strength of girders is to be calculated according to **4.1.3**.

The floors and girders to be considered when calculating the shear capacity of the double bottom are those inside the hold boundaries formed by the hopper tanks and stools or transverse bulkheads if no stool is fitted. Where both ends of girders or floors are not directly connected to the hold boundaries, their strength is to be evaluated for the connected end only.

The hopper tank side girders and the floors directly below the connection of the stools or transverse bulkheads if no stool is fitted to the inner bottom may not be included.

For special double bottom designs, the shear capacity of the double bottom is to be calculated by means of direct calculations carried out in accordance with requirements specified in **Pt 1**, **Ch 7**, as applicable.

4.1.2 Floor shear strength

The floor shear strength, in *kN*, is to be taken as given in the following formulae:

- In way of the floor panel adjacent to the hopper tank:

$$S_{f1} = A_f \frac{\tau_A}{\eta_1} 10^{-3}$$

- In way of the openings in the outermost bay (i.e., that bay which is closer to the hopper tank):

$$S_{f2} = A_{f,h} \frac{\tau_A}{\eta_2} 10^{-3}$$

where:

$A_f$: Net sectional area, in $mm^2$, of the floor panel adjacent to the hopper tank.

$A_{f,h}$: Net sectional area, in $mm^2$, of the floor panels in way of the openings in the outermost bay (i.e., the bay which is closer to the hopper tank).

$\tau_A$: Allowable shear stress, in $N/mm^2$, to be taken as the lesser of:

$$\tau_A = 0.645 \frac{R_{eH}^{0.6}}{(s/t)^{0.8}} \text{ and } \tau_A = \frac{R_{eH}}{\sqrt{3}}$$

For floors adjacent to the stools or transverse bulkheads, $\tau_A$ is taken as:

$$\frac{R_{eH}}{\sqrt{3}}$$

$t$: Floor web net thickness, in *mm*.

$s$: Spacing, in *m*, of stiffening members of the panel considered.

$\eta_1$: Coefficient to be taken equal to 1.1.

$\eta_2$: Coefficient to be taken equal to 1.2. It may be reduced to 1.1 where appropriate reinforcements are fitted in way of the openings in the outermost bay, to be examined by the Society on a case-by-case basis.

4.1.3 Girder shear strength

The girder shear strength, in *kN*, is to be taken as given in the following formulae:

- In way of the girder panel adjacent to the stool or transverse bulkhead, if no stool is fitted:

$$S_{g1} = A_g \frac{\tau_A}{\eta_1} 10^{-3}$$

- In way of the largest opening in the outermost bay (i.e., that bay which is closer to the stool) or transverse bulk-head, if no stool is fitted:

$$S_{g2} = A_{g,h} \frac{\tau_A}{\eta_2} 10^{-3}$$

where:

$A_g$: Net sectional area, in $mm^2$, of the girder panel adjacent to the stool (or transverse bulkhead, if no stool is fitted).

$A_{g,h}$: Net sectional area, in $mm^2$, of the girder panel in way of the largest opening in the outermost bay (i.e. that bay which is closer to the stool) or transverse bulkhead, if no stool is fitted.

$\tau_A$: Allowable shear stress, in $N/mm^2$, as defined in **4.1.2** where $t$ is the girder web net thickness.

$\eta_1$ : Coefficient to be taken equal to 1.1.

$\eta_2$ : Coefficient to be taken equal to 1.15. It may be reduced to 1.1 where appropriate reinforcements are fitted in way of the largest opening in the outermost bay, to be examined by the Society on a case-by-case basis.

4.1.4 Allowable hold loading

The allowable hold loading, in *t*, is to be taken as:

$$W = \rho_c V \frac{1}{F}$$

where:

$\rho_C$ : Density of the dry bulk cargo, in $t/m^3$, as defined **Pt 1**, **Ch 4**, **Sec 6**, **2.3.3**.

$V$ : Volume, in $m^3$, occupied by the cargo up to the level $h_B$.

$F$ : Coefficient to be taken as:

$F = 1.1$ in general

$F = 1.05$ for steel mill products.

$h_B$ : Level of cargo, in $m$, to be taken as:

$$h_B = \frac{P}{\rho_c g}$$

$P$ : Pressure, in $kN/m^2$, to be taken as:

- For dry bulk cargoes, the lesser of:

$$P = \frac{Z + \rho g(z_F - 0.1D_1 - h_F)}{1 + \frac{\rho}{\rho_c}(perm - 1)}$$

$$P = Z + \rho g(z_F - 0.1D_1 - h_F\,perm)$$

- For steel mill products:

$$P = \frac{Z + \rho g(z_F - 0.1D_1 - h_F)}{1 - \frac{\rho}{\rho_{st}}}$$

$\rho_{st}$ : Density of steel, in $t/m^3$, to be taken as 7.85.

$D_1$ : Distance, in $m$, from the baseline to the freeboard deck at side amidships.

$h_F$ : Inner bottom flooded height, in $m$, measured vertically with the ship in the upright position, from the inner bottom to the flooded level $z_F$.

$z_F$ : Flooded level, in $m$, as defined in **Pt 1**, **Ch 4**, **Sec 6**, **3.2.3**.

$perm$ : Permeability of cargo, which need not be taken greater than 0.3.

$Z$ : Pressure, in $kN/m^2$, to be taken as the lesser of:

$$Z = \frac{C_H}{A_{DB,H}}$$

$$Z = \frac{C_E}{A_{DB,E}}$$

$C_H$ : Shear capacity of the double bottom, in $kN$, to be calculated according to **4.1.1**, considering, for each floor, the lesser of the shear strengths $S_{f1}$ and $S_{f2}$ as defined in **4.1.2** and, for each girder, the lesser of the shear strengths $S_{g1}$ and $S_{g2}$ as defined in **4.1.3**.

$A_{DB,H}$ : Area, in $m^2$, taken as:

$$A_{DB,H} = \sum_{i=1}^{n} S_i B_{DB,i}$$

$C_E$ : Shear capacity of the double bottom, in $kN$, to be calculated according to **4.1.1**, considering, for each floor, the shear strength $S_{f1}$ as defined in **4.1.2** and, for each girder, the lesser of the shear strengths $S_{g1}$ and $S_{g2}$ as defined in **4.1.3**.

$A_{DB,E}$ : Area, in $m^2$, taken as:

$$A_{DB,E} = \sum_{i=1}^{n} S_i (B_{DB} - s)$$

$n$ : Number of floors between stools or transverse bulkheads, if no stool is fitted.

$S_i$ : Space of $i$-th floor, in $m$.

$B_{DB,i}$ : Length, in $m$, to be taken equal to:

$B_{DB,\,i} = B_{DB} - s$ for floors for which $S_{f1} < S_{f2}$

$B_{DB,\,i} = B_{DB,\,h}$ for floors for which $S_{f1} \geq S_{f2}$

$B_{DB}$ : Breadth, in $m$, of double bottom between the hopper tanks as shown in **Fig. 8**.

$B_{DB,h}$ : Distance, in $m$, between the two openings considered as shown in **Fig. 8**.

$s$ : Spacing, in $m$, of inner bottom longitudinal ordinary stiffeners adjacent to the hopper tanks.

Fig. 7 Double Bottom Structure

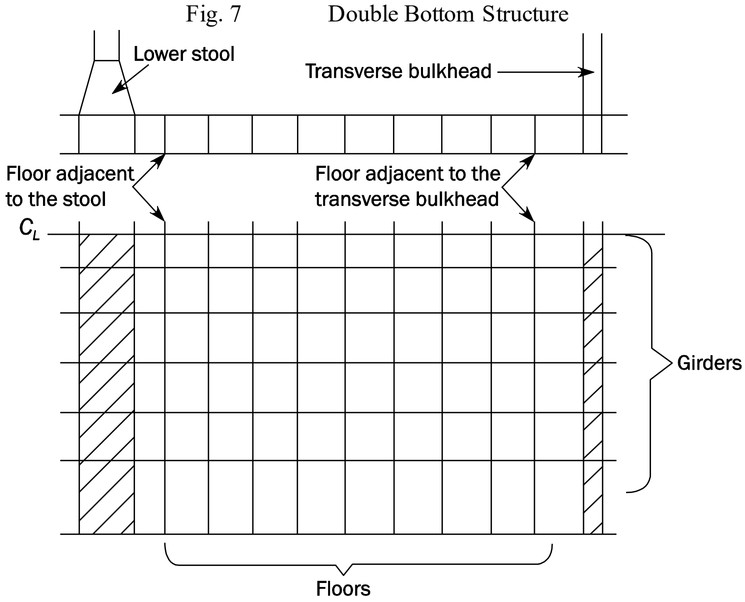
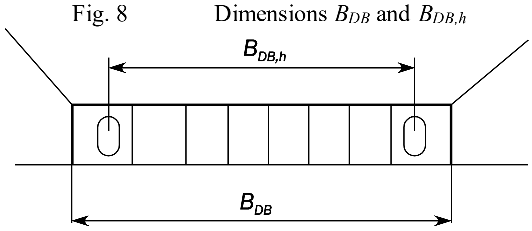



Fig. 8 Dimensions $B_{DB}$ and $B_{DB,h}$



# Section 4 HULL LOCAL SCANTLINGS FOR BULK CARRIERS $L_{LL}$ < 150*M*

**Symbols**

For symbols not defined in this section, refer to **Pt 1, Ch 1, Sec 4**.

$C_{t\text{-}pr}$ : Permissible shear stress coefficient for primary supporting members taken equal to:
$C_{t\text{-}pr}$ = 0.70 for AC-S.
$C_{t\text{-}pr}$ = 0.85 for AC-SD.

$\ell_{DB}$ : Length of the double bottom within hold under consideration, in *m*. Where stools are provided at transverse bulkheads, $\ell_{DB}$ may be taken as the distance between the toes.

$B_{DB}$ : Distance between the toes of hopper tanks at centre of $\ell_{DB}$ within hold under consideration, in *m*.

$x_c$ : *X* coordinate, in *m*, of the centre of double bottom structure under consideration with respect to the reference coordinate system, as defined in **Pt 1, Ch 1, Sec 4, 3.6**.

*x, y, z* : *X*, *Y* and *Z* coordinates, in *m*, of the evaluation point with respect to the reference coordinate system, as defined in **Pt 1, Ch 1, Sec 4, 3.6**.

$\phi$ : Depth of the openings in parallel to web depth of primary support members, in *m*.

$\alpha$ : The greater of *a* or $S_1$, in *m*.

## 1. General

### 1.1 Application

1.1.1

Unless otherwise defined, the requirements of this section define the strength criteria applicable to bulk carriers with freeboard length $L_{LL}$ less than 150 *m*.

## 2. Struts Connecting Stiffeners

### 2.1 Scantling Requirements

2.1.1 Net sectional area and moment of inertia

The net sectional area $A_{SR}$, in $cm^2$, and the net moment of inertia $I_{SR}$ about the main axes, in $cm^4$, of struts connecting stiffeners are not to be less than the values obtained from the following formulae:

$$A_{SR} = \frac{P_{SR}\, s\ell}{20000}$$

$$I_{SR} = \frac{0.75 s\ell(P_{SR1} + P_{SR2}) A_{ASR}\, \ell_{SR}^2}{47200 A_{ASR} - s\ell(P_{SR1} + P_{SR2})}$$

where:

$P_{SR}$ : Pressure to be taken as the greater of the following values, in $kN/m^2$:
$P_{SR} = 0.5\,(P_{SR1} + P_{SR2})$
$P_{SR} = P_{SR3}$

$P_{SR1}$ : External pressure in way of the strut, in $kN/m^2$, acting on one side, outside the compartment in which the strut is located.

$P_{SR2}$ : External pressure in way of the strut, in $kN/m^2$, acting on the opposite side, outside the compartment in which the strut is located.

$P_{SR3}$ : Internal pressure at mid-span of the strut, in $kN/m^2$, in the compartment in which the strut is located.

*s* : Spacing, in *mm*, of stiffeners, measured at mid-span along the chord.

$\ell$ : Span, in *m*, of stiffeners connected by the strut defined in **Pt 1, Ch 3, Sec 7, 1.1.5**.

$\ell_{SR}$ : Length of the strut, in $m$.

$A_{ASR}$ : Actual net sectional area of the strut, in $cm^2$.

## 3. Transverse Corrugated Bulkheads of Ballast Holds

### 3.1 Plate Thickness

3.1.1

The net thickness of web and flange plating is not to be less than the values obtained in **Pt 1, Ch 6, Sec 3, 1.1.1** and **Pt 1, Ch 6, Sec 4, 1.2**.

### 3.2 Net Section Modulus

3.2.1

The net section modulus $Z$, in $cm^3$, of corrugated bulkhead of ballast holds, subjected to lateral pressure are not to be less than the values obtained from the following formula:

$$Z = K \frac{P s_{cg} \ell^2}{f_{bdg} C_s R_Y}$$

where:

$K$ : Coefficient given in **Table 1** and **Table 2**, according to the type of end connection. When $d_H < 2.5\, d_0$, both section modulus per half pitch of corrugated bulkhead and section modulus of lower stool at inner bottom are to be calculated.

$P$ : Design pressure for the design load set as defined in **Pt 1, Ch 6, Sec 2, Table 1** and calculated at the load calculation point defined in **Pt 1, Ch 3, Sec 7, 3.2**, in $kN/m^2$.

$s_{cg}$ : Half pitch length, in $mm$, of the corrugation, as defined in **Pt 1, Ch 3, Sec 6, Fig. 21**.

$\ell$ : Length, in $m$, between the supports, as indicated in **Fig. 1**.

$C_s$ : Coefficient defined in **Pt 1, Ch 6, Sec 5, 1.1.2**.

$f_{bdg}$ : Coefficient defined in **Pt 1, Ch 6, Sec 5, 1.1.2**.

The effective width of the corrugation flange in compression is to be considered according to **Ch 1, Sec 3, 3.3.1** when the net section modulus of corrugated bulkhead is calculated.

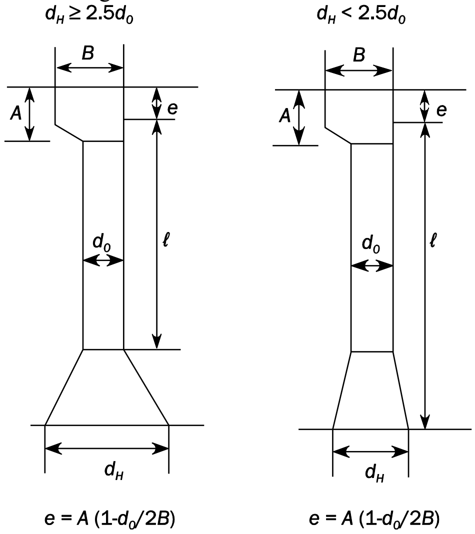
Table 1 Values of $K$, in case $d_H \geq 2.5\, d_0$

| Upper end support | |
|---|---|
| Welded directly to deck | Welded to stool efficiently supported by ship structure |
| 1.00 | 0.83 |

Table 2 Values of $K$, in case $d_H < 2.5\, d_0$

| Section modulus of | Upper end support | |
|---|---|---|
| | Connected to deck | Connected to stool |
| Corrugated bulkhead | 0.71 | 0.65 |
| Stool at bottom | 1.25 | 1.13 |

Fig. 1 Measurement of $\ell$




## 4. Primary Supporting Members

### 4.1 Application

4.1.1

The requirements of this section apply to the strength check of primary supporting members in cargo hold structures, subjected to lateral pressure for ships having a freeboard length $L_{LL}$ less than 150 $m$.

4.1.2

As an alternative to **4.1.1**, the strength check may be verified by direct strength assessment deemed as appropriate by the Society.

### 4.2 Design Load Sets

4.2.1 Application

Design load sets as given in **Table 3** are to be considered for primary supporting members on cargo hold boundaries of bulk carriers with freeboard length $L_{LL}$ less than 150 $m$.

4.2.2 Loading conditions

The severest loading conditions from the loading manual or otherwise specified by the designer are to be considered for the calculation of $P_{in}$ in design load sets $BC$-11 to $BC$-12.

For Primary supporting member in bilge hopper tanks and topside tanks, applicable design load sets in **Pt 1, Ch 6, Sec 2, Table 1** are to be considered.

Table 3 Design Load Sets for Primary Supporting Members in Cargo Hold Region

| Item | Design load set | Load component | Draught | Design load | Loading condition |
|---|---|---|---|---|---|
| • Double bottom floors and girders<br>• Stringers and transverse web frames in double side structures | *WB*-4 (1) | $P_{in} - P_{ex}$ | $T_{BAL-H}$ | *S+D* | Heavy ballast condition |
| | *WB*-6 (1) | $P_{in}$ | - | *S* | Harbour/test condition |
| | *BC*-11 | $P_{in} - P_{ex}$ | $T_{SC}$ | *S+D* | Full load condition |
| | *BC*-12 | $P_{in} - P_{ex}$ | $T_{SC}$ | *S* | Harbour condition |
| | *FD*-1 (2) | $P_{in}$ | $T_{SC}$ | *S+D* | Flooded condition |
| | *FD*-2 (2) | $P_{in}$ | | *S* | Flooded condition |
| (1) Only applicable to holds assigned as ballast hold.<br>(2) Not applicable to holds assigned as ballast hold. | | | | | |

### 4.3 Centre Girders and Side Girders

4.3.1 Net web thickness

The net thickness of girders in double bottom structure, in *mm*, is not to be less than the greater of the value $t_1$ and $t_2$ specified in the followings according to each location:

$$t_1 = C_1 \frac{|P|\, S\, |x - x_c|}{(d_0 - d_1) C_{t-pr}\, \tau_{eH}} \left\{ 1 - 4\left(\frac{y}{B_{DB}}\right)^2 \right\}$$

where $|x - x_c|$ is less than $0.25\ \ell_{DB}$, $|x - x_c|$ is to be taken as $0.25\ \ell_{DB}$.

$$t_2 = 1.75 \sqrt[3]{\frac{H^2 a^2 C_{t-pr}\, \tau_{eH}}{C_1'} t_1}$$

where:

- $P$ : Design pressure in $kN/m^2$, for the design load set being considered according to **Pt 1, Ch 6, Sec 2, 2.1.3**, calculated at mid-point of a floor located midway between transverse bulkheads or transverse bulkhead and toe of stool, where fitted.
- $S$ : Distance between the centres of the two spaces adjacent to the centre or side girder under consideration, in *m*.
- $d_0$ : Depth of the centre or side girder under consideration, in *m*.
- $d_1$ : Depth of the opening, if any, at the point under consideration, in *m*.
- $C_1$ : Coefficient given in **Table 4** depending on $B_{DB}/\ell_{DB}$. For intermediate values of $B_{DB}/\ell_{DB}$, $C_1$ is to be obtained by linear interpolation.
- $a$ : Depth of girders at the point under consideration, in *m*. However, where horizontal stiffeners are fitted on the girder, $a$ is the distance from the horizontal stiffener under consideration to the bottom shell plating or inner bottom plating, or the distance between the horizontal stiffeners under consideration.
- $S_1$ : Spacing, in *m*, of vertical stiffeners or floors.
- $C_1'$ : Coefficient given in **Table 5** depending on $S_1/a$. For intermediate values of $S_1/a$, $C_1'$ is to be determined by linear interpolation.
- $H$ : Value obtained from the following formulae:
  - Where the girder is provided with an unreinforced opening:

    $H = 1 + 0.5 \dfrac{\phi}{\alpha}$
  - In other cases:

    $H = 1.0$

Table 4 Coefficient $C_1$

| $B_{DB}/\ell_{DB}$ | 0.4 and under | 0.6 | 0.8 | 1.0 | 1.2 | 1.4 | 1.6 and over |
|---|---|---|---|---|---|---|---|
| $C_1$ | 0.5 | 0.71 | 0.83 | 0.88 | 0.95 | 0.98 | 1.00 |

Table 5 Coefficient $C_1'$

| $S_1/a$ | 0.3 and under | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 | 1.2 | 1.4 and over |
|---|---|---|---|---|---|---|---|---|---|---|
| $C_1'$ | 64 | 38 | 25 | 19 | 15 | 12 | 10 | 9 | 8 | 7 |

### 4.4 Floors

4.4.1 Net web thickness

The net thickness of floors in the double bottom structure, in *mm*, is not to be less than the greatest of values $t_1$ and $t_2$ specified in the following according to each location:

$$t_1 = C_2 \frac{|P|\, S\, B_{DB}}{(d_0 - d_1)\, C_{t-pr}\, \tau_{eH}} \left(\frac{2|y|}{B'_{DB}}\right) \left\{1 - 2\left(\frac{x - x_c}{\ell_{DB}}\right)^2\right\}$$

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

$$t_2 = 1.75 \sqrt[3]{\frac{H^2 a^2\, C_{t-pr}\, \tau_{eH}}{C_2'}\, t_1}$$

where:

$P$ : Design pressure in $kN/m^2$, for the design load set being considered according to **Pt 1, Ch 6, Sec 2, 2.1.3**, calculated at mid-point of a floor located midway between transverse bulkheads or transverse bulkhead and toe of stool, where fitted.

$S$ : Spacing of solid floors, in $m$.

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

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

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

$C_2$ : Coefficient given in **Table 6** depending on $B_{DB}/\ell_{DB}$. For intermediate values of $B_{DB}/\ell_{DB}$, $C_2$ is to be obtained by linear interpolation.

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

$S_1$ : Spacing, in $m$, of vertical stiffeners or girders.

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

$H$ : Value obtained from the following formulae:

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

- Where slots without reinforcement are provided:

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

- Where slots with reinforcement are provided:

$H = 1.0$.

Where openings without reinforcement are provided on solid floors:

- Where slots without reinforcement are provided:

$$H = \sqrt{4.0\frac{d_2}{S_1} - 1.0} \qquad \text{without being taken less than } 1 + 0.5\frac{\phi}{d_0}$$

- where slots with reinforcement are provided:

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

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

Table 6 Coefficient $C_2$

| $B_{DB}/\ell_{DB}$ | 0.4 and under | 0.6 | 0.8 | 1.0 | 1.2 | 1.4 | 1.6 and over |
|---|---|---|---|---|---|---|---|
| $C_2$ | 0.48 | 0.47 | 0.45 | 0.43 | 0.40 | 0.37 | 0.34 |

Table 7 Coefficient $C_2'$

| $S_1/d_0$ | 0.3 and under | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 | 1.2 | 1.4 and over |
|---|---|---|---|---|---|---|---|---|---|---|
| $C_2'$ | 64 | 38 | 25 | 19 | 15 | 12 | 10 | 9 | 8 | 7 |

### 4.5 Stringer of Double Side Structure

4.5.1 Net web thickness

The net thickness of stringers in double side structure, in $mm$, is not to be less than the greater of the value $t_1$ and $t_2$ specified in the followings according to each location:

$$t_1 = C_3\frac{|P|\ S\ |x - x_c|}{(d_0 - d_1)C_{t-pr}\tau_{eH}}$$

where $|x - x_c|$ is under 0.25 $\ell_{DS}$, $|x - x_c|$ is to be taken as 0.25 $\ell_{DS}$.

$$t_2 = 1.75\sqrt[3]{\frac{H^2 a^2\ C_{t-pr}\tau_{eH}}{C_3'}t_1}$$

where:

$P$ : Design pressure in $kN/m^2$, for the design load set being considered according to **Pt 1, Ch 6, Sec 2, 2.1.3**, as measured vertically at the upper end of hopper tank, longitudinally at the centre of $\ell_{DS}$.

$S$ : Breadth of part supported by stringer, in $m$.

$d_0$ : Depth of stringers, in $m$.

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

$\ell_{DS}$ : Length of the double side structure between the transverse bulkheads under consideration, in $m$.

$h_{DS}$ : Height of the double side structure between the upper end of hopper tank and the lower end of topside tank located midway between transverse bulkheads of hold under consideration, in m.

$C_3$ : Coefficient given in **Table 8** depending on $h_{DS}/\ell_{DS}$. For intermediate values of $h_{DS}/\ell_{DS}$, $C_3$ is to be obtained by linear interpolation.

$a$ : Depth of stringers at the point under consideration, in $m$. However, where horizontal stiffeners are fitted on the stringer, $a$ is the distance from the horizontal stiffener under consideration to the side shell plating or the longitudinal bulkhead of double side structure or the distance between the horizontal stiffeners under consideration.

$S_1$ : Spacing, in $m$, of transverse stiffeners or web frames.

$C_3'$ : Coefficient given in **Table 9** depending on $S_1/a$. For intermediate values of $S_1/a$, $C_3'$ is to be obtained by linear interpolation.

$H$ : Value obtained from the following formulae:

- Where the stringer is provided with an unreinforced opening:

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

- In other cases:

$$H = 1.0$$

Table 8 Coefficient $C_3$

| $h_{DS}/\ell_{DS}$ | 0.5 and under | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 | 1.1 | 1.2 | 1.3 and over |
|---|---|---|---|---|---|---|---|---|---|
| $C_3$ | 0.16 | 0.23 | 0.30 | 0.36 | 0.41 | 0.44 | 0.47 | 0.50 | 0.54 |

Table 9 Coefficient $C_3'$

| $S_1/a$ | 0.3 and under | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 | 1.2 | 1.4 and over |
|---|---|---|---|---|---|---|---|---|---|---|
| $C_3'$ | 64 | 38 | 25 | 19 | 15 | 12 | 10 | 9 | 8 | 7 |

### 4.6 Transverse Web in Double Side Structure

4.6.1 Net web thickness

The net thickness of transverse webs in double side structure, in *mm*, is not to be less than the greater of the value $t_1$ and $t_2$ specified in the followings according to each location:

$$t_1 = C_4 \frac{|P|\, S\, h_{DS}}{(d_0 - d_1)\ C_{t-pr}\ \tau_{eH}} \left(1 - 1.75\, \frac{z - z_{BH}}{h'_{DS}}\right)$$

where $z - z_{BH}$ is greater than 0.4 $h'_{DS}$, $z - z_{BH}$ is to be taken as 0.4 $h'_{DS}$.

$$t_2 = 1.75 \sqrt[3]{\frac{H^2 a^2\, C_{t-pr} \tau_{eH}}{C_4'} t_1}$$

where:

$P$ : Design pressure in $kN/m^2$, for the design load set being considered according to **Pt 1, Ch 6, Sec 2, 2.1.3**, as measured vertically at the upper end of hopper tank, longitudinally at the centre of $\ell_{DS}$.

$S$ : Breadth of part supported by transverses, in $m$.

$d_0$ : Depth of transverses, in $m$.

$d_1$ : Depth of opening at the point under consideration, in $m$.

$C_4$ : Coefficient given in **Table 10** depending on $h_{DS}/\ell_{DS}$. For intermediate values of $h_{DS}/\ell_{DS}$, C4 is to be obtained by linear interpolation.

$z_{BH}$ : $Z$ coordinate, in m, of the upper end of hopper tank with respect to the reference coordinate system defined in **Pt 1, Ch 1, Sec 4, 3.6**.

$h_{DS}$ : As defined in the requirements of **4.5.1.**

$h'_{DS}$ : Height of the double side structure between the upper end of hopper tank and the lower end of topside tank at the position under consideration, in $m$.

$\ell_{DS}$ : As defined in the requirements of **4.5.1**.

$a$ : Depth of transverses at the point under consideration, in $m$. However, where vertical stiffeners are fitted on the transverse, $a$ is the distance from the vertical stiffener under consideration to the side shell or the longitudinal bulkhead of double side hull or the distance between the vertical stiffeners under consideration.

$S_1$ : Spacing, in $m$, of horizontal stiffeners or stringers.

$C_4'$ : Coefficient given in **Table 11** depending on $S_1/a$. For intermediate values of $S_1/a$, $C_4'$ is to be obtained by linear interpolation.

$H$ : Value obtained from the following formulae:

- Where the transverse is provided with an unreinforced opening:

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

- In other cases:

  $$H = 1.0$$

$\alpha$ : The greater of $a$ or $S_1$, in $m$.

Table 10 Coefficient $C_4$

| $h_{DS}/\ell_{DS}$ | 0.5 and under | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 | 1.1 | 1.2 | 1.3 and over |
|---|---|---|---|---|---|---|---|---|---|
| $C_4$ | 0.62 | 0.61 | 0.59 | 0.55 | 0.52 | 0.49 | 0.46 | 0.43 | 0.41 |

Table 11 Coefficient $C_4'$

| $S_1/a$ | 0.3 and under | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 | 1.2 | 1.4 and over |
|---|---|---|---|---|---|---|---|---|---|---|
| $C_4'$ | 64 | 38 | 25 | 19 | 15 | 12 | 10 | 9 | 8 | 7 |

## 4.7 Primary Supporting Member in Bilge Hopper Tanks and Topside Tanks

4.7.1 Boundary conditions

The requirements of this sub-article apply to primary supporting members considered as clamped at both ends. For boundary conditions deviated from the above, the yielding check is to be considered on a case-by-case basis.

4.7.2 Net section modulus, net shear sectional area and web thickness

The net section modulus $Z$, in $cm^3$, the net shear sectional area $A_{shr}$, in $cm^2$, and the net web thickness $t_w$, in $mm$, subjected to lateral pressure are not to be less than the values obtained from the following formulae:

$$Z = \frac{|P|\,S\,\ell_{bdg}^{\;2}}{f_{bdg}\,C_{s-pr}\,R_{eH}}10^3$$

$$A_{shr} = \frac{5|P|S\ell_{shr}}{C_{t-pr}\tau_{eH}}$$

$$t_w = 1.75\sqrt[3]{\frac{h_w C_{t-pr}\tau_{eH}}{10^4 C_5}A_{shr}}$$

where:

$P$ : Design pressure in $kN/m^2$, for the design load set being considered according to **Pt 1, Ch 6, Sec 2, 2.1.3**, calculated at the mid-point of span $\ell$ of a web frame located midway between transverse bulkheads of holds.

$S$ : Spacing of primary supporting members, in $m$.

$\ell_{bdg}$: Effective bending span, in m, of primary supporting members, measured between the supporting members as defined in **Pt 1, Ch 3, Sec 7, 1.1.6**.

$\ell_{shr}$: Effective shear span, in $m$, of primary supporting members, measured between the supporting members as defined in **Pt 1, Ch 3, Sec 7, 1.1.7**.

$f_{bdg}$: Bending moment factor:

- For continuous primary supporting members and where end connections are fitted consistent with idealisation of the primary supporting members as having fixed ends and is not to be taken higher than:
  $f_{bdg} = 10$
- For primary supporting members with reduced end fixity, the yield check is to be considered on a case-by-case basis.

$C_{s-pr}$: Permissible bending stress coefficient for primary supporting members taken equal to:

$C_{s-pr} = 0.70$ for AC-S.

$C_{s-pr} = 0.85$ for AC-SD.

$h_w$ : Web height, in $mm$.

$C_5$ : Coefficient defined in **Table 12** according to $s_1$ and $d_0$. For intermediate values of $s_1/d_0$, coefficient $C_5$ is to be obtained by linear interpolation.

$s_1$ : Spacing of stiffeners or tripping brackets on web plate, in $m$.

$d_0$ : Spacing of stiffeners parallel to shell plate on web plate, in $m$.

Table 12 Coefficient $C_5$

| $s_1/d_0$ | 0.3 and less | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 | 1.5 | 2.0 and over |
|---|---|---|---|---|---|---|---|---|---|---|

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| $C_5$ | 60.0 | 40.0 | 26.8 | 20.0 | 16.4 | 14.4 | 13.0 | 12.3 | 11.1 | 10.2 |

# Section 5 CARGO HATCH COVERS

## Symbols

For symbols not defined in this section, refer to **Pt 1, Ch 1, Sec 4**.

$P_S$ : Still water pressure, in $kN/m^2$, as defined in **4.1**.

$P_W$ : Wave pressure, in $kN/m^2$, as defined in **4.1**.

$P_C$ : Pressure acting on the hatch coaming, in $kN/m^2$, as defined in **6.2**.

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

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

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

$b_p$ : Effective breadth, in $mm$, of the plating attached to the stiffener, as defined in **3**.

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

$f_{bc}$ : Boundary coefficient for stiffeners and primary supporting members, taken equal to:

$f_{bc} = 8$, in the case of stiffeners and primary supporting members simply supported at both ends or supported at one end and clamped at the other end.

$f_{bc} = 12$, in the case of stiffeners and primary supporting members clamped at both ends.

$t_c$ : Total corrosion addition, in $mm$, as defined in **1.4**.

$\sigma_a$, $\tau_a$ : Allowable stresses, in $N/mm^2$, as defined in **1.5**.

## 1. General

### 1.1 Application

1.1.1

The requirements in **1** to **8** apply to steel hatch covers in positions 1 and 2 on weather decks, as defined in **Pt 1, Ch 1, Sec 4, 3.2**.

### 1.2 Materials

1.2.1 Steel

The formulae for scantlings given in **5** are applicable to steel hatch covers.

Materials used for the construction of steel hatch covers are to comply with the applicable requirements of **Part K**.

1.2.2 Other materials

The use of materials other than steel is to be considered by the Society on a case-by-case basis, by checking that criteria adopted for scantlings are such as to ensure strength and stiffness equivalent to those of steel hatch covers.

### 1.3 Net Scantlings

1.3.1

All scantlings referred to in this section are net, i.e. they do not include any margin for corrosion. When calculating the stresses $\sigma$ and $\tau$ in **5.3** and **5.4**, the net scantlings are to be used.

The gross scantlings are obtained as specified in **Pt 1, Ch 3, Sec 2**.

The corrosion additions are given in **1.4**.

### 1.4 Corrosion Additions

1.4.1

The total corrosion addition for both sides to be considered for the plating and internal members of hatch covers is equal to the value specified in **Table 1**.

The corrosion addition for hatch coamings and coaming stays is defined according to **Pt 1, Ch 3, Sec 3**.

Table 1 Corrosion Addition $t_c$ for Hatch Covers

| Corrosion addition $t_c$, in $mm$, for both sides | |
|---|---|
| Plating and stiffeners of single skin hatch cover | 2.0 |
| Top and bottom plating of double skin hatch cover | 2.0 |
| Internal structures of double skin hatch cover | 1.5 |

### 1.5 Allowable Stresses

1.5.1

The allowable stresses $\sigma_a$, in $N/mm^2$, are to be obtained from **Table 2**.

Table 2 Allowable Stresses

| Members of | Subjected to | $\sigma_a$, in $N/mm^2$ |
|---|---|---|
| Weathertight hatch cover | External pressure, as defined in **4.1.2** | $0.80R_{eH}$ |
| Weathertight hatch cover | Other loads, as defined in **4.1.3** to **4.1.6** | $0.90R_{eH}$ for load combination: $S+D$<br>$0.72R_{eH}$ for load combination: $S$ |

The allowable buckling utilisation factors are given in **Table 3**:

Table 3 Allowable Buckling Utilisation Factors

| Structural component | Subject to | $\eta_{all}$, Allowable buckling utilisation factor |
|---|---|---|
| Plates and stiffeners<br>Web of PSM | External pressure, as defined in **4.1.2** | 0.80 for load combination: $S+D$ |
| | Other loads, as defined in **4.1.3** to **4.1.6** | 0.90 for load combination: $S+D$<br>0.72 for load combination: $S$ |

## 2. Arrangements

### 2.1 Hatch Covers

2.1.1

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

2.1.2

The spacing of primary supporting members parallel to the direction of stiffeners is not to be greater than 1/3 of the span of primary supporting members.

2.1.3

The breadth of the primary supporting member face plate is not to be less than 40% of their depth for laterally unsupported spans greater than $3m$. Tripping brackets attached to the face plate may be considered as a lateral support for primary supporting members.

The face plate outstand is not to exceed 15 times the gross face plate thickness.

2.1.4

Efficient retaining arrangements are to be provided to prevent translation of the hatch cover under the action of the longitudinal and transverse forces exerted by cargoes on the cover, if any. These retaining arrangements are to be located in way of the hatch coaming side brackets.

2.1.5

The width of each bearing surface for hatch covers is to be at least $65mm$.

### 2.2 Hatch Coamings

2.2.1

Coamings, stiffeners and brackets are to be capable of withstanding the local forces in way of the clamping devices and handling facilities necessary for securing and moving the hatch covers as well as those due to cargo stowed on the latter.

2.2.2

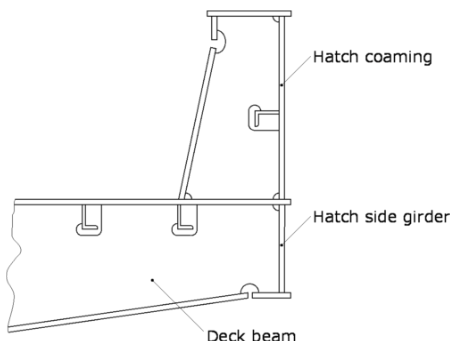
Special attention is to be paid to the strength of the fore transverse coaming of the forward hatch and to the scantlings of the closing devices of the hatch cover on this coaming.

2.2.3

Longitudinal coamings are to be vertically extended at least to the lower edge of deck beams, or hatch side girders below deck are to be fitted in line with longitudinal coamings. Extended coaming plates are to be flanged or fitted with face bars or half-round bars at the level of lower edge of the deck beams. Fig. 1 gives an example.

- Where they are not part of continuous deck girders, the lower edge of longitudinal coamings including below deck structures as an extension measure above are to extend for at least two frame spaces beyond the end of the hatch openings.
- Where they are part of continuous deck girders, their scantlings are to be as required in Pt 1, Ch 6, Sec 6 and Pt 1, Ch 8, Sec 3.

Fig. 1 Example of extension to lower edge of deck beams of longitudinal coaming by fitting a hatch side girder




2.2.4

A web frame or a similar structure is to be provided below the deck in line with the transverse coaming. Transverse coamings are to extend below the deck and to be connected with the web frames.

## 3. Width of Attached Plating

### 3.1 Stiffeners

3.1.1

The width of the attached plating bp, in mm, to be considered for the check of stiffeners is to be taken as:

- Where the attached plating extends on both sides of the stiffener:
  $b_p = s$
- Where the attached plating extends on one side of the stiffener:
  $b_p = 0.5\, s$

# 4. Load Model

## 4.1 Lateral Pressures and Forces

4.1.1 General

The lateral pressures and forces to be considered as acting on hatch covers are given in **4.1.2** to **4.1.6**. When two or more panels are connected by hinges, each individual panel is to be considered separately.

In any case, the sea pressures defined in **4.1.2** are to be considered for hatch covers located on exposed decks.

Additionally, when the hatch cover is intended to carry uniform cargoes, special cargoes or containers, the pressures and forces defined in **4.1.3** to **4.1.6** are to be considered independently from the sea pressures.

4.1.2 Sea pressures

The still water and wave lateral pressures are to be considered and are to be taken equal to:

- Still water pressure: $P_S = 0$.
- Wave pressure $P_W=P_{HC}$, as defined in **Pt 1, Ch 4, Sec 5, 5.2**.

4.1.3 Internal pressures due to ballast water

If applicable, the internal static and dynamic lateral pressures due to ballast water are to be considered and are defined in **Pt 1, Ch 4, Sec 6, 1**.

4.1.4 Pressures due to uniform cargoes

If applicable, the static and dynamic pressures due to uniform cargoes are to be considered and are defined in **Pt 1, Ch 4, Sec 5, 5.3.1**.

4.1.5 Pressures or forces due to special cargoes

In the case of carriage of special cargoes (e.g. pipes, etc) on the hatch covers which may temporarily retain water during navigation, the lateral pressures or forces to be applied are considered by the Society on a case-by-case basis.

4.1.6 Forces due to containers

In the case of carriage of containers on the hatch covers, the concentrated forces under the containers corners are to be determined in accordance with the applicable requirements of the Society.

4.1.7 Self weight

The effect of the hatch cover structure weight is to be included in the static loads but not in the dynamic loads.

## 4.2 Load Point

4.2.1 Wave lateral pressure for hatch covers on exposed decks

The wave lateral pressure to be considered as acting on each hatch cover is to be calculated at a point located:

- Longitudinally, at the hatch cover mid-length.
- Transversely, on the longitudinal plane of symmetry of the ship.
- Vertically, at the top of the hatch cover.

4.2.2 Lateral pressures other than the wave pressure

The lateral pressure is to be calculated at the level of the tight boundary of the cover:

- In way of the geometrical centre of gravity of the plate panel, for plating.
- At mid-span, for stiffeners and primary supporting members.

# 5. Strength Check

## 5.1 General

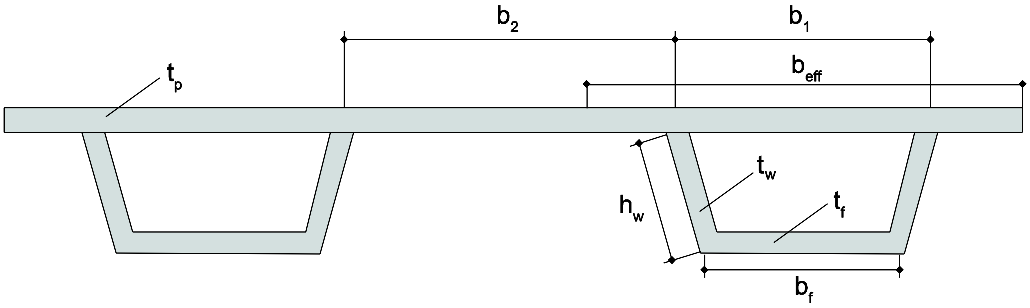
5.1.1 Application

The strength check is applicable to rectangular hatch covers subjected to lateral pressure and/or concentrated loads, designed with primary supporting members arranged in one direction or as a grillage of longitudinal and transverse primary supporting members.

It is also applicable for hatch covers fitted with U-type stiffeners as shown in **Fig. 2**. The stresses in all structural members are to be determined by a finite element analysis with the modelling requirements as described in **5.6.1**.

It is to be checked that stresses of all structural members comply with the yield strength assessment requirement in **5.6.2** and the buckling strength assessment as described in 5.2.3, 5.3.4, 5.4.6, 5.6.3 and 5.6.4.

Fig. 2 Example of Hatch Cover Fitted with U Type Stiffener




5.1.2 Hatch covers supporting containers

The scantlings of hatch covers supporting containers are to comply with the applicable requirements of the Society.

5.1.3 Hatch covers subjected to special cargoes

For hatch covers supporting special cargoes, stiffeners and primary supporting members are generally to be checked by direct calculations, taking into account the stiffener arrangements and their relative inertia. It is to be checked that stresses induced by special cargoes are in accordance with the criteria in 5.4.4.

**5.2 Plating**

5.2.1 Net thickness

The net thickness, in $mm$, of steel hatch cover top plating is not to be taken less than:

$$t = 0.0158 F_p b \sqrt{\frac{F_s P_s + F_W P_W}{0.95 R_{eH}}}$$

where:

$F_p$ : Factor for combined membrane and bending response, equal to:

$F_p = 1.5$ in general.

$F_p = 1.9 \frac{\sigma}{\sigma_a}$ for $\sigma \geq 0.8\sigma_a$ for the attached plating of primary supporting members.

$\sigma$ : Normal stress, in $N/mm^2$, in the attached plating of primary supporting members, calculated according to 5.4.3 or determined through a grillage analysis or a finite element analysis.

5.2.2 Minimum net thickness

In addition to 5.2.1, the net thickness, in mm, of the plating forming the top of the hatch cover is not to be taken less than the greater of the following values:

$$t = \frac{b}{100}$$

$t = 6$

5.2.3 Buckling strength

The buckling strength of the hatch cover plating subjected to loading conditions as defined in 4.1 is to comply with the requirements in 5.6.3.

For hatch covers fitted with U type stiffeners, it is to comply with the requirements in 5.6.4.

**5.3 Stiffeners**

5.3.1

Stiffeners are to comply with the applicable slenderness and proportion requirements given in Pt 1, Ch 8, Sec 2, 3.1.1 and **3.1.2**.

5.3.2 Minimum net thickness of web

The net thickness, in $mm$, of the stiffener web is to be taken not less than 4 $mm$.

5.3.3 Net section modulus and net shear sectional area

The net section modulus $Z$, in $cm^3$, and the net shear sectional area $A_{shr}$, in $cm^2$, of a stiffener subject to lateral pressure are to be taken not less than given by the following formulae:

$$Z = \frac{(F_S P_S + F_W P_W)\, s \cdot \ell_s^2}{f_{bc}\, \sigma_a}$$

$$A_{shr} = \frac{5(F_S P_S + F_W P_W)\, s \ell_s}{\tau_a} 10^{-3}$$

where:

$\ell_s$ : Stiffener span, in $m$, to be taken as the spacing, in m, of primary supporting members or the distance between a primary supporting member and the edge support, as applicable. When brackets are fitted at both ends of all stiffener spans, the stiffener span may be reduced by an amount equal to 2/3 of the minimum brackets arm length, but not greater than 10% of the gross span, for each bracket.

5.3.4 Buckling strength

The buckling strength of the hatch cover stiffeners subjected to loading conditions as defined in **4.1** is to comply with the requirements in **5.6.3**.

The buckling strength of the hatch cover fitted with U type stiffeners subjected to loading conditions as defined in **4.1** is to comply with the requirements in **5.6.4**.

**5.4 Primary Supporting Members**

5.4.1 Application

Primary supporting members are to be checked with the requirements in **5.4.2** to **5.4.7**.

5.4.2 Minimum net thickness of web

The web net thickness of primary supporting members, in mm, is not to be less than 6 $mm$.

5.4.3 (Void)

5.4.4 (Void)

5.4.5 Deflection limit

The net moment of inertia of a primary supporting member, when loaded by sea pressure, excluding the self-weight of the structure, is to be such that the deflection does not exceed $\mu \ell_{\max}$.

where:

$\mu$ : Coefficient taken equal to:

$\mu = 0.0056$ for weathertight hatch covers.

$\ell_{\max}$: Greatest span, in m, of primary supporting members.

5.4.6 Buckling strength of the web panels of the primary supporting members

The web of primary supporting members subject to loading conditions as defined in **4.1** is to comply with the requirements in **5.6.3**.

5.4.7 Slenderness criteria

For buckling stiffeners on webs of primary supporting members, the ratio $h_w/t_w$ is to comply with the following formula:

$$\frac{h_w}{t_w} \le 15\sqrt{\frac{235}{R_{eH}}}$$

**5.5 (Void)**

Fig. 3 (Void)

**5.6 Finite element model and buckling assessment**

5.6.1 Finite element model

For the strength assessments of hatch covers subjected to loading conditions as defined in **4.1**, by means of FE analysis, the hatch cover geometry shall be idealized as realistically as possible. In no case shall the element width be larger than stiffener spacing. In way of force transfer points and cutouts the mesh is to be refined where applicable. The ratio of element length to width shall not exceed 3.

The element size along the height of webs of primary supporting member is not to exceed one-third of the web height. 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 **Fig. 2** 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.

5.6.2 Yield strength assessment

All hatch cover structural members are to comply with the following formula

$\sigma_{vm} \leq \sigma_a$ for shell elements in general.

$\sigma_{axial} \leq \sigma_a$ for rod or beam elements in general.

where,

$\sigma_a$ : Allowable stress as defined in **1.5.1**, **Table 2**.

$\sigma_{vm}$ : Von Mises stress, in $N/mm^2$, to be taken as follows:

$$\sigma_{vm} = \sqrt{\sigma_x^2 - \sigma_x\sigma_y + \sigma_y^2 + 3\tau_{xy}^2}$$

$\sigma_x$ : Normal stress, in $N/mm^2$, in x-direction.

$\sigma_y$ : Normal stress, in $N/mm^2$, in y-direction.

$\tau_{xy}$ : Shear stress, in $N/mm^2$, in the x-y plane.

$\sigma_{axial}$ : Axial stress in rod or beam element, in $N/mm^2$.

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

In case of FEM calculations using shell (or plate) 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 shall not exceed the allowable stress. Where shell elements are used, the stresses are to be evaluated at the mid plane of the element.

5.6.3 Buckling strength assessment

The plate panel of a hatch cover structure is to be modelled as stiffened panel (SP) or unstiffened panel (UP). Assessment Method A (-A) and Method B (-B) as defined in **Pt 1, Ch 8, Sec 1, 3** are to be used in accordance with **Table 4**, **Fig. 4** and **Fig. 5**. For a web panel with opening, the procedure for opening should be used for its buckling assessment.

Wherever necessary, the following corresponding buckling requirements for direct strength analysis in **Pt 1, Ch 8, Sec 4** can be referred to:

(1) Average thickness of plate panel, in **Pt 1, Ch 8, Sec 4, 2.1.2.**

(2) Irregular plate panel, in **Pt 1, Ch 8, Sec 4, 2.3**.

(3) Reference stress, in **Pt 1, Ch 8, Sec 4, 2.4**.

(4) Lateral pressure, in **Pt 1, Ch 8, Sec 4, 2.5**.

(5) Buckling criteria, in **Pt 1, Ch 8, Sec 4, 2.6**, but using allowable buckling utilisation factors as defined in **Pt 2, Ch 1, Sec 5, Table 3**.

Table 4 Structural members and assessment methods

| Structural elements | Assessment method (1) (2) | Normal panel definition |
|---|---|---|
| Hatch cover top/bottom plating structures, see **Fig. 4** | | |
| Hatch cover top/bottom plating | SP-A | Length: between transverse girders<br>Width: between longitudinal girders |
| Irregularly stiffened panels | UP-B | Plate between local stiffeners/PSM |
| Hatch cover webs of primary supporting members, see **Fig. 5** | | |
| Web of transverse/longitudinal girder (single skin type) | UP-B | Plate between local stiffeners/face plate/PSM |
| Web of transverse/longitudinal girder (double skin type) | SP-B(3) | Length: between PSM<br>Width: full web depth |
| Web panel with opening | Procedure for opening | Plate between local stiffeners/face plate/PSM |
| Irregularly stiffened panels | UP-B | Plate between local stiffeners/face plate/PSM |

Note 1: SP and UP stand for stiffened and unstiffened panel respectively.
Note 2: A and B stand for Method A and Method B respectively.
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.

Fig. 4 Hatch cover top/bottom plating structures

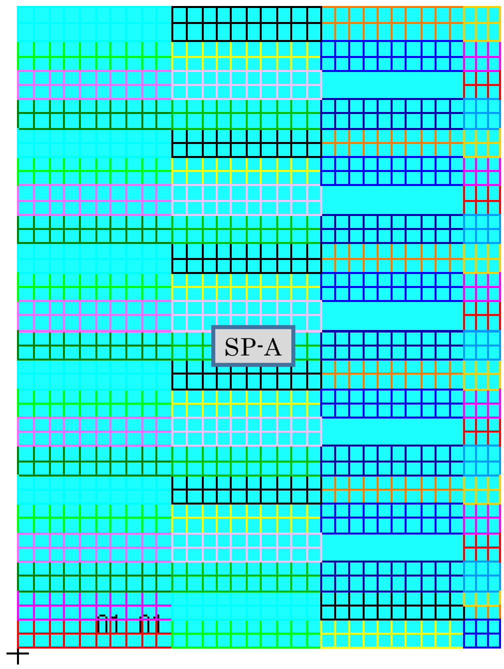
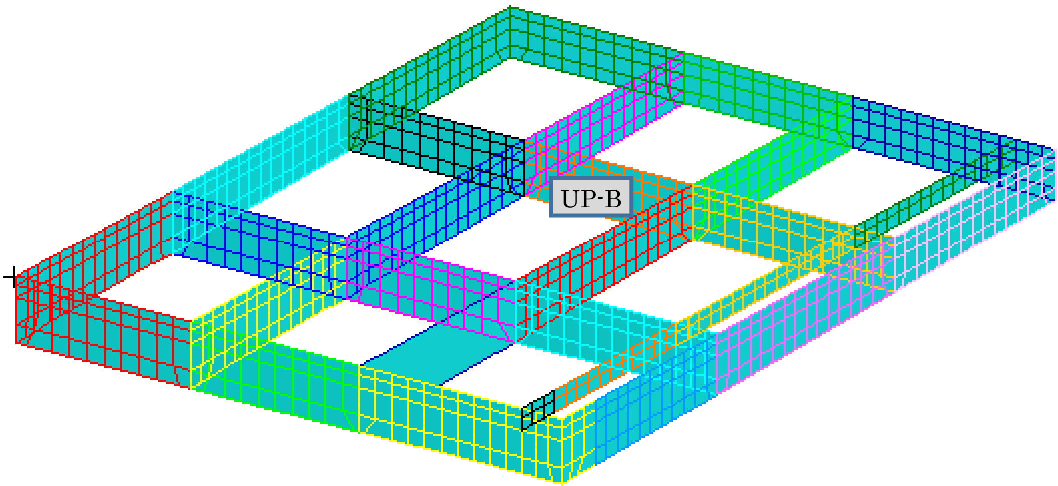



Fig. 5 Hatch cover webs of primary supporting members




5.6.4 Buckling assessment of stiffened panels with U-type stiffeners

For hatch covers fitted 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 **Fig. 2**) separately as follows:

- The attached plate panels EPP $b_1$ and $b_2$ are to be assessed using SP-A model, where in the calculation of buckling factors $K_x$ as defined in **Pt 1, Ch 8, Sec 5, Table 3**, the correction factor Flong for U-type stiffeners as defined in **Pt 1, Ch 8, Sec 5, Table 2** is to be used; and in the calculation of $K_y$ as defined in **Pt 1, Ch 8, Sec 5, Table 3**, the $F_{tran}$ for U-type stiffeners as defined in **Pt 1, Ch 8, Sec 5, 2.2.5** is to be used.
- 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.

The overall stiffened panel capacity and ultimate capacity of stiffeners of the hatch cover fitted with U-type 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:

- 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.
- Effective width of the attached plating, $b_{eff}$, taken as the sum of the $b_{eff}$ calculated for the EPP $b_1$ and $b_2$ respectively according

to SP-A model.

- Effective width of the attached plating of a stiffener without the shear lag effect, $b_{eff1}$, taken as the sum of the $b_{eff1}$ calculated for the EPP $b_1$ and $b_2$ respectively.

## 6. Hatch Coamings

### 6.1 Stiffening

6.1.1

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

6.1.2

Coamings are to be stiffened on their upper edges with a stiffener suitably shaped to fit the hatch cover closing appliances.

6.1.3

Where the height of the coaming exceeds 900 *mm*, additional strengthening may be required.

However, reductions may be granted for transverse coamings in protected areas.

6.1.4

When two hatches are close to each other, under deck stiffeners are to be fitted to connect the longitudinal coamings in order to maintaining the continuity of their strength.

Similar stiffening is to be provided over 2 frame spacings at ends of hatches exceeding 9 frame spacings in length.

In some cases, the Society may require the continuity of coamings to be maintained above the deck.

6.1.5

Where watertight metallic hatch covers are fitted, other arrangements of equivalent strength may be adopted.

### 6.2 Load Model

6.2.1

The wave lateral pressure, $P_C$ in $kN/m^2$, to be considered as acting on the hatch coamings is defined in **6.2.2** and **6.2.3**.

6.2.2

The wave lateral pressure, $P_C$ in $kN/m^2$, on the No. 1 forward transverse hatch coaming is to be taken equal to:

- $P_C = 220$, when a forecastle is fitted in accordance with **Ch 1, Sec 1, 1**.
- $P_C = 290$, in the other cases.

6.2.3

The wave lateral pressure, $P_C$ in $kN/m^2$, on the hatch coamings other than the No. 1 forward transverse hatch coaming is to be taken equal to:

$$P_C = 220$$

6.2.4

For cargo holds intended for the carriage of ballast water, the liquid internal pressures applied on hatch coaming is also to be determined according to **Pt 1, Ch 4, Sec 6**.

### 6.3 Scantlings

6.3.1 Plating

The net thickness, in mm, of the hatch coaming plate is not to be taken less than the greater value given by the following formulae:

$$t = 0.016b\sqrt{\frac{P_c}{0.95R_{eH}}}$$

$$t = 9.5$$

6.3.2 Stiffeners

The net section modulus, $Z$, in $cm^3$, of longitudinal or transverse stiffeners fitted on hatch coamings is not to be taken less than:

$$Z = 1.21\frac{P_C\, s\, \ell^2}{f_{bc}\, c_p\, R_{eH}}$$

where:

$f_{bc}$ : Coefficient taken equal to:

$f_{bc}$ = 16 in general.

$f_{bc}$ = 12 for the end span of stiffeners sniped at the coaming corners.

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

$c_p$ = 1.16 in the absence of more precise evaluation.

6.3.3 Coaming stays

At the connection with deck, the net section modulus $Z$, in $cm^3$, and the net thickness $t_w$, in $mm$, of the coaming stays designed as beams with flange connected to the deck or sniped and fitted with a bracket (examples shown in **Fig. 6** and **Fig. 7**) are to be taken not less than:

$$Z = \frac{s_C P_C H_C^2}{1.9 R_{eH}}$$

$$t_w = \frac{s_C P_C H_C}{0.5\, h\, R_{eH}}$$

where:

$H_C$ : Stay height, in $m$.

$s_C$ : Stay spacing, in $mm$.

$h$ : Stay depth, in $mm$, at the connection with deck.

Fig. 6 Coaming Stay (Example 1)

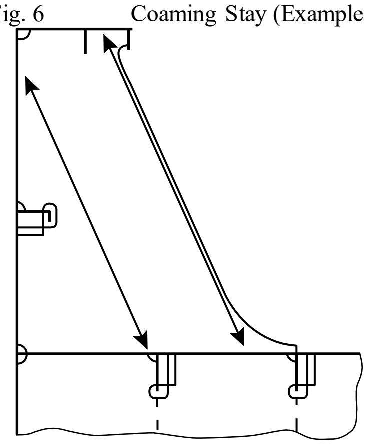
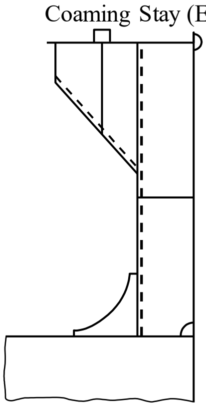


Fig. 7 Coaming Stay (Example 2)



For calculating of offered section modulus of coaming stays, the face plate area may be taken into account only when it is welded with full penetration welds to the deck plating and provided with adequate under deck structure supporting the coaming stay in the deck structure.

For other designs of coaming stays, such as those shown in **Fig. 8** and **Fig. 9**, the stress levels determined through a grillage analysis or finite element analysis, as the case may be, apply and are to be checked at the highest stressed locations. The stress levels are to comply with the following formulae:

$\sigma \leq 0.95 R_{eH}$

$\tau \leq 0.5 R_{eH}$

Fig. 8 Coaming Stay (Example 3)

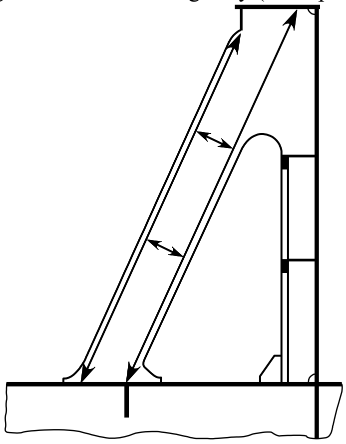
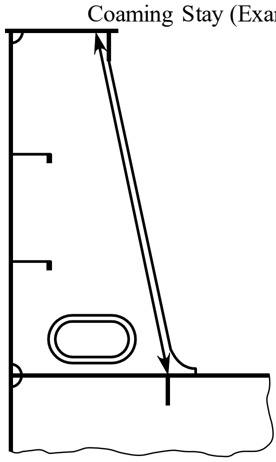


Fig. 9 Coaming Stay (Example 4)



6.3.4 Local details

The design of local details is to comply with the requirements in this section ensuring adequate structural continuity from the hatch covers into the supporting deck structure.

Hatch coamings and supporting structures are to be adequately stiffened to accommodate the loading from hatch covers, in longitudinal, transverse and vertical directions.

The normal stress $\sigma$ and the shear stress $\tau$, in $N/mm^2$, induced in the under deck structures by the loads transmitted by stays are to comply with the following formulae:

$\sigma \leq 0.95 R_{eH}$

$\tau \leq 0.5 R_{eH}$

Unless otherwise stated, weld connections and materials are to be dimensioned and selected in accordance with the requirements of **Part M**.

Double continuous fillet welding is to be adopted for the connections of stay webs with deck plating and the weld leg length is not to be less than $0.62 t_w$, where $t_w$ is the gross thickness of the stay web.

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

# 7. Weathertightness, Closing Arrangement, Securing Devices and Stoppers

## 7.1 Weathertightness

7.1.1

Where the hatchway is exposed, the weathertightness is to be ensured by gaskets and clamping devices sufficient in number and quality.

7.1.2

In general, a minimum of two securing devices or equivalent is to be provided on each side of the hatch cover.

## 7.2 Gaskets

7.2.1

The weight of hatch covers and any cargo stowed thereon, together with inertia forces generated by ship motions, are to be transmitted to the ship's structure.

7.2.2

The sealing is to be obtained by a continuous gasket of relatively soft elastic material compressed to achieve the necessary weathertightness. Similar sealing is to be arranged between cross-joint elements.

Where fitted, compression flat bars or angles are to be well rounded where in contact with the gasket and to be made of a corrosion-resistant material.

7.2.3

The gasket and the securing arrangements are to maintain their efficiency when subjected to large relative movements between the hatch cover and the ship's structure or between hatch cover elements.

If necessary, suitable devices are to be fitted to limit such movements.

7.2.4

The gasket material is to be of a quality suitable for all environmental conditions likely to be encountered by the ship, and is to be compatible with the cargoes transported.

The material and form of gasket selected are to be considered in conjunction with the type of hatch cover, the securing arrangement and the expected relative movement between the hatch cover and the ship's structure.

The gasket is to be effectively secured to the hatch cover.

7.2.5

Coamings and steel parts of hatch covers in contact with gaskets are to have no sharp edges.

7.2.6

Metallic contact is required to ensure earthing connection between the hatch cover and the hull structures.

## 7.3 Closing Arrangement, Securing Devices and Stoppers

7.3.1 General

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

Hatch covers provided with special sealing devices, insulated hatch covers, flush hatch covers and those having coamings of a reduced height according to **2.1.2** are to be considered by the Society on a case-by-case basis.

7.3.2 Arrangements

The securing and stopping devices are to be arranged so as to ensure sufficient compression on gaskets between hatch covers and coamings and between adjacent hatch covers.

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

At cross-joints of multi-panel covers, (male/female) vertical guides are to be fitted to prevent excessive relative vertical deflections between loaded/unloaded panels.

The location of stoppers is to be compatible with the relative movements between hatch covers and the ship's structure in order to prevent damage to them. The number of stoppers is to be as small as possible.

7.3.3 Spacing

The spacing of the securing arrangements is not to be greater than 6 $m$.

7.3.4 Construction

Securing arrangements with reduced scantlings may be accepted provided it can be demonstrated that the possibility of water reaching the deck is negligible.

Securing devices are to be of reliable construction and securely attached to the hatchway coamings, decks or hatch covers.

Individual securing devices on each hatch cover are to have approximately the same stiffness characteristics.

7.3.5 Area of securing devices

The gross cross area of each securing device is not to be less than the value obtained, in $cm^2$, from the following formula:

$$A = 1.4 S_S \left(\frac{235}{R_{eH}}\right)^{\alpha}$$

where:

$S_S$ : Spacing, in m, of securing devices.

$\alpha$ : Coefficient taken equal to:

$\alpha = 0.75$ for $R_{eH} > 235\ N/mm^2$.

$\alpha = 1.0$ for $R_{eH} \le 235\ N/mm^2$.

In the above calculations, $R_{eH}$ may not be taken greater than $0.7\ R_m$.

Between hatch cover and coaming and at cross-joints, a packing line pressure sufficient to obtain weathertightness is to be maintained by securing devices. For packing line pressures exceeding 5 $N/mm$, the net cross area A is to be increased in direct proportion. The packing line pressure is to be specified.

In the case of securing arrangements which are particularly stressed due to the unusual width of the hatchway, the net cross area $A$ of the above securing arrangements is to be determined through direct calculations.

7.3.6 Inertia of edges elements

The hatch cover edge stiffness is to be sufficient to maintain adequate sealing pressure between securing devices.

The moment of inertia of edge elements is not to be less than the value obtained, in $cm^4$, from the following formula:

$$I = 6\, P_L\, S_S^4$$

where:

$P_L$ : Packing line pressure, in $N/mm$, to be taken not less than 5.

$S_S$ : Spacing, in $m$, of securing devices.

7.3.7 Diameter of rods or bolts

Rods or bolts are to have a gross diameter not less than 19 $mm$ for hatchways exceeding 5 $m^2$ in area.

7.3.8 Stoppers

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

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

No. 1 hatch cover is to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 230 $kN/m^2$. This pressure may be reduced to 175 $kN/m^2$ if a forecastle is fitted in accordance with **Ch 1, Sec 1, 1**.

The equivalent stress in stoppers, their supporting structures and calculated in the throat of the stopper welds is to be equal to or less than the allowable value, equal to 0.8 $R_{eH}$.

### 7.4 Cleats

7.4.1

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

7.4.2

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

## 8. Drainage

### 8.1 Arrangement

8.1.1

Drainage is to be arranged inside the line of gaskets by means of a gutter bar or vertical extension of the hatch side and end coaming.

8.1.2

Drain openings are to be arranged at the ends of drain channels and are to be provided with efficient means for preventing ingress of water from outside, such as non-return valves or equivalent.

8.1.3

Cross-joints of multi-panel hatch covers are to be arranged with drainage of water from the space above the gasket and a drainage channel below the gasket.

8.1.4

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

# Section 6 ADDITIONAL CLASS NOTATION GRAB

**Symbols**

$M_{GR}$ : Mass of unladen grab, in *t*.

## 1. General

### 1.1 Application

1.1.1

The additional class notation *GRAB[X]* is assigned, in accordance with **Pt 1, Ch 1, Sec 1, 3.2.2**, to ships with holds designed for loading/unloading by grabs having a maximum mass of unladen grab, in tons up to *[X]* tons, in compliance with the requirements of this section.

1.1.2

It is to be noted that this additional class notation does not negate the use of heavier grabs, but the owner and operators are to be made aware of the increased risk of local damage and possible early renewal of inner bottom plating if heavier grabs are used regularly or occasionally to discharge cargo.

## 2. Scantlings

### 2.1 Plating

2.1.1 General

The net thickness of plating of inner bottom and vertical sloped cargo hold; excluding bilge wells, is to be taken as the greater of the following values:

- $t$, as obtained according to requirements in **Pt 1, Ch 6** and **Pt 1, Ch 7**.
- $t_{GR}$, as defined in **2.1.2** and **2.1.3**.

2.1.2 Inner bottom plating

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

$$t_{GR} = 0.62\sqrt{bk}\left(\frac{M_{GR}}{20}\right)^{0.25}$$

2.1.3 Vertical and sloped cargo hold boundaries

The net thickness $t_{GR}$, in $mm$, as defined in this sub-section apply to the following structural elements.

- Hopper tank sloped plating.
- Transverse lower stool plating.
- Transverse plane bulkhead plating.
- Face plates of transverse corrugated bulkheads without lower stool.
- Inner hull.

Up to a height of 3.0 $m$ above, the lowest point of the inner bottom is to be obtained from the following formula:

$$t_{GR} = 0.55\sqrt{bk}\left(\frac{M_{GR}}{20}\right)^{0.25}$$

# Chapter 2 OIL TANKERS

## Section 1 GENERAL ARRANGEMENT DESIGN

### 1. General

#### 1.1 General

1.1.1

This section covers the general structural arrangement requirements for oil tankers, which are based on national and international regulations.

### 2. Separation of Cargo Tanks

#### 2.1 General

2.1.1

The designer's attention is to be drawn on the arrangement of the cargo pump room, cargo tanks, slop tanks and cofferdams, main cargo control stations, control stations, accommodation and service spaces as well as on the need to separate the cargo tanks from the machinery space.

### 3. Double Hull Arrangement

#### 3.1 General

3.1.1

All oil tankers are to be provided with double bottom tanks and spaces, and double side tanks and spaces, in accordance with **Pt 1, Ch 2, Sec 3**. The double bottom and double side tanks and spaces, protect the cargo tanks or spaces, and are not to be used for the carriage of oil cargoes.

3.1.2

Cargo tanks are to be of a size and arrangement that hypothetical oil outflow from side and bottom damage, anywhere in the length of the ship, is limited.

### 4. Access Arrangements

#### 4.1 Special Requirements for Oil Tankers

4.1.1

Where a duct keel or pipe tunnel is fitted, provision is to be made for at least two exits to the open deck arranged at a maximum distance from each other. The duct keel or pipe tunnel is not to pass into machinery spaces. The aft access may lead from the pump room to the duct keel. Where an aft access is provided from the pump room to the duct keel, the access opening from the pump room to the duct keel is to be provided with an oil-tight cover plate or a watertight door.

Mechanical ventilation is to be provided and such spaces are to be sufficiently ventilated prior to entry. A notice board is to be fitted at each entrance to the pipe tunnel stating that before any attempt is made to enter, the ventilating fan must have been in operation for a sufficient period. In addition, the atmosphere in the tunnel is to be sampled by a gas monitor, and where an inert gas system is fitted in cargo tanks, an oxygen monitor is to be provided.

4.1.2

Where a watertight door is fitted in the pump room for access to the duct keel, the scantlings of the watertight door are to comply with the requirements of the individual Society and the following additional requirements:

(a) The watertight door is to be capable of being manually closed from outside the main pump room entrance, in addition to bridge operation. A means of indicating whether the door is open or closed is to be provided locally and on the bridge.

(b) A notice is to be affixed at each operating position to the effect that the watertight door is to be kept closed during normal operations of the ship, except when access to the pipe tunnel is required.

4.1.3

Special consideration is to be given to any proposals to fit permanent repair/maintenance access openings with oil-tight covers in cargo tank bulkheads. Attention is drawn to the relevant national regulations concerning load line and oil outflow aspects of such arrangements.

# Section 2 STRUCTURAL DESIGN PRINCIPLES

## 1. Corrosion Protection

### 1.1 General

1.1.1 Cathodic protection systems in cargo tanks

Cathodic protection systems, if fitted in cargo tanks, are to comply with **1.2**.

1.1.2 Paint containing aluminium

Paint containing aluminium, when used in cargo tanks, is to comply with **1.3**.

### 1.2 Internal Cathodic Protection Systems

1.2.1

When a cathodic protection system is to be fitted to steel structures in tanks used for liquid cargo with flash point below 60°C, a plan of the fitting arrangement is to be submitted for approval. The arrangements are to be considered for safety against fire and explosion. This approval also applies to adjacent tanks.

1.2.2

Permanent magnesium or magnesium alloy anodes in tanks are not acceptable, except in tanks solely intended for water ballast that are not adjacent to cargo tanks.

Impressed current systems are not to be used in cargo tanks due to the development of chlorine and hydrogen that can result in an explosion.

Aluminium anodes are accepted, however, in tanks with liquid cargo with flash point below 60°C and in adjacent ballast tanks, aluminium anodes are to be located so a kinetic energy of not more than 275 *J* is developed in the event of their loosening and becoming detached.

1.2.3

Aluminium anodes are to be located in such a way that they are protected from falling objects. They are not to be located under tank hatches or Butterworth openings unless protected by adjacent structure.

1.2.4

Tanks, in which anodes are installed, are to have sufficient holes for the circulation of air to prevent gas from collecting in pockets.

### 1.3 Paint Containing Aluminium

1.3.1

The use of aluminium coatings containing greater than 10% aluminium by weight in the dry film is prohibited in cargo tanks, cargo tank deck area, pump rooms, cofferdams or any other area where cargo vapour may accumulate.

1.3.2

Aluminised pipes may be permitted in ballast tanks, in inerted cargo tanks and, provided the pipes are protected from accidental impact, in hazardous areas on open deck.

# Section 3 HULL LOCAL SCANTLING

**Symbols**

For symbols not defined in this section, refer to **Pt 1, Ch 1, Sec 4**.

$S$ : Primary supporting member spacing as defined in **Pt 1, Ch 3, Sec 7, 1.2.2**, in $m$.

$C_{t\text{-}pr}$ : Permissible shear stress coefficient for primary supporting members taken equal to:

$C_{t\text{-}pr} = 0.70$ for AC-S.

$C_{t\text{-}pr} = 0.85$ for AC-SD.

$C_{s\text{-}pr}$ : Permissible bending stress coefficient for primary supporting members taken equal to:

$C_{s\text{-}pr} = 0.70$ for AC-S.

$C_{s\text{-}pr} = 0.85$ for AC-SD.

$s_{cg}$ : Half pitch length of corrugation, in $mm$. See **Fig.4**.

$\ell_{cg}$ : Length of corrugation, in $m$, which is defined as the distance between the lower stool and the upper stool. Where no lower or upper stool is fitted, $\ell_{cg}$ is to be measured to lower or upper end as shown in **Fig. 4**.

## 1. Primary Supporting Members in Cargo Hold Region

### 1.1 General

1.1.1

The following requirements relate to the determination of scantlings of the primary supporting members within $0.4L_{CSR}$ amidships and those outside $0.4L_{CSR}$ amidships provided that the geometry and fixation of primary supporting member is similar with those amidships.

1.1.2

The section modulus and shear area criteria for primary supporting members contained in this sub-section apply to structural configurations shown in **Pt 1, Ch 1, Sec 1, Fig. 3** and are applicable to the following structural elements:

(a) Floors and girders within the double bottom,

(b) Deck transverses,

(c) Side transverses within double side structure,

(d) Vertical web frames on longitudinal bulkheads with or without cross ties,

(e) Horizontal stringers on transverse bulkheads, except those fitted with buttresses or other intermediate supports,

(f) Cross ties in wing cargo and centre cargo tanks.

1.1.3

Floors, horizontal stringers, side transverses and vertical webs adjacent to transverse bulkheads which get additional supports by horizontal stringers or buttresses are excluded from the application of this section.

1.1.4

Webs of the primary supporting members are to be stiffened in accordance with **Pt 1, Ch 8, Sec 2, 4**.

1.1.5

Webs of the primary supporting members are to have a depth of not less than given by the requirements of **1.5.1**, **1.7.1** and **1.8.1**, as applicable.

1.1.6

In any case, primary supporting members that have open slots for stiffeners are to have a depth not less than 2.5 times the depth of the slots if slots are not closed.

1.1.7

Where it is impracticable to fit a primary supporting member with the required web depth, then it is permissible to fit a member with reduced depth provided that the fitted member has equivalent moment of inertia or deflection to the required member. The required equivalent moment of inertia is to be based on an equivalent section given by the effective width of plating at mid span with required plate thickness, web of required depth and thickness and face plate of sufficient width and thickness to satisfy the required mild steel section modulus.

The equivalent moment of inertia may be also demonstrated by an equivalent member having the same deflection as the required member.

All other rule requirements, such as minimum thicknesses, slenderness ratio, section modulus and shear area, are to be satisfied for the member of reduced depth.

### 1.2 Design Load Sets

1.2.1

The design load sets for the evaluation of primary supporting members are given in **Table 1**.

Table 1 Design Load Sets for Primary Supporting Members

| Item | Design load set (1) (5) (6) | Load component | Draught | Design load | Loading condition |
|---|---|---|---|---|---|
| Double bottom floors and girders (3) | *SEA-1* | $P_{ex}$ | $0.9T_{SC}$ (2) | *S+D* | Sea pressure only |
| | *SEA-2* | $P_{ex}$ | $T_{SC}$ | *S* | |
| | *OT-4* | $P_{in} - P_{ex}$ | $0.6T_{SC}$ | *S+D* | Net pressure difference between cargo pressure and sea pressure |
| | *OT-5* | $P_{in} - P_{ex}$ | (4) | *S* | |
| Side transverses (3) | *SEA-1* | $P_{ex}$ | $0.9\ T_{SC}$ | *S+D* | Sea pressure only |
| | *SEA-2* | $P_{ex}$ | $T_{SC}$ | *S* | |
| | *OT-1* | $P_{in}$ | $T_{SC}$ | *S+D* | Cargo pressure only |
| | *OT-2* | $P_{in}$ | $0.6T_{SC}$ | *S+D* | |
| | *OT-3* | $P_{in}$ | - | *S* | |
| Deck transverses | *SEA-1* | $P_{ex}$ | $T_{SC}$ | *S+D* | Green sea pressure only or other loads on deck |
| | *OT-1* | $P_{in}$ | $T_{SC}$ | *S+D* | Cargo pressure only |
| | *OT-2* | $P_{in}$ | $0.6T_{SC}$ | *S+D* | |
| | *OT-3* | $P_{in}$ | - | *S* | |
| Vertical web frames on longitudinal bulkheads | *OT-1* | $P_{in}$ | $T_{SC}$ | *S+D* | Pressure from one side only. Full cargo tank with adjacent cargo tank empty |
| | *OT-2* | $P_{in}$ | $0.6T_{SC}$ | *S+D* | |
| | *OT-3* | $P_{in}$ | - | *S* | |
| Horizontal stringers on transverse bulkhead | *OT-1* | $P_{in}$ | $T_{SC}$ | *S+D* | Pressure from one side only. Full cargo tank with adjacent forward or aft cargo tank empty. |
| | *OT-2* | $P_{in}$ | $0.6T_{SC}$ | *S+D* | |
| | *OT-3* | $P_{in}$ | - | *S* | |
| Cross ties in centre tanks | *OT-1* | $\frac{P_{in-pt} + P_{in-stb}}{2}$ | $T_{SC}$ | *S+D* | Full wing cargo tanks, centre tank empty. |
| | *OT-2* | $\frac{P_{in-pt} + P_{in-stb}}{2}$ | $0.6T_{SC}$ | *S+D* | |
| | *OT-3* | $P_{in}$ | - | *S* | |

| | | | | | |
|---|---|---|---|---|---|
| Cross ties in wing tanks | *SEA-1* | $\frac{P_{in}+P_{ex}}{2}$ | $T_{SC}$ | *S+D* | Full centre tank, wing cargo tanks empty. |
| | *SEA-2* | $\frac{P_{in}+P_{ex}}{2}$ | 0.6 $T_{SC}$ | *S+D* | |
| | *OT-4* | $\frac{P_{in}+P_{ex}}{2}$ | $T_{SC}$ | *S* | |

where:

$P_{in-pt}$ : Design pressure from port side wing cargo tank, in $kN/m^2$.

$P_{in-stb}$ : Design pressure from starboard side wing cargo tank, in $kN/m^2$.

(1) The static and dynamic load components are to be determined in accordance with **Pt 1, Ch 4, Sec 7, Table 1**.

(2) If the loading condition where the combination of an empty cargo tank and a mean ship's draught greater than 0.9 $T_{SC}$ is included in ship's loading manual, the maximum corresponding draught is to be considered.

(3) Draughts specified for bottom floors, girders and side transverses are based on operational limits specified in **Pt 1, Ch 4, Sec 8, 2** and **Pt 1, Ch 4, Sec 8, 3**. Where the optional loading conditions exceed the minimum Rule required loading conditions, the draughts will be subject to special consideration.

(4) For tankers with two oil-tight longitudinal bulkheads, the draught is to be taken as 0.25 $T_{SC}$. For tankers with a centreline bulkhead, the draught is to be taken as 0.33 $T_{SC}$.

(5) When the ship's configuration cannot be described by the structural members or structural configurations identified above, then the applicable Design Load Sets to determine the scantling requirements of primary supporting member are to be selected so as to specify all applicable cases from the following:

- A full tank on one side of the member with the tank or space on the other side empty.
- A full tank on one side of the member with the external pressure minimised.
- External pressure maximised with the adjacent tank or space empty.

The boundary is to be evaluated for loading from both sides. Design Load Sets are to be selected based on the tank or space contents and are to maximise the net pressure on the structural boundary, the draught to use is to be taken in accordance with the Design Load Set and this table. Design Load Sets covering the *S* and *S+D* design load combinations are to be selected.

(6) For a void or dry space, the pressure component from the void side is to be ignored.

### 1.3 Floors in Double Bottom

1.3.1 Structural arrangement

Plate floors are to be arranged in way of transverse bulkheads and bulkhead stools.

1.3.2 Net shear area

The net shear area, $A_{shr-n50}$ in $cm^2$, of the floors at any position in the floor is not to be less than:

$$A_{shr-n50}=\frac{8.5Q}{C_{t-pr}\tau_{eH}}$$

where:

$Q$: Design shear force, in $kN$.

$$Q=f_{shr}PS\ell_{shr}$$

$f_{shr}$: Shear force distribution factor:

$$f_{shr}=f_{shr-i}(1-\frac{2y_i}{\ell_{shr}})$$ but not to be taken as less than 0.2.

$f_{shr-i}$: Shear force distribution factor at the end of the span, $\ell_{shr}$, as given in **Table 2**.

$\ell_{shr}$: Effective shear span, of the double bottom floor, in $m$, as shown in **Fig. 2**. In way of bracket ends, the effective shear span is measured to the toes of the effective end bracket, as defined in **Pt 1, Ch 3, Sec 7, 1.1.7**. Where the floor ends on a girder at a hopper or stool structure, the effective shear span is measured to a point that is one-half of the distance from the girder to the adjacent bottom and inner-bottom longitudinal, as shown in **Fig. 2**.

$y_i$ : Distance from the considered cross section of the floor to the nearest end of the effective shear span, $\ell_{shr}$ in $m$.

$P$ : Design pressure given in **Table 1** for the design load set being considered, calculated at mid point of effective shear span, $\ell_{shr}$ of a floor located midway between transverse bulkheads or transverse bulkhead and wash bulkhead, where fitted, in $kN/m^2$.

Table 2 Shear Force Distribution Factors of Floors

| Structural configuration | Centre tank ($f_{shr3}$ in **Fig. 1**) | Wing tank: At inboard end ($f_{shr2}$ in **Fig. 1**) | Wing tank: At hopper knuckle end ($f_{shr1}$ in **Fig. 1**) |
|---|---|---|---|
| Ships with centreline longitudinal bulkhead | - | 0.40 | 0.60 |
| Ships with two longitudinal bulkheads | 0.5 | 0.50 | 0.65 |

Fig. 1 Shear Force Distribution Factors of Floors

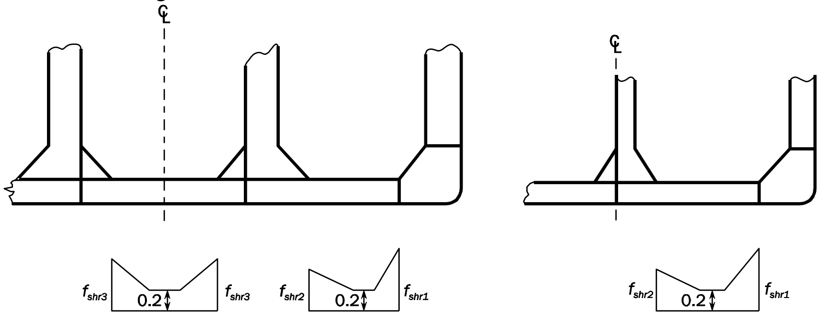
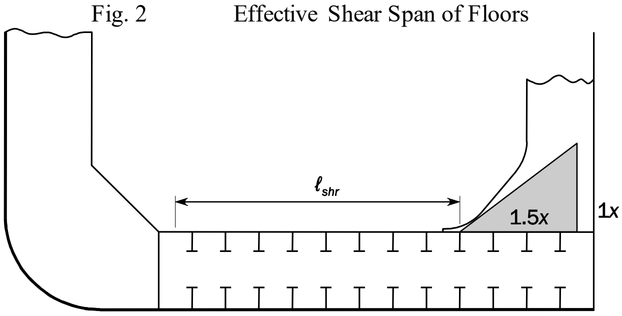
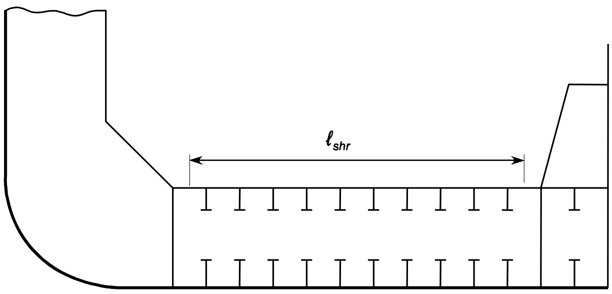



Fig. 2 Effective Shear Span of Floors




Typical arrangement with hopper and end bracket




Typical arrangement with hopper and stool

### 1.4 Girders in Double Bottom

1.4.1 Structural arrangement

Continuous double bottom girders are to be arranged at the centreline or duct keel, at the hopper side and in way of longitudinal bulkheads and bulkhead stools.

1.4.2 Net shear area of centre girders

For double bottom centre girders where no longitudinal bulkhead is fitted above, the net shear area, $A_{shr-n50}$ in $cm^2$, of the double bottom centre girder in way of the first bay from each transverse bulkhead and wash bulkhead, where fitted, is not to be less than:

$$A_{shr-n50} = \frac{8.5Q}{C_{t-pr}\tau_{eH}}$$

where:

$Q$: Design shear force, in $kN$, taken as:

$$Q = 0.21 n_1 n_2 P \ell_{shr}^2$$

$\ell_{shr}$: Effective shear span as defined in 1.3.2.

$P$: Design pressure, in $kN/m^2$, as defined in 1.3.2.

$n_1$: Coefficient taken as:

$$n_1 = 0.00935\left(\frac{\ell_{shr}}{S}\right)^2 - 0.163\left(\frac{\ell_{shr}}{S}\right) + 1.289$$

$n_2$: Coefficient taken as:

$$n_2 = 1.3 - \left(\frac{S}{12}\right)$$

$S$: Double bottom floor spacing, in $m$, as defined in Pt 1, Ch 3, Sec 7, 1.2.2.

1.4.3 Net shear area of side girders

For double bottom side girders where no longitudinal bulkhead is fitted above, the net shear area, $A_{shr-n50}$ in $cm^2$, of the double bottom side girder in way of the first bay from each transverse bulkhead and wash bulkhead, where fitted, is not to be less than:

$$A_{shr-n50} = \frac{8.5Q}{C_{t-pr}\tau_{eH}}$$

where:

$Q$: Design shear force, in $kN$.

$$Q = 0.14 n_3 n_4 P \ell_{shr}^2$$

$n_3$: Coefficient taken as:

$$n_3 = 1.072 - 0.0357\left(\frac{\ell_{shr}}{S}\right)$$

$n_4$: Coefficient taken as:

$$n_4 = 1.2 - \left(\frac{S}{18}\right)$$

$S$: Double bottom floor spacing, in $m$, as defined in Pt 1, Ch 3, Sec 7, 1.2.2.

$\ell_{shr}$: Effective shear span as defined in 1.3.2.

$P$: Design pressure, in $kN/m^2$, as defined in 1.3.2.

### 1.5 Deck Transverses

1.5.1 Web depth

The web depth of under deck transverses is not to be less than:

- 0.20 $\ell_{bdg-dt}$ for deck transverses in the wing cargo tanks of ships with two longitudinal bulkheads.
- 0.13 $\ell_{bdg-dt}$ for deck transverses in the centre cargo tanks of ships with two longitudinal bulkheads. The web depth of deck transverses in the centre cargo tank is not to be less than 90% of that of the deck transverses in the wing cargo tank.
- 0.10 $\ell_{bdg-dt}$ for the deck transverses of ships with a centreline longitudinal bulkhead.
- The web height required in 1.1.6.

The web depth of above deck transverses is not to be less than:

- 0.10 $\ell_{bdg-dt}$
- The web height required in **1.1.6**.

where:

$\ell_{bdg-dt}$: Effective bending span, in $m$, as defined in **1.5.2**.

1.5.2 Net section modulus of deck transverses fitted below the upper deck

The net section modulus of deck transverses fitted below the upper deck, in $cm^3$, is not to be less than $Z_{in-n50}$ and $Z_{ex-n50}$ as given by the following formulae.

The net section modulus of the deck transverses fitted below the upper deck in the wing cargo tanks is also not to be less than required for the deck transverses fitted below the upper deck in the centre tanks.

$$Z_{in-n50} = \frac{850 M_{in}}{C_{s-pr} R_{eH}}$$

$$Z_{ex-n50} = \frac{850 M_{ex}}{C_{s-pr} R_{eH}}$$

where:

$M_{in}$ : Design bending moment due to cargo pressure, in $kNm$, taken as:

- For deck transverses in wing cargo tanks of ships with two longitudinal bulkheads, and for deck transverses in cargo tanks of ships with a centreline longitudinal bulkhead:

  $M_{in} = 0.042 \varphi_t P_{in-dt} S \ell_{bdg-dt}^2 + M_{st}$ but is not to be taken as less than $M_0$.

- For deck transverses in centre cargo tank of ships with two longitudinal bulkheads:

  $M_{in} = 0.042 \varphi_t P_{in-dt} S \ell_{bdg-dt}^2 + M_{vw}$ but is not to be taken as less than $M_0$.

$M_{st}$ : Bending moment transferred from the side transverse, in $kNm$:

$$M_{st} = c_{st} \beta_{st} P_{in-st} S \ell_{bdg-st}^2$$

where a cross tie is fitted in a wing cargo tank and $\ell_{bdg-st-ct}$ is greater than 0.7 $\ell_{bdg-st}$, then $\ell_{bdg-st}$ in the above formula may be taken as $\ell_{bdg-st-ct}$.

$M_{vw}$ : Bending moment transferred from the vertical web frame on the longitudinal bulkhead, in $kNm$:

$$M_{vw} = c_{vw} \beta_{vw} P_{in-vw} S \ell_{bdg-vw}^2$$

where $\ell_{bdg-vw-ct}$ is greater than 0.7 $\ell_{bdg-vw}$, then $\ell_{bdg-vw}$ in the above formula may be taken as $\ell_{bdg-vw-ct}$. For vertically corrugated bulkheads, $M_{vw}$ is to be taken equal to bending moment in upper end of corrugation over the spacing between deck transverses.

$M_0$ : Minimum bending moment, in $kNm$.

$$M_0 = 0.083 P_{in-dt} S \ell_{bdg-dt}^2$$

$M_{ex}$: Design bending moment due to green sea pressure, in $kNm$.

$$M_{ex} = 0.067 P_{ex-dt} S \ell_{bdg-dt}^2$$

$P_{in-dt}$ : Design cargo pressure given in **Table 1** for the design load set being considered, calculated at mid-point of effective bending span, $\ell_{bdg-dt}$ of the deck transverse located at mid tank, in $kN/m^2$.

$P_{in-st}$ : Corresponding design cargo pressure in wing cargo tank given in **Table 1** for the design load set being considered, calculated at the mid-point of effective bending span, $\ell_{bdg-st}$ of the side transverse located at mid-tank, in $kN/m^2$.

$P_{in-vw}$ : Corresponding design cargo pressure in the centre cargo tank of ships with two longitudinal bulkheads given in **Table 1** for the design load set being considered, calculated at mid-point of effective bending span, $\ell_{bdg-vw}$ of the vertical web frame on the longitudinal bulkhead located at mid-tank, in $kN/m^2$.

$P_{ex-dt}$ : Design green sea pressure given in **Table 1** for the design load set being considered, calculated at mid-point of effective bending span, $\ell_{bdg-dt}$ of the deck transverse located at mid tank, in $kN/m^2$.

$\varphi_t$ : Coefficient taken as:

$$\varphi_t = 1 - 5\left(\frac{y_{toe}}{\ell_{bdg-dt}}\right) \quad \text{but not taken less than 0.6.}$$

$y_{toe}$ : Distance from the end of effective bending span, $\ell_{bdg-dt}$ to the toe of the end bracket of the deck transverse, in $m$.

$\beta_{st}$ : Coefficient taken as:

$$\beta_{st} = 0.9\left(\frac{\ell_{bdg-st}}{\ell_{bdg-dt}}\right)\left(\frac{I_{dt-n50}}{I_{st-n50}}\right) \quad \text{but not taken less than 0.10 or greater than 0.65.}$$

$\beta_{vw}$ : Coefficient taken as:

$$\beta_{vw} = 0.9\left(\frac{\ell_{bdg-vw}}{\ell_{bdg-dt}}\right)\left(\frac{I_{dt-n50}}{I_{vw-n50}}\right) \quad \text{but not taken less than 0.10 or greater than 0.50.}$$

$\ell_{bdg-dt}$: Effective bending span of the deck transverse, in $m$, see **Pt 1, Ch 3, Sec 7, 1.1.6** and **Fig. 3**, but is not to be taken as less than 60% of the breadth of the tank at the location being considered.

$\ell_{bdg-st}$ : Effective bending span of the side transverse, in $m$, between the deck transverse and the bilge hopper, see **Pt 1, Ch 3, Sec 7, 1.1.6** and **Fig. 3**.

$\ell_{bdg-st-ct}$: Effective bending span of the side transverse, in $m$, between the deck transverse and the mid depth of the cross tie, where fitted in wing cargo tank, see **Pt 1, Ch 3, Sec 7, 1.1.6**.

$\ell_{bdg-vw}$ : Effective bending span of the vertical web frame on the longitudinal bulkhead, in $m$, between the deck transverse and the bottom structure, see **Pt 1, Ch 3, Sec 7, 1.1.6** and **Fig. 3**.

$\ell_{bdg-vw-ct}$: Effective bending span of the vertical web frame on longitudinal bulkhead, in $m$, between the deck transverse and the mid depth of the cross tie, see **Pt 1, Ch 3, Sec 7, 1.1.6**.

$I_{dt-n50}$ : Net moment of inertia of the deck transverse at mid-span with an effective breadth of attached plating specified in **Pt 1, Ch 3, Sec 7, 1.3.2**, in $cm^4$.

$I_{st-n50}$ : Net moment of inertia of the side transverse at mid-span with an effective breadth of attached plating specified in **Pt 1, Ch 3, Sec 7, 1.3.2**, in $cm^4$.

$I_{vw-n50}$ : Net moment of inertia of the longitudinal bulkhead vertical web frame at mid-span with an effective breadth of attached plating specified in **Pt 1, Ch 3, Sec 7, 1.3.2**, in $cm^4$.

$c_{st}$ : Coefficient given in **Table 3**.

$c_{vw}$ : Coefficient given in **Table 3**.

Table 3 Values of $c_{st}$ and $c_{vw}$ for Deck Transverses

| Structural configuration | | | $c_{st}$ | $c_{vw}$ |
|---|---|---|---|---|
| Ships with centreline longitudinal bulkhead | | | 0.056 | - |
| Ships with two longitudinal bulkheads | Cross tie in centre cargo tank | $M_{vw}$ based on $\ell_{bdg-vw-ct}$ | - | 0.044 |
| | | $M_{st}$ based on $\ell_{bdg-st}$ or $M_{vw}$ based on $\ell_{bdg-vw}$ | 0.044 | 0.016 |
| | Cross ties in wing cargo tanks | $M_{st}$ based on $\ell_{bdg-st-ct}$ or $M_{vw}$ based on $\ell_{bdg-vw-ct}$ | 0.044 | 0.044 |
| | | $M_{st}$ based on $\ell_{bdg-st}$ or $M_{vw}$ based on $\ell_{bdg-vw}$ | 0.041 | 0.015 |

1.5.3 Net shear area of deck transverses fitted below the upper deck

The net shear area of deck transverses fitted below the upper deck, in $cm^2$, is not to be less than $A_{shr-in-n50}$ and $A_{shr-ex-n50}$ as given by:

$$A_{shr-in-n50} = \frac{8.5Q_{in}}{C_{t-pr}\tau_{eH}}$$

$$A_{shr-ex-n50} = \frac{8.5Q_{ex}}{C_{t-pr}\tau_{eH}}$$

where:

$Q_{in}$ : Design shear force due to cargo pressure, in $kN$.

$$Q_{in} = 0.65 P_{in-dt} S \ell_{shr} + c_1 D b_{ctr} S \rho_L g$$

$Q_{ex}$ : Design shear force due to green sea pressure, in $kN$.

$$Q_{ex} = 0.65 P_{ex-dt} S \ell_{shr}$$

$P_{in-dt}$ : Design pressure in $kN/m^2$, defined in **1.5.2**.

$P_{ex-dt}$ : Design pressure in $kN/m^2$, defined in **1.5.2**.

$\ell_{bdg-dt}$ : Effective span, in $m$, defined in **1.5.2**.

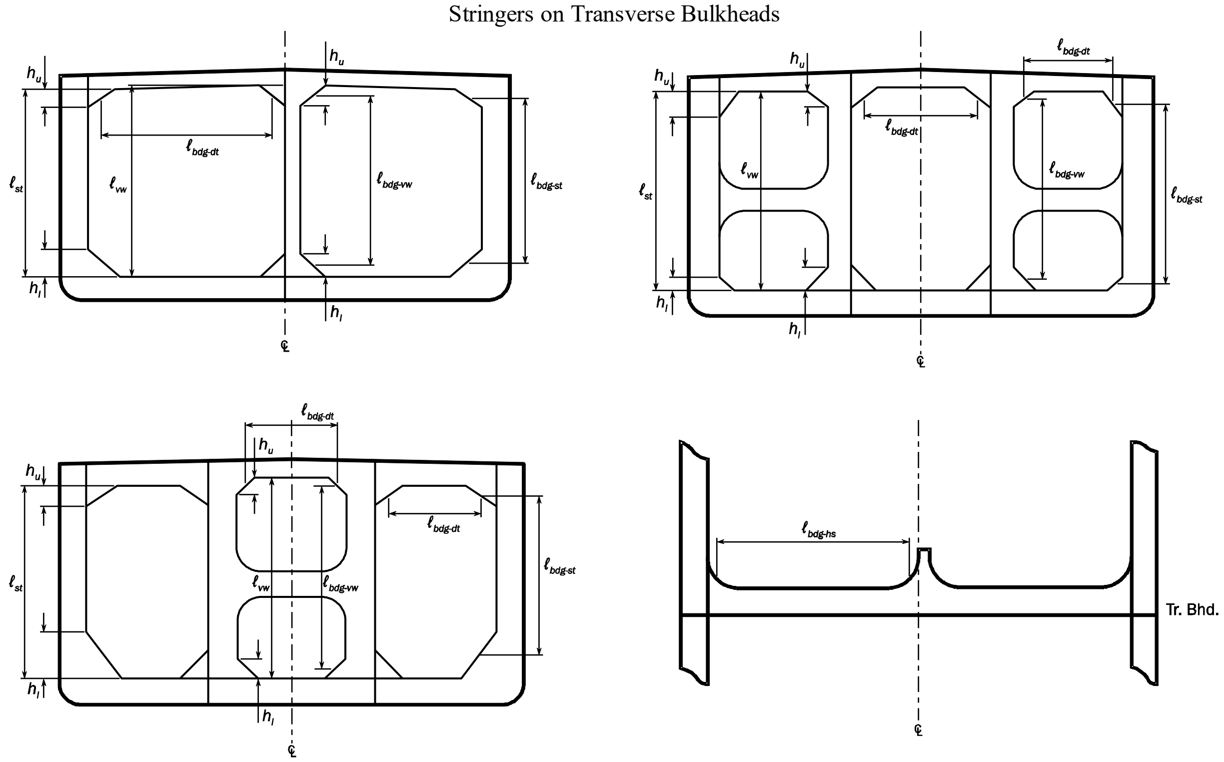
$\ell_{shr}$ : Effective shear span, of the deck transverse, in $m$, see **Pt 1, Ch 3, Sec 7, 1.1.7**.

$c_1$ : Coefficient taken as:

- $c_1 = 0.04$ in way of wing cargo tanks of ships with two longitudinal bulkheads.
- $c_1 = 0.00$ in way of centre tank of ships with two longitudinal bulkheads.
- $c_1 = 0.00$ for ships with a centreline longitudinal bulkhead.

$b_{ctr}$ : Breadth of the centre tank, in $m$.

Fig. 3 Definition of Spans of Deck, Side Transverses, Vertical Web Frames on Longitudinal Bulkheads and Horizontal Stringers on Transverse Bulkheads




1.5.4 Deck transverses fitted above the upper deck

When deck transverses are fitted above the upper deck, the net section modulus and shear area of deck transverses are not to be less than $Z_{n50}$ and $A_{shr-n50}$, in $cm^3$ and $cm^2$ respectively, as given by the following formulae. The required section modulus and shear area are to be maintained over the full length of span.

$$Z_{n50} = \frac{850 |P| S \ell_{bdg}^2}{f_{bdg} C_{s-pr} R_{eH}}$$

$$A_{shr-n50} = \frac{8.5 f_{shr} |P| S \ell_{shr}}{C_{t-pr} \tau_{eH}}$$

where:

$P$ : Design pressure given in **Table 1** for the design load set being considered, calculated at midpoint of effective bending span, $\ell_{bdg}$ of the deck transverse located at mid tank, in $kN/m^2$.

$f_{bdg}$ : Coefficient taken as:

$f_{bdg}$ = 12 for design load set *OT*-1, *OT*-2 and *OT*-3 as defined in **Table 1**.

$f_{bdg}$ = 15 for design load set *SEA*-1 as defined in **Table 1**.

$f_{shr}$ : Coefficient taken as:

$f_{shr}$ = 0.5

$\ell_{bdg}$ : Effective bending span of the deck transverse fitted above upper deck, in $m$, measured from inner hull welded to deck to longitudinal bulkhead, or upper stool plating where upper stool is fitted

$\ell_{shr}$ : Effective shear span of the deck transverse fitted above upper deck, in $m$, measured from inner hull welded to deck to longitudinal bulkhead, or upper stool plating where upper stool is fitted

As an alternative, the required section modulus and shear area may be obtained by finite element method in accordance with **Pt 1, Ch 7** and with in consideration of loading patterns A1, A2 or B1, B2 as defined in **Pt 1, Ch 4, Sec 8, 3.2.9** with draught equal to $T_{SC}$ and cargo density of 1.025 $t/m^3$.

1.5.5 Deck transverse adjacent to transverse bulkhead

The scantling of deck transverse adjacent to the transverse bulkhead is to comply with the requirements of **1.5.2** to **1.5.4** for design green sea pressure only.

### 1.6 Side Transverses

1.6.1 Net shear area

The net shear area, $A_{shr-n50}$, in $cm^2$, of side transverses is not to be less than:

$$A_{shr-n50} = \frac{8.5Q}{C_{t-pr}\tau_{eH}}$$

where:

$Q$ : Design shear force as follows, in $kN$:

$Q = Q_u$ for upper part of the side transverse.

$Q = Q_l$ for lower part of the side transverse.

$Q_u$ : Shear force, in kN, taken as:

$$Q_u = S[c_u \ell_{st}(P_u + P_l) - h_u P_u]$$

where a cross tie is fitted in a wing cargo tank and $\ell_{st-ct}$ is greater than 0.7 $\ell_{st}$, then $\ell_{st}$ in the above formula is taken as $\ell_{st-ct}$.

$Q_l$ : Shear force, in $kN$, taken as the greater of the following:

- $S[c_l \ell_{st}(P_u + P_l) - h_l P_l]$
- $0.35 c_l S \ell_{st}(P_u + P_l)$
- $1.2 Q_u$

where a cross tie is fitted in a wing cargo tank and $\ell_{st-ct}$ is greater than 0.7 $\ell_{st}$, then $\ell_{st}$ in the above formula is taken as $\ell_{st-ct}$.

$P_u$ : Design pressure given in **Table 1** for the design load set being considered, in $kN/m^2$, calculated at mid length of tank and at mid height of $h_u$.

$P_l$ : Design pressure given in **Table 1** for the design load set being considered, calculated at mid height $h_l$ located at mid length of tank, in $kN/m^2$.

$\ell_{st}$ : Length of the side transverse, in $m$, taken as follows:

- Where deck transverses are fitted below deck, $\ell_{st}$ is the length between the flange of the deck transverse and the inner bottom, see **Fig. 3**.
- Where deck transverses are fitted above deck, $\ell_{st}$ is the length between the elevation of the deck at side and the inner bottom.

$\ell_{st-ct}$: Length of the side transverse, in $m$, taken as follows:

- Where deck transverses are fitted below deck, $\ell_{st-ct}$ is the length between the flange of the deck transverse and mid depth of cross tie, where fitted in wing cargo tank.
- Where deck transverses are fitted above deck, $\ell_{st-ct}$ is the length between the elevation of the deck at side

and mid depth of the cross tie, where fitted in wing cargo tank.

$h_u$ : Effective length of upper bracket of the side transverse, in $m$, taken as follows:

- Where deck transverses are fitted below deck, $h_u$ is as shown in **Fig. 3**.
- Where deck transverses are fitted above deck:
  - When an inner hull longitudinal bulkhead is arranged with a top wing structure as follows, $h_u$ is taken as the distance between the deck at side and the lower end of slope plate of the top wing structure:
    - The breadth at top of the wing structure is greater than 1.5 times the breadth of the double side and.
    - The angle along a line between the point at base of the slope plate at its intersection with the inner hull longitudinal bulkhead and the point at the intersection of top wing structure and deck is 30 *deg* or more to vertical.
  - In the other cases: $h_u$ is taken as 0.

$h_l$ : Height of bilge hopper, in m, as shown in **Fig. 3**.

$c_u$ : Coefficient defined in **Table 4**.

$c_l$ : Coefficient defined in **Table 4**.

Table 4 Values of $c_u$ and $c_l$ for Side Transverses

<table>
<tr><td colspan="3">Structural configuration</td><td colspan="2">$c_u$</td><td colspan="2">$c_l$</td></tr>
<tr><td colspan="3">Number of side stringers</td><td>Less than three</td><td>Equal to or greater than three</td><td>Less than three</td><td>Equal to or greater than three</td></tr>
<tr><td colspan="3">Ships with a centreline longitudinal bulkhead</td><td rowspan="3">0.12</td><td rowspan="3">0.09</td><td rowspan="3">0.29</td><td rowspan="3">0.21</td></tr>
<tr><td rowspan="3">Ships with two longitudinal bulkheads</td><td colspan="2">Cross tie in centre cargo tank</td></tr>
<tr><td rowspan="2">Cross ties in wing cargo tanks</td><td>$Q_u$ or $Q_l$ based on $\ell_{st-ct}$</td></tr>
<tr><td>$Q_u$ or $Q_l$ based on $\ell_{st}$</td><td colspan="2">0.08</td><td colspan="2">0.20</td></tr>
</table>

1.6.2 Shear area over the length of the side transverse

The shear area over the length of the side transverse is to comply with the following. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

(a) The required shear area for the upper part is to be maintained over the upper 0.2 $\ell_{shr}$.

(b) The required shear area for the lower part is to be maintained over the lower 0.2 $\ell_{shr}$.

(c) Where $Q_u$ and $Q_l$ are determined based on $\ell_{st-ct}$, the required shear area for the lower part is also to be maintained below the cross tie.

(d) For ships without cross ties in the wing cargo tanks, the required shear area between the upper and lower parts is to be reduced linearly towards 50% of the required shear area for the lower part at mid-span.

(e) For ships with cross ties in the wing cargo tanks, the required shear area along the span is to be tapered linearly between the upper and lower parts.

where:

$\ell_{shr}$ : Effective shear span of the side transverse, in $m$.

$\ell_{shr} = \ell_{st} - h_u - h_l$ where $Q_u$ and $Q_l$ are determined based on $\ell_{st}$.

$\ell_{shr} = \ell_{st-ct} - h_u$ where $Q_u$ and $Q_l$ are determined based on $\ell_{st-ct}$.

$\ell_{st}$, $\ell_{st-ct}$, $h_u$, $h_l$, $Q_u$, $Q_l$ : Parameters defined in **1.6.1**.

### 1.7 Vertical Web Frames on Longitudinal Bulkhead

1.7.1 Web depth

The web depth of the vertical web frame on the longitudinal bulkhead is not to be less than:

- $0.14\ \ell_{bdg-vw}$ for ships with a centreline longitudinal bulkhead.
- $0.09\ \ell_{bdg-vw}$ for ships with two longitudinal bulkheads.
- The web height required in 1.1.6.

where:

$\ell_{bdg-vw}$ : Effective bending span, in m, defined in 1.7.2.

1.7.2 Net section modulus

The net section modulus, $Z_{n50}$ in $cm^3$, of the vertical web frame is not to be less than:

$$Z_{n50} = \frac{850M}{C_{s-pr}R_{eH}}$$

where:

$M$ : Design bending moment, in $kNm$, as follows:

$M = c_u P S l_{bdg-vw}^2$ for upper part of the web frame.

$M = c_l P S l_{bdg-vw}^2$ for lower part of the web frame.

where a cross tie is fitted and $\ell_{bdg-vw-ct}$ is greater than 0.7 $\ell_{bdg-vw}$, then $\ell_{bdg-vw}$ in the above formula is to be taken as $\ell_{bdg-vw-ct}$.

$P$ : Design pressure given in Table 1 for the design load set being considered, calculated at mid-point of the effective bending span, $\ell_{bdg-vw}$ of the vertical web frame located at mid tank, in $kN/m^2$.

$\ell_{bdg-vw}$ : Effective bending span of the vertical web frame on the longitudinal bulkhead, between the deck transverse and the bottom structure, in $m$, see Fig. 3.

$\ell_{bdg-vw-ct}$: Effective bending span of the vertical web frame on longitudinal bulkhead, between the deck transverse and mid-depth of the cross tie on ships with two longitudinal bulkheads, in $m$.

$c_u$ : Coefficient defined in Table 5.

$c_l$ : Coefficient defined in Table 5.

Table 5 Values of Cu and Cl for Vertical Web Frame on Longitudinal Bulkheads

| Structural configuration | | | $c_u$ | $c_l$ |
|---|---|---|---|---|
| Ships with a centreline longitudinal bulkhead | | | 0.057 | 0.071 |
| Ships with two longitudinal bulkheads | Cross tie in centre cargo tank | $M$ based on $\ell_{bdg-vw-ct}$ | 0.057 | 0.071 |
| | | $M$ based on $\ell_{bdg-vw}$ | 0.012 | 0.028 |
| | Cross ties in wing cargo tanks | $M$ based on $\ell_{bdg-vw-ct}$ | 0.057 | 0.071 |
| | | $M$ based on $\ell_{bdg-vw}$ | 0.016 | 0.032 |

1.7.3 Section modulus over the length of the vertical web frame

The section modulus over the length of the vertical web frame on the longitudinal bulkhead is to comply with the following. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

(a) The required section modulus for the upper part is to be maintained over the upper 0.2 $\ell_{bdg-vw}$ or 0.2 $\ell_{bdg-vw-ct}$ as applicable.

(b) The required section modulus for the lower part is to be maintained over the lower 0.2 $\ell_{bdg-vw}$ or 0.2 $\ell_{bdg-vw-ct}$ as applicable.

(c) Where the required section modulus is determined based on $\ell_{bdg-vw-ct}$, the required section modulus for the lower part is also to be maintained below the cross tie.

(d) The required section modulus between the upper and lower parts is to be reduced linearly to 70% of the required section modulus for the lower part at mid-span.

where:

$\ell_{bdg-vw}$, $\ell_{bdg-vw-ct}$ : Effective bending span, in $m$, defined in **1.7.2**.

1.7.4 Net shear area

The net shear area, $A_{shr-n50}$ in $cm^2$, of the vertical web frame is not to be less than:

$$A_{shr-n50} = \frac{8.5Q}{C_{t-pr}\tau_{eH}}$$

where:

$Q$ : Design shear force as follows, in $kN$:

$Q = Q_u$ for upper part of the web frame.

$Q = Q_l$ for lower part of the web frame.

$Q_u$ : Shear force, in $kN$, taken as:

$$Q_u = S[c_u \ell_{vw}(P_u + P_l) - h_u P_u]$$

where a cross tie is fitted in a centre or wing cargo tank and $\ell_{vw-ct}$ is greater than 0.7 $\ell_{vw}$, then $\ell_{vw}$ in the above formula is to be taken as $\ell_{vw-ct}$.

$Q_l$ : Shear force, in $kN$, taken as the greater of the following:

- $S[c_l l_{vw}(P_u + P_l) - h_u P_l]$
- $c_w S c_l l_{vw}(P_u + P_l)$
- $1.2Q_u$

where a cross tie is fitted in a centre or wing cargo tank and $\ell_{vw-ct}$ is greater than 0.7 $\ell_{vw}$, then $\ell_{vw}$ in the above formula is to be taken as $\ell_{vw-ct}$.

$P_u$ : Design pressure given in **Table 1** for the design load set being considered, calculated at mid-height of upper bracket of the vertical web frame, $h_u$ located at mid tank, in $kN/m^2$.

$P_l$ : Design pressure given in **Table 1** for the design load set being considered, calculated at mid-height of lower bracket of the vertical web frame, $h_l$ located at mid tank, in $kN/m^2$.

$\ell_{vw}$ : Length of the vertical web frame, in $m$, between the flange of the deck transverse and the inner bottom, see **Fig.3**.

$\ell_{vw-ct}$: Length of the vertical web frame, in $m$, between the flange of the deck transverse and mid-depth of the cross tie, where fitted.

$h_u$ : Effective length of upper bracket of the vertical web frame, in $m$, as shown in **Fig.3**.

$h_l$ : Effective length of lower bracket of the vertical web frame, in $m$, as shown in **Fig.3**.

$c_u$ : Coefficient defined in **Table 6**.

$c_l$ : Coefficient defined in **Table 6**.

$c_w$ : Coefficient taken as:

- $c_w = 0.57$ for ships with a centreline longitudinal bulkhead,
- $c_w = 0.50$ for ships with two longitudinal bulkheads.

Table 6 Values of Cu and Cl for Vertical Web Frame on Longitudinal Bulkhead

| Structural configuration | | $c_u$ | $c_l$ |
|---|---|---|---|
| Ships with a centreline longitudinal bulkhead | | 0.17 | 0.28 |
| Ships with two longitudinal bulkheads | $Q_u$ or $Q_l$ based on $\ell_{vw-ct}$ | | |
| | $Q_u$ or $Q_l$ based on $\ell_{vw}$ | 0.075 | 0.18 |

1.7.5 Shear area over the length of the vertical web frame

The shear area over the length of the vertical web frame on the longitudinal bulkhead is to comply with the following. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

(a) The required shear area for the upper part is to be maintained over the upper 0.2 $\ell_{shr}$.

(b) The required shear area for the lower part is to be maintained over the lower 0.2 $\ell_{shr}$.

(c) Where $Q_u$ and $Q_l$ are determined based on $\ell_{vw-ct}$, the required shear area for the lower part is also to be maintained below the cross tie.

(d) For ships without cross ties in the wing or centre cargo tanks, the required shear area between the upper and lower parts is to be reduced linearly towards 50% of the required shear area for the lower part at mid-span.

(e) For ships with cross ties in the wing or centre cargo tanks, the required shear area along the span is to be tapered linearly between the upper and lower parts.

where:

$\ell_{shr}$ : Effective shear span of the vertical web frame, in $m$.

$\ell_{shr} = \ell_{vw} - h_u - h_l$ where $Q_u$ and $Q_l$ are determined based on $\ell_{vw}$.

$\ell_{shr} = \ell_{vw-ct} - h_u$ where $Q_u$ and $Q_l$ are determined based on $\ell_{vw-ct}$.

$\ell_{vw}$, $\ell_{vw-ct}$, $h_u$, $h_l$, $Q_u$, $Q_l$: Parameters defined in **1.7.4**.

## 1.8 Horizontal Stringers on Transverse Bulkheads

### 1.8.1 Web depth

The web depth of horizontal stringers on transverse bulkhead is not to be less than:

- 0.28 $\ell_{bdg-hs}$ for horizontal stringers in wing cargo tanks of ships with two longitudinal bulkheads.
- 0.20 $\ell_{bdg-hs}$ for horizontal stringers in centre tanks of ships with two longitudinal bulkheads, but the web depth of horizontal stringers in centre tank is not to be less than required depth for a horizontal stringer in wing cargo tanks.
- 0.20 $\ell_{bdg-hs}$ for horizontal stringers of ships with a centreline longitudinal bulkhead.
- The web height required in **1.1.6**.

where:

$\ell_{bdg-hs}$ : Effective bending span, in m, defined in **1.8.2**.

### 1.8.2 Net section modulus

The net section modulus, $Z_{n50}$ in $cm^3$, of the horizontal stringer over the end 0.2 $\ell_{bdg-hs}$ is not to be less than:

$$Z_{n50} = \frac{850M}{C_{s-pr}R_{eH}}$$

where:

$M$ : Design bending moment, in $kNm$.

$$M = cPSl_{bdg-hs}^2$$

$P$ : Design pressure given in Table 1 for the design load set being considered, calculated at mid-point of effective bending span, $\ell_{bdg-hs}$ and at mid-point of the spacing, $S$ of the horizontal stringer, in $kN/m^2$.

$\ell_{bdg-hs}$ : Effective bending span of the horizontal stringer, in $m$, but is not to be taken as less than 50% of the breadth of the tank at the location being considered, see **Fig. 3**.

$c$ : Coefficient taken as:

- $c = 0.073$ for horizontal stringers in cargo tanks of ships with a centreline bulkhead.
- $c = 0.083$ for horizontal stringers in wing cargo tanks of ships with two longitudinal bulkheads.
- $c = 0.063$ for horizontal stringers in the centre tank of ships with two longitudinal bulkheads.

### 1.8.3 Section modulus over the length of horizontal stringers

The required section modulus at mid effective bending span is to be taken as 70% of that required at the ends, intermediate values are to be obtained by linear interpolation. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

### 1.8.4 Net shear area

The net shear area, $A_{shr-n50}$ in $cm^2$, of the horizontal stringer over the end 0.2 $\ell_{shr}$ is not to be less than:

$$A_{shr-n50} = \frac{8.5Q}{C_{t-pr}\tau_{eH}}$$

where:

$Q$ : Design shear force, in $kN$.

$$Q = 0.5PS_{hs}l_{shr}$$

$P$ : Design pressure given in Table 1 for the design load set being considered, calculated at mid-point of effective bending span, $\ell_{bdg-hs}$ and at mid-point of the spacing, $S$ of the horizontal stringer, in $kN/m^2$.

$S_{hs}$ : Spacing, in $m$, defined in **1.8.2**.

$\ell_{shr}$: Effective shear span of the horizontal stringer, in $m$.

1.8.5 Shear area at mid effective shear span

The required shear area at mid effective shear span is to be taken as 50% of that required in the ends, intermediate values are to be obtained by linear interpolation. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

### 1.9 Cross Ties

1.9.1 Maximum applied design axial load

The maximum applied design axial load on cross ties, $W_{ct}$ is to be less than or equal to the permissible load, $W_{ct-perm}$ as given by:

$$W_{ct} \leq W_{ct-perm}$$

where:

$W_{ct}$ : Applied axial load, in $kN$.

$$W_{ct} = Pb_{ct}S$$

$W_{ct-perm}$ : Permissible load, in $kN$.

$$W_{ct-perm} = 0.12A_{ct-n50}\eta_{all}\sigma_{cr}$$

$P$ : Maximum design pressure for all the applicable design load sets being considered given in **Table 1**, calculated at centre of the area supported by the cross tie located at mid tank, in $kN/m^2$.

$b_{ct}$ : Span, in $m$, taken as:

- Cross tie fitted in centre cargo tank: $b_{ct} = 0.5\ \ell_{bdg-vw}$
- Cross ties fitted in wing cargo tanks:
- $b_{ct} = 0.5\ \ell_{bdg-vw}$ for design cargo pressure from the centre cargo tank.
- $b_{ct} = 0.5\ \ell_{bdg-st}$ for design sea pressure.

$\ell_{bdg-vw}$ : Effective bending span, in $m$, defined in **1.5.2**.

$\ell_{bdg-st}$ : Effective bending span, in $m$, defined in **1.5.2**.

$\eta_{all}$ : Allowable buckling utilisation factor as defined in **Pt 1, Ch 8, Sec 1, 3.3**.

$\sigma_{cr}$ : Critical buckling stress in compression of the cross tie, in $N/mm^2$, as calculated using the net sectional properties in accordance with **Pt 1, Ch 8, Sec 5, 3.1.1**.

$A_{ct-n50}$ : Net cross sectional area of the cross tie, in $cm^2$.

1.9.2 Welded connections

Special attention is to be paid to the adequacy of the welded connections for the transmission of the forces, and also to the stiffening arrangements, in order to provide effective means for transmission of the compressive forces into the webs.

Particular attention is to be paid to the welding at the toes of all end brackets of the cross ties.

1.9.3 Horizontal stiffeners

Horizontal stiffeners are to be located in line with, and attached to, the longitudinals at the ends of the cross ties.

## 2. Vertically Corrugated Bulkheads

### 2.1 Application

2.1.1

In addition to the requirements of **Pt 1, Ch 6, Sec 4, 1**, vertically corrugated bulkheads of oil tankers are also to comply with the requirements of **2.2**.

### 2.2 Scantling Requirements

2.2.1 Net plate thickness over the height

The net plate thicknesses as required by **2.2.3** and **2.2.4** are to be maintained for two thirds of the corrugation length, $\ell_{cg}$ from the lower end. Above that, the net plate thickness may be reduced by 20% from the net thickness required in **2.2.3** for the mid part of the corrugation provided that the net section modulus of the upper end of the corrugation complies with **2.2.4**.

2.2.2 Net web plating thickness over the height

The net web plating thickness of the lower 15% of the corrugation, $t_w$ in $mm$, is to be taken as the greatest value calculated for all applicable design load sets, as given in **Pt 1, Ch 6, Sec 2, 2**, and given by the following. This requirement is not applicable to corrugated bulkheads without a lower stool.

$$t_w = \frac{1000|Q_{cg}|}{d_{cg}C_{t-cg}\tau_{eH}}$$

where:

$Q_{cg}$: Design shear force imposed on the web plating at the lower end of the corrugation, in $kN$.

$$Q_{cg} = \frac{s_{cg}l_{cg}|3P_l + P_u|}{8000}$$

$P_l$ : Design pressure given in **Pt 1, Ch 6, Sec 2, Table 1** for the design load set being considered, calculated at the lower end of the corrugation, in $kN/m^2$.

$P_u$ : Design pressures given in **Pt 1, Ch 6, Sec 2, Table 1** for the design load set being considered, calculated at the upper end of the corrugation, in $kN/m^2$.

$d_{cg}$: Depth of corrugation, in $mm$, see **Fig.4**.

$C_{t-cg}$ : Permissible shear stress coefficient:

$C_{t-cg} = 0.75$ for acceptance criteria set AC-S.

$C_{t-cg} = 0.90$ for acceptance criteria set AC-SD.

2.2.3 Net thicknesses of the flanges over the height

The net thicknesses of the flanges of corrugated bulkheads, $t_f$ in $mm$, for two thirds of the corrugation length from the lower end are to be taken as the greatest value calculated for all applicable design load sets, as given in **Pt 1, Ch 6, Sec 2, 2**, and given by the following. This requirement is not applicable to corrugated bulkheads without a lower stool.

$$t_f = \frac{6.57 b_{f-cg}\sqrt{\sigma_{bdg-\max}}}{C_f}10^{-3}$$

where:

$\sigma_{bdg-\max}$: Maximum value of the vertical bending stresses in $N/mm^2$ in the flange. The bending stress is to be calculated at the lower end and at the mid span of the corrugation length.

$$\sigma_{bdg-\max} = \frac{M_{cg}}{Z_{cg-act}}10^3$$

$M_{cg}$ : Vertical bending moment, in $kNm$, as defined in **2.2.4**.

$Z_{cg-act}$ : Actual net section modulus at the lower end and at the mid length of the corrugation, in $cm^3$.

$b_{f-cg}$ : Breadth of flange plating, in $mm$. See **Fig.4**.

$b_{w-cg}$ : Breadth of web plating, in $mm$. See **Fig.4**.

$C_f$ : Coefficient taken as:

$$C_f = 7.65 - 0.26\left(\frac{b_{w-cg}}{b_{f-cg}}\right)^2$$

2.2.4 Net section modulus over the height

The net section modulus at the lower and upper ends and at the mid length of the corrugation ($\ell_{cg}/2$) of a unit corrugation, $Z_{cg}$ are to be taken as the greatest value calculated for all applicable design load sets, as given in **Pt 1, Ch 6, Sec 2, 2** and given by the following.

$$Z_{cg} = \frac{1000 M_{cg}}{C_{s-cg} R_{eH}}$$

where:

$M_{cg}$ : Vertical bending moment in $kNm$.

$$M_{cg} = \frac{C_i |P| s_{cg} l_0^2}{12000}$$

$P$ : Averaged pressure in $kN/m^2$.

$$P = \frac{P_u + P_l}{2}$$

$P_l$, $P_u$ : Design pressure given in **Pt 1, Ch 6, Sec 2, Table 1** for the design load set being considered, calculated at the lower and upper ends of the corrugation, respectively, in $kN/m^2$:

- For transverse corrugated bulkheads, the pressures are to be calculated at a section located at $b_{tk}$ / 2 from the longitudinal bulkheads of each tank.
- For longitudinal corrugated bulkheads, the pressures are to be calculated at the ends of the tank, i.e. the intersection of the forward and aft transverse bulkheads and the longitudinal bulkhead.

$b_{tk}$ : Maximum breadth of tank under consideration measured at the bulkhead, in $m$.

$\ell_o$ : Effective bending span of the corrugation, in $m$, measured from the mid depth of the lower stool to the mid depth of the upper stool. Where no lower or upper stool is fitted, $\ell_o$ is to be measured to lower or upper end. See **Fig. 4**.

$C_i$ : Bending moment coefficient given in Table 7.

$C_{s-cg}$ : Permissible bending stress coefficient at the mid-length of the corrugation length, $\ell_{cg}$:

$C_{s-cg} = c_e$ but not to be taken as greater than 0.75 for acceptance criteria set AC-S.

$C_{s-cg} = c_e$ but not to be taken as greater than 0.90 for acceptance criteria set AC-SD.

At the lower and upper ends of the corrugation length, $\ell_{cg}$:

$C_{s-cg} = 0.75$ for acceptance criteria set AC-S.

$C_{s-cg} = 0.90$ for acceptance criteria set AC-SD.

$c_e$ : Coefficient taken as:

$$c_e = \frac{2.25}{\beta} - \frac{1.25}{\beta^2} \quad \text{for } \beta \geq 1.25$$

$$c_e = 1.0 \quad \text{for } \beta < 1.25$$

$\beta$ : Coefficient taken as:

$$\beta = \frac{b_{f-cg}}{t_f}\sqrt{\frac{R_{eH}}{E}}$$

$b_{f-cg}$: Breadth of flange plating, in $mm$, see **Fig. 4**.

$t_f$ : Net thickness of the corrugation flange, in $mm$.

Table 7 Values of $C_i$

| Bulkhead | At lower end of $\ell_{cg}$ | At mid-length of $\ell_{cg}$ | At upper end of $\ell_{cg}$ |
|---|---|---|---|
| Transverse bulkhead | $C_1$ | $C_{m1}$ | $0.65C_{m1}$ |
| Longitudinal bulkhead | $C_3$ | $C_{m3}$ | $0.65C_{m3}$ |

where:

$C_1$ : Coefficient taken as:

$C_1 = a_1 + b_1 \sqrt{\frac{A_{dt}}{b_{dk}}}$ but not taken less than 0.60.

$C_1 = a_1 - b_1 \sqrt{\frac{A_{dt}}{b_{dk}}}$ for transverse bulkhead with no lower stool, but not taken less than 0.55.

$a_1$ : Coefficient taken as:

$a_1 = 1.0$ for transverse bulkhead with no lower stool.

$a_1 = 0.95 - \frac{0.41}{R_{bt}}$

$b_1$ : Coefficient taken as:

$b_1 = 0.13$ for transverse bulkhead with no lower stool.

$b_1 = -0.20 + \frac{0.078}{R_{bt}}$

$C_{m1}$ : Coefficient taken as:

$C_{m1} = a_{m1} + b_{m1} \sqrt{\frac{A_{dt}}{b_{dk}}}$ but not taken less than 0.55.

$C_{m1} = a_{m1} - b_{m1} \sqrt{\frac{A_{dt}}{b_{dk}}}$ for transverse bulkhead with no lower stool, but not taken less than 0.60.

$a_{m1}$ : Coefficient taken as:

$a_{m1} = 0.85$ for transverse bulkhead with no lower stool.

$a_{m1} = 0.63 + \frac{0.25}{R_{bt}}$

$b_{m1}$ : Coefficient taken as:

$b_{m1} = 0.34$ for transverse bulkhead with no lower stool.

$b_{m1} = -0.25 - \frac{0.11}{R_{bt}}$

$C_3$ : Coefficient taken as:

$C_3 = a_3 + b_3 \sqrt{\frac{A_{dl}}{\ell_{dk}}}$ but not taken less than 0.60.

$C_3 = a_3 - b_3 \sqrt{\frac{A_{dl}}{\ell_{dk}}}$ for longitudinal bulkhead with no lower stool, but not taken less than 0.55.

$a_3$ : Coefficient taken as:

$a_3 = 1.0$ for longitudinal bulkhead with no lower stool.

$a_3 = 0.86 - \frac{0.35}{R_{bl}}$

$b_3$ : Coefficient taken as:

$b_3 = 0.13$ for longitudinal bulkhead with no lower stool.

$b_3 = -0.17 + \frac{0.10}{R_{bl}}$

$C_{m3}$ : Coefficient taken as:

$C_{m3} = a_{m3} + b_{m3} \sqrt{\frac{A_{dl}}{\ell_{dk}}}$ but not taken less than 0.55.

$C_{m3} = a_{m3} - b_{m3} \sqrt{\frac{A_{dl}}{\ell_{dk}}}$ for longitudinal bulkhead with no lower stool, but not taken less than 0.60.

$a_{m3}$ : Coefficient taken as:

$a_{m3} = 0.85$ for longitudinal bulkhead with no lower stool.

$a_{m3} = 0.32 + \frac{0.24}{R_{bl}}$

$b_{m3}$ : Coefficient taken as:

$b_{m3} = 0.19$ for longitudinal bulkhead with no lower stool.

$$b_{m3} = -0.12 - \frac{0.10}{R_{bl}}$$

$R_{bt}$ : Coefficient taken as:

$$R_{bt} = \frac{A_{bt}}{b_{ib}}\left(1 + \frac{\ell_{ib}}{b_{ib}}\right)\left(1 + \frac{b_{av-t}}{h_{st}}\right)$$ for transverse bulkheads.

$R_{bl}$ : Coefficient taken as:

$$R_{bl} = \frac{A_{bl}}{b_{ib}}\left(1 + \frac{\ell_{ib}}{b_{ib}}\right)\left(1 + \frac{b_{av-l}}{h_{sl}}\right)$$ for longitudinal bulkheads.

$A_{dt}$ : Cross sectional area enclosed by the moulded lines of the transverse bulkhead upper stool, in $m^2$.

$A_{dt} = 0$ if no upper stool is fitted.

$A_{dl}$ : Cross sectional area enclosed by the moulded lines of the longitudinal bulkhead upper stool, in $m^2$.

$A_{dl} = 0$ if no upper stool is fitted.

$A_{bt}$ : Cross sectional area enclosed by the moulded lines of the transverse bulkhead lower stool, in $m^2$.

$A_{bl}$ : Cross sectional area enclosed by the moulded lines of the longitudinal bulkhead lower stool, in $m^2$.

$b_{av-t}$ :Average width of transverse bulkhead lower stool, in $m$. See **Fig. 4**.

$b_{av-l}$ :Average width of longitudinal bulkhead lower stool, in $m$. See **Fig. 4**.

$h_{st}$ : Height of transverse bulkhead lower stool, in $m$. See **Fig. 4**.

$h_{sl}$ : Height of longitudinal bulkhead lower stool, in $m$. See **Fig. 4**.

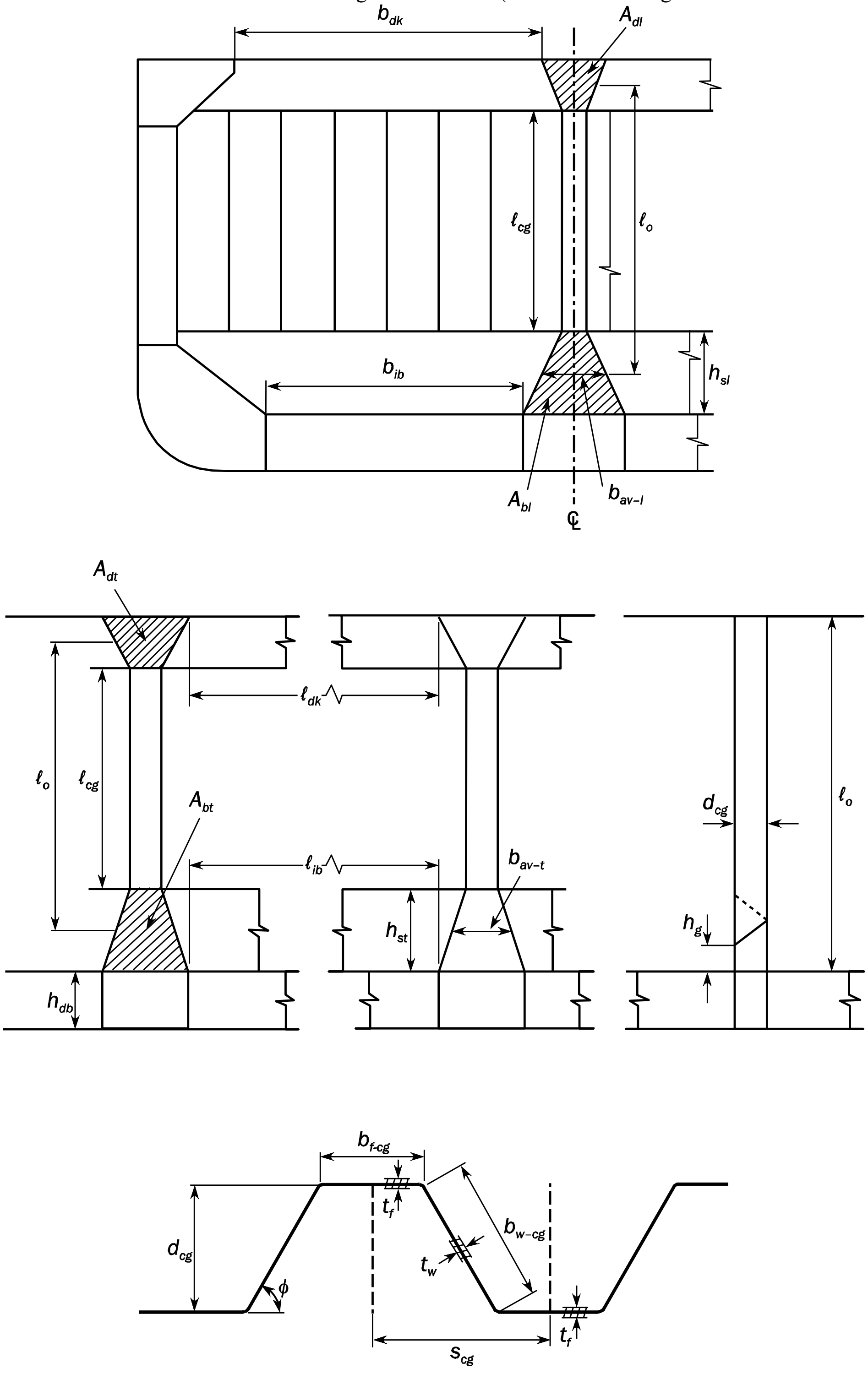
$b_{ib}$ : Breadth of cargo tank at the inner bottom level between hopper tanks, or between the hopper tank and centreline lower stool, in $m$. See **Fig. 4**.

$b_{dk}$ : Breadth of cargo tank at the deck level between upper wing tanks, or between the upper wing tank and centreline deck box or between the corrugation flanges if no upper stool is fitted, in $m$. See **Fig. 4**.

$\ell_{ib}$: Length of cargo tank at the inner bottom level between transverse lower stools, in $m$. See **Fig. 4**.

$\ell_{dk}$: Length of cargo tank at the deck level between transverse upper stools or between the corrugation flanges if no upper stool is fitted, in $m$. See **Fig. 4**.

Fig. 4 Definition of Parameters for Corrugated Bulkhead (Tankers with Longitudinal Bulkhead at Centreline)



# Section 4 HULL OUTFITTING

## 1. Supporting Structures for Components Used in Emergency Towing Arrangements

### 1.1 General

1.1.1

It is the responsibility of the designer to provide emergency towing arrangements fitted at both the bow and stern of every tanker with a deadweight of 20,000 tonnes or more, as required by *SOLAS*, as amended.

1.1.2

The designer is reminded that design and construction of the towing arrangements are to be approved by the Flag Administration or the Society on their behalf.

### 1.2 Documents to be Submitted

1.2.1

Plans showing details of the supporting structure for the emergency towing arrangement, including the connection to the deck, are to be provided for approval. Information on emergency towing arrangement showing sufficient detail to enable the position and direction of load actions to be ascertained is to be submitted for reference.

### 1.3 Structural Arrangement

1.3.1 Continuity of strength

The structural arrangement is to provide continuity of strength.

1.3.2 Stress concentrations

The structural arrangement of the ship's structure in way of the emergency towing equipment is to be such that, abrupt changes of shape or section are to be avoided in order to minimise stress concentrations. Sharp corners and notches are to be avoided, especially in high stress areas.

### 1.4 Minimum Thickness Requirements

1.4.1 Deck plating

The deck in way of strong-points and fairleads is to have a minimum gross thickness of 15 *mm*.

### 1.5 Loads

1.5.1 Safe working loads

Safe working load of emergency towing arrangements is not to be taken less than:

- 1,000 *kN* for tankers having a deadweight greater than or equal to 20,000 *t*, but less than 50,000 *t*.
- 2,000 *kN* for tankers having a deadweight greater than or equal to 50,000 *t*.

1.5.2 Load case

The design load for the connection of the strong-point and fittings to the deck and its supporting structure is to be taken as twice the safe working load. Information on lines of action of the applied design load provided in emergency towing arrangement plan is to be taken into account.

### 1.6 Scantling Requirements

1.6.1 General

The scantlings of the support structure are to be dimensioned to ensure that for the load cases specified in **1.5.2**, the calculated stresses in the support structure do not exceed the permissible stress levels specified in **1.6.3**.

The capacity of the structure to resist buckling failure is also to be assured.

1.6.2 Calculation procedure

These requirements are to be assessed using a simplified engineering analysis based on elastic beam theory, two dimensional grillage or finite element analysis using gross scantlings.

1.6.3 Permissible stresses

For the design load given in **1.5.2**, the shear stresses and normal stresses, including bending stresses induced in the supporting structure and welds, in way of strong-points and fairleads, are not to be exceed the permissible values given below based on the gross thickness of the structure:

- Normal stress, $1.00R_{eH}$.
- Shear stress, $0.58R_{eH}$.

Allowable buckling utilization factor is to be used as given in **Pt 1**, **Ch 8**, **Sec 1**, **Table 1**, for static and dynamic load scenario, *S+D*. Buckling assessment method is to be used according to **Pt 1**, **Ch 8**, **Sec 4**, **2**.

## 2. Miscellaneous Deck Attachments

### 2.1 Cargo Manifolds

2.1.1 Cargo manifold support

The design of the cargo manifold support is to be such as to distribute the loads imposed on the pipework into the ship structure in seagoing or in harbour operations during loading and unloading. To achieve this, the connection of the cargo manifold support to the deck is to be arranged to align with stiffening members of the main hull structure or stiffening is to be fitted in order to avoid the creation of hard points. Attention is to be paid to the detail design of the structure forming the deck attachment in order to minimise the effects of change of section. The arrangement of such details and their approval is considered on a case-by-case basis by the Society.

## 3. Guard Rails and Bulwarks

### 3.1 General

3.1.1

Generally, open guard rails are to be fitted on the upper deck. Plate bulwarks, with a 230 *mm* high continuous opening, at the lower edge, may be accepted provided the arrangement allows for the acceptable handling of spillage on deck and minimises the possibility for accumulation of volatile gas.

3.1.2

Deck spills are to be prevented from spreading to the accommodation and service areas and from discharge into the sea by a permanent continuous coaming with a minimum height of 100 *mm* surrounding the cargo deck. Along the sides at the aft end of the cargo deck of oil tankers, the coaming is to have a minimum height of 300 *mm* extending a minimum of 4.5 *m* forward from each corner. At the aft end of the cargo deck, the coaming is to have a minimum height of 300 *mm* and is to extend from side to side of the ship.

3.1.3

Scupper plugs of mechanical type are to be provided. Means of draining or removing oil or oily water within the coaming are also to be provided.