Common Structural Rules for Bulk Carriers and Oil Tankers

Corrigenda 1 to 01 January 2024 version

Notes: (1) This Corrigenda enter into force on 1st July 2024

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2.1 Structural details to be assessed

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The structural details listed in Table 2 for which FE fine mesh models have been analysed according to yielding requirements given in Ch 7, Sec 3 are to be assessed using the screening fatigue procedure as given in Ch 9, Sec 5, [6]. or to be assessed by very fine mesh analysis according to Ch 9, Sec 5, [1] to [4].

Table 2: Structural details for screening fatigue assessment

No	Critical detail	Applicability	
		Oil tanker	Bulk carrier
1	Bracket toe of transverse web frame	Applicable (1)	N/A
2	Toe of horizontal stringer.	Applicable (1)	N/A
3	Welded ~~L~~lower hopper knuckle connection in EA hold (2) and in FA hold (2) not assigned as a ballast hold	N/A	Applicable (1)
4	Connections of transverse bulkhead lower stool to inner bottom in EA hold (2) and in FA hold (2)	N/A	Applicable (1)
(1)	For details assessed by fine mesh analysis according to Ch 7, Sec 3, [3.2].		
(2)	Cargo hold located closest to the midship		

SECTION 3 FATIGUE EVALUATION

3 REFERENCE STRESS FOR FATIGUE ASSESSMENT

3.3 Thickness effect

3.3.1 Welded joints

Plate thickness primarily influences the fatigue strength of welded joints through the effect of geometry, and through-thickness stress distribution. The correction factor, f_{thick}, for plate thickness effect is taken as:

[Omitted]

ℓ_{leg} : Fillet weld leg length, in mm.

~~When post-weld treatment methods are applied to improve the fatigue life of considered welded joint, the thickness exponent is provided in [6].~~

4 S-N CURVES

4.1 Basic S-N curves

4.1.4 In-air environment

The basic design curves in-air environment shown in Figure 3 are represented by linear relationships between log (Δσ) and log (N) as follows:

$\log(N) = \log(K_2) - m \cdot \log(\Delta\sigma)$

where:

$\cancel{\log(K_2) = \log(K_1) - 2 \cdot \log(\delta)}$

$\log(K_2) = \log(K_1) - 2\delta$

K_1 : Constant related to mean S-N curve, as given in Table 2.

K_2 : Constant related to design S-N curve, as given in Table 2.

δ : Standard deviation of log (N), as given in Table 2.

$\Delta\sigma_q$: Stress range at $N = 10^7$ cycles related to design S-N curve, in N/mm^2, as given in Table 2.

Table 2: Basic S-N curve data, in-air environment

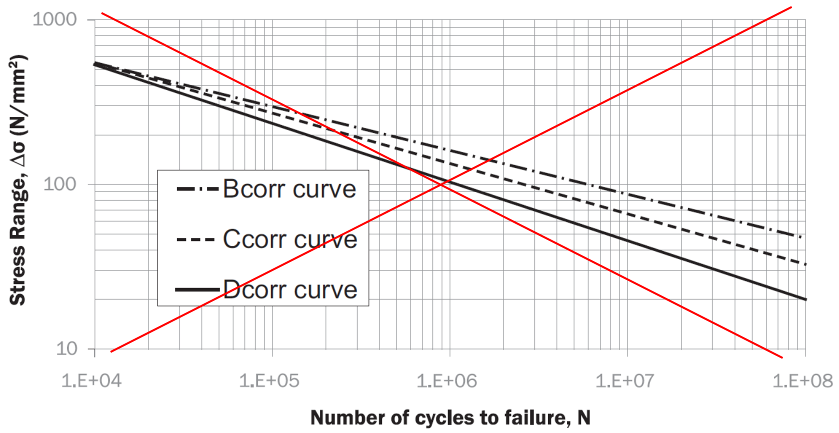
Class	~~K_1~~		m	~~Standard deviation~~ δ	K_2	Design stress range at 10^7 cycles	Design stress range at 2×10^6 cycles
	K_1	$\log_{10}K_1$		~~$\log_{10}\delta$~~	~~K_2~~	$\Delta\sigma q$ N/mm^2	N/mm^2
B	2.343E15	15.3697	4.0	0.1821	1.01E15	100.2	149.9
C	1.082E14	14.0342	3.5	0.2041	4.23E13	78.2	123.9
D	3.988E12	12.6007	3.0	0.2095	1.52E12	53.4	91.3

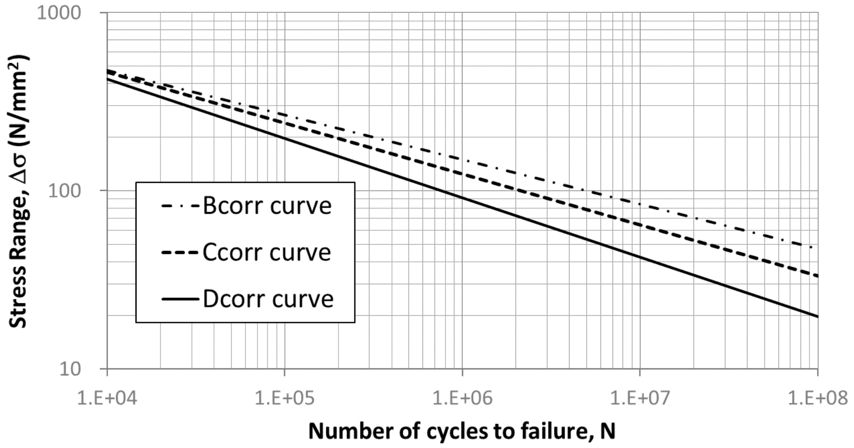
4.1.5 Corrosive environment

The basic design curves for corrosive environment shown in Figure 4 are represented by linear relationships between log(Δσ) and log(N) as follows:

[Omitted]

Figure 4 Basic design S-N curves, corrosive environment





5 FATIGUE DAMAGE CALCULATION

5.2 Elementary fatigue damage

5.2.1

[Omitted]

where:

N_D : Total number of ~~wave~~ stress cycles due to wave loads ~~experienced by ship~~ assumed during the design fatigue life, taken as:

$$N_D = 31.557\times10^6\,(f_0 T_D) / (4 \log L)$$

[Omitted]

SECTION 4 SIMPLIFIED STRESS ANALYSIS

3 HULL GIRDER STRESS

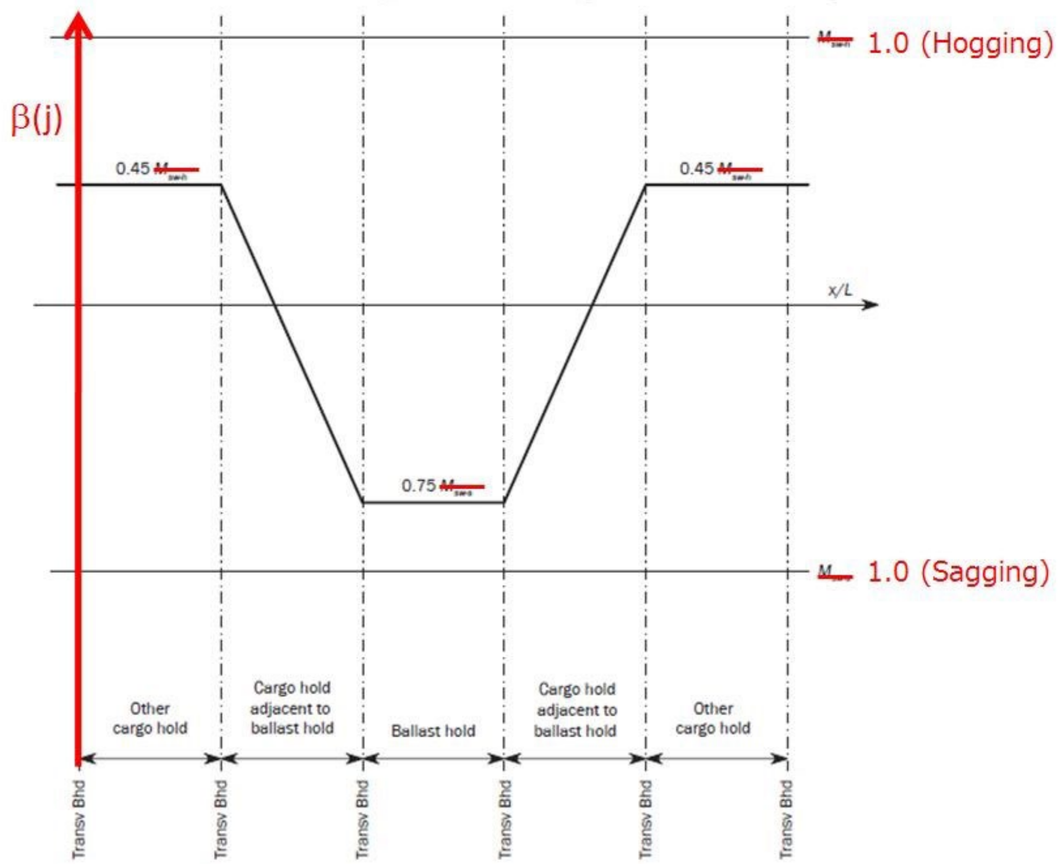
3.2 Stress due to Still Water Hull Girder Bending Moment

3.2.1

The hull girder hot spot stress due to still water bending moment, in N/mm^2, in loading condition (j) is obtained from the following formula:

[Omitted]

Figure 1: Distribution of fraction of permissible still water vertical bending moment, $\beta_{(j)}$, for fatigue assessment in way of ballast hold



4 LOCAL STIFFENER STRESS

4.1 Stress due to Stiffener Bending

4.1.2 Stress due to static pressure

The hot spot stress due to local static pressure, in N/mm2, for loading condition (j) is obtained from the following formula:

$$\sigma_{LS,(j)} = \frac{K_b K_n s l_{bdg}^2 \left(\eta_S P_{S,(j)} + \eta_{ls} P_{ls,(j)} + \eta_{bs} P_{bs,(j)}\right)\left(1 - \frac{6x_e}{l_{bdg}} + \frac{6x_e^2}{l_{bdg}^2}\right)}{12 Z_{eff-n50}}$$

where:

$P_{S,(j)}$: Static external pressure, in kN/m^2, in loading condition (j) specified in Ch 4, Sec 5, [1.2].

$P_{ls,(j)}$: Static liquid tank pressure, in *kN/m²*, in loading condition (*j*) specified in Ch 4, Sec 6, [1.1.1]. Pressure acting on both sides could be simultaneously considered if relevant in the loading condition.

For the deck longitudinal stiffeners of bulk carriers, no internal pressure from the topside tank is considered.

$P_{bs,(j)}$: Static dry bulk cargo pressure, in *kN/m²*, in loading condition (*j*) specified in Ch 4, Sec 6, [2.4.1].

$\eta_S, \eta_{ls}, \eta_{bs}$: Pressure normal coefficients, taken as:

$\eta = 1$ when the considered pressure is applied on the stiffener side.

$\eta = -1$ otherwise

4.2 Stress due to Relative Displacement

4.2.6 Stress due to relative displacement derived using FE method

The following procedure is based on a cargo hold model complying with Ch 7, Sec 2, [2] to calculate the stress due to relative displacements. The stress due to relative displacements, in *N/mm²*, for load case $i1$ and $i2$ of loading condition (*j*) for both locations "*a*" and "*f*" is to be calculated directly using the following expression:

[omitted]

$I_{Fwd-n50}, I_{Aft-n50}$: Net moment of inertia, in cm^4, of forward (*Fwd*) and afterward (*Aft*) longitudinal, with effective breadth of attached plating defined in Ch 9, Sec 4, [4.1.1].

$Z_{Fwd-n50}, Z_{Aft-n50}$: Net section modulus of forward (*Fwd*) and afterward (*Aft*) stiffener, in cm^3, with effective breadth of attached plating defined in Ch 9, Sec 4, [4.1.1].

[omitted]

SECTION 5 FINITE ELEMENT STRESS ANALYSIS

3 HOT SPOT STRESS FOR DETAILS DIFFERENT FROM WEB-STIFFENED CRUCIFORM JOINTS

3.1 Welded details

3.1.1

For hot spot type '*b*', the stress distribution is not dependent on the plate thickness; the structural hot spot stress, σ_{HS}, is derived from a finite element analysis with mesh density 10×10 mm and is obtained by the following formula:

$\sigma_{HS} = 1.12\ .\sigma$

where:

σ : ~~Surface principal stress~~ Beam element stress, in N/mm^2, read out at ~~an absolute~~ a distance of 5 mm from the intersection line ~~of 5 mm~~.

SECTION 6 DETAIL DESIGN STANDARD

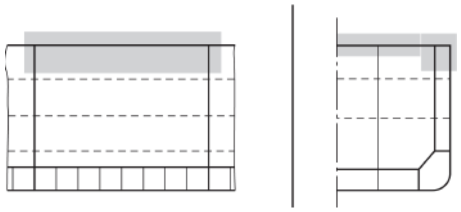
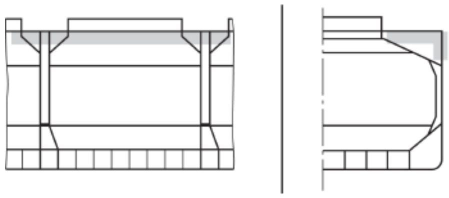
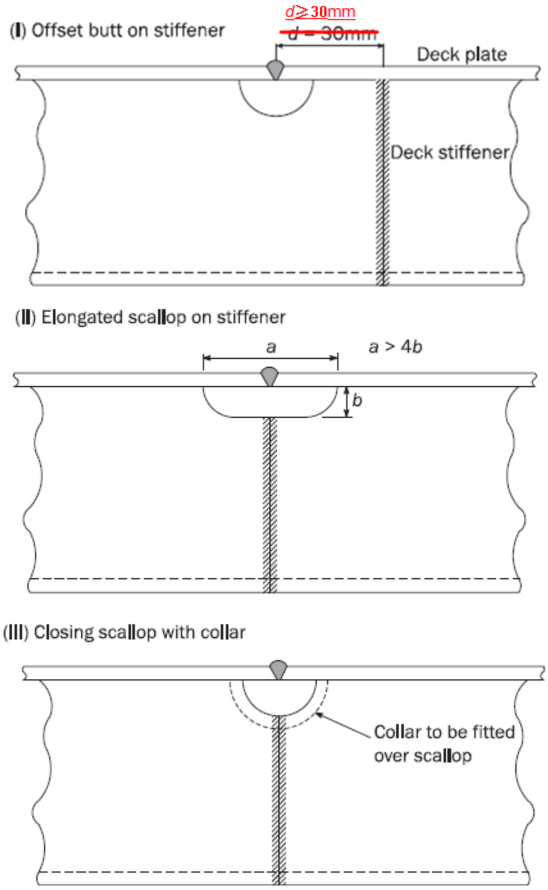
3 SCALLOPS IN WAY OF BLOCK JOINTS

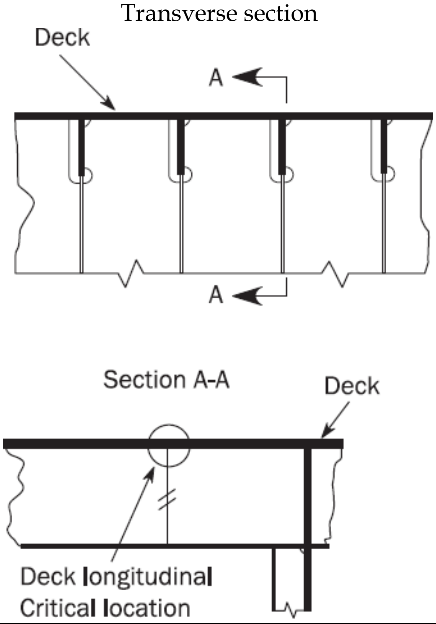
3.1 Design standard B

3.1.1

Scallops in way of block joints in the cargo tank/hold region, located on the stiffeners fitted on strength deck, and side above 0.9 *D* from the baseline, are required to be designed according to the design standard B as shown in Table 2.

Table 2: Design standard B – scallops in way of block joints

<table>
<tr><td colspan="2">Welding of deck stiffeners in way of block joints</td></tr>
<tr><td>Critical areas Design standard B</td><td>Critical areas Design standard B</td></tr>
<tr><td>Double-Hull Oil Tanker

Bulk Carrier
</td><td rowspan="3">

Note1: Alternative scallop geometry to that shown in option II may be accepted subject to demonstration of satisfactory fatigue life based on hull girder loads taking into account additional stress concentration factor in way of weld</td></tr>
<tr><td>Critical locations</td></tr>
<tr><td>Transverse section

</td></tr>
</table>

Critical location	Welding of deck stiffeners in way of block joints in cargo tank region, the strength deck and side above 0.9D from the baseline.
Detail design standard	All scallops are to be fitted according to detail design standard B.
Building tolerances	Ensure alignment of all structural members according to IACS Recommendation No. 47.
Welding requirements	Full penetration butt weld, free of undercut or notches, around the web and flange of the longitudinal stiffener at block joints, particularly in way of the weld termination at the scallop for option II.

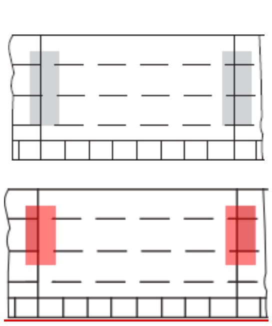
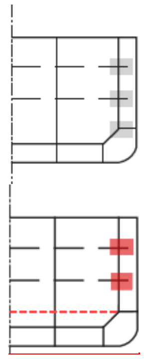
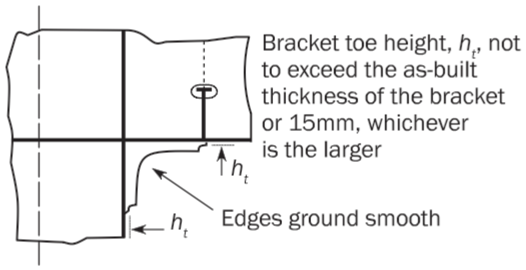
5 HORIZONTAL STRINGER HEEL

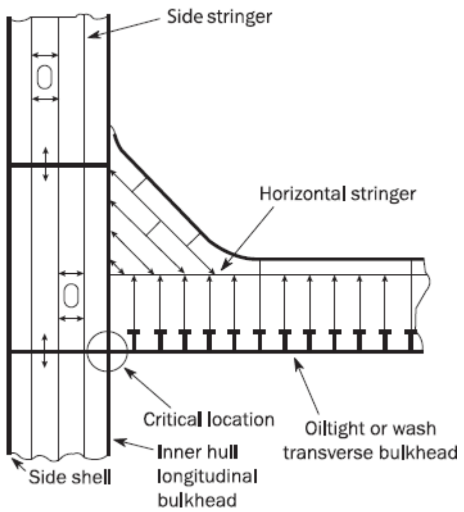
5.1 Design standard I

5.1.1

The horizontal stringer heel location between transverse oil-tight/swash bulkhead plating and inner hull longitudinal bulkhead plating for double hull oil tankers are required to be designed according to design standard I, as shown in Table 9.

Table 9: Design Standard I – transverse bulkhead horizontal stringer heel

<table>
<tr><td colspan="3">Connections of horizontal stringer on plane oil-tight transverse bulkheads or
wash bulkheads to inner hull longitudinal bulkheads</td></tr>
<tr><td colspan="2">Critical areas</td><td>Design standard I</td></tr>
<tr><td></td><td></td><td rowspan="3">

Note1: Where a face plate is considered necessary, it is recommended that design features be adopted to reduce the stress concentration at the face plate termination (e.g. taper and soft nose). Adequate fatigue life of the weld on the bracket edge in way of such terminations is to be confirmed.
Note2: ‘Slit type cut-outs are to be adopted in way of the bracket toe as shown. Alternatively, cut-outs with insert type collars will be accepted. Scallops are to be avoided.’</td></tr>
<tr><td colspan="2">Critical locations</td></tr>
<tr><td colspan="2">
</td></tr>
</table>

Critical location	Intersections of webs of transverse bulkhead horizontal stringer and double side tank side stringer forming square corners.
Detail design standard	A soft toe backing bracket is to be fitted. The following bracket sizes are recommended: ● VLCC: 800×800×30, *R*600 with soft toe as shown in figure above, ● Other tankers: 800×600×25, *R*550 with soft toe as shown in figure above, where the longer arm length is in way of the inner skin. The specified minimum yield stress for the bracket is not to be less than 315 N/mm^2. The free edge is to be ground smooth with corners rounded.
Building tolerances	The nominal distance between the centres of thickness of the two abutting members should not exceed 1/3 of the as-built plate thickness of the inner hull longitudinal bulkhead.
Welding requirements	Vertical weld between the inner hull plating and transverse bulkhead plating, fillet welding having minimum weld factor 0.44. Welding between the backing bracket and the adjoining plates is to be double sided fillet welding having minimum weld factor 0.44 except in way of the bracket toes. Full penetration welding is to be used for the connection of bracket toes to the inner hull and transverse bulkhead plating for a distance of 200 mm from the toes and the weld toes are to be ground smooth in way.

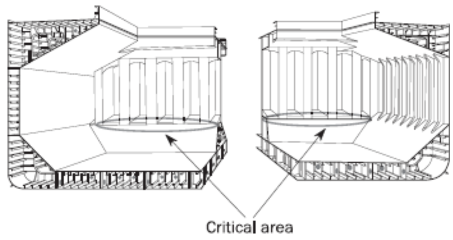
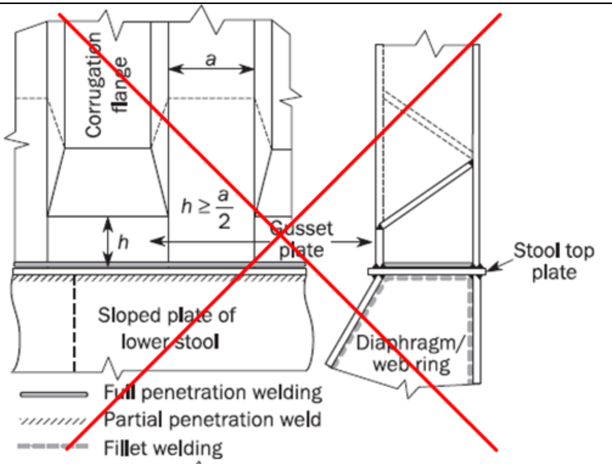
6 BULKHEAD CONNECTION TO LOWER AND UPPER STOOL

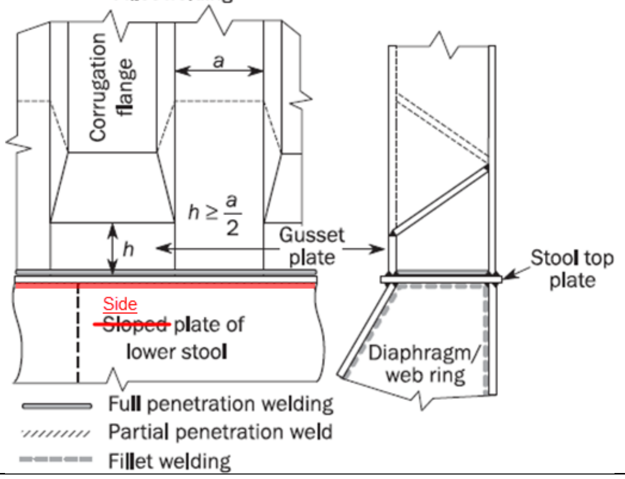
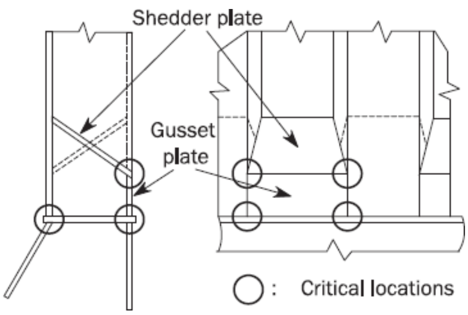
6.1 Design standard J, K and L

6.1.1

The welded connection of bulkhead to lower stool of bulk carriers and oil tankers are to be designed according to the design standard J and K respectively, as shown in Table 10 and Table 11.

Table 10: Design standard J – transverse bulkhead connection detail, bulk carrier (Ballast hold)

<table>
<tr><td colspan="3">Connections of transverse bulkhead with lower stool</td></tr>
<tr><td colspan="2">Critical areas</td><td>Design standard J</td></tr>
<tr><td colspan="2">
</td><td rowspan="3">


</td></tr>
<tr><td colspan="2">Critical location</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Critical location</td><td colspan="2">Connections of lower stool shelf plate to lower stool and corrugated transverse bulkheads.
Connections of shedder plates to corrugated transverse bulkhead.</td></tr>
<tr><td>Critical location</td><td colspan="2">The use of scallops is to be avoided on diaphragms/web at lower stool top plates.
Gusset plates are to be fitted to corrugated bulkheads.
Gusset plates are to be made out of the same material and have the same as-built thickness as corrugated bulkheads; and, the height of gusset plates is to be greater than half of breadth of the corrugation.
To reduce stress concentrations at the crossing of the shedder plates one plate is to be moved higher than the other (as shown in Figure). Alternatively, bracketed stiffener can be fitted at the crossing points underneath the shedder plating facing the ballast hold.</td></tr>
<tr><td>Building tolerances</td><td colspan="2">Ensure alignment between lower stool sloping plates and corrugation faces according to IACS Recommendation No. 47.</td></tr>
</table>

Welding requirement	Full penetration welding is to be applied between lower stool top plates and the side plating of lower stools and corrugated bulkheads. Partial or full penetration welding is to be applied around gusset plates. However, full penetration welding is to be applied between lower stool top plates and gusset plates. Ensure start and stop of welding is as far away as practicable from the critical corners.

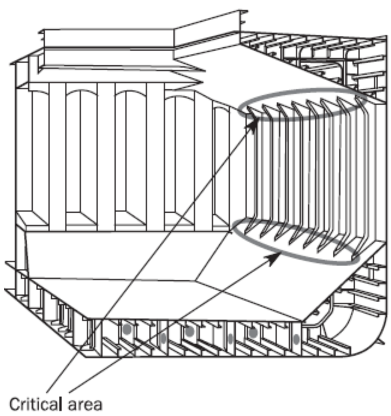
8 LOWER AND UPPER TOE OF HOLD FRAME

8.1 Design standard N

8.1.1

The welded connections of lower and upper bracket toes of hold frame of bulk carriers are to be designed according to design standard N, as shown in Table 14

Table 14: Design standard N – lower and upper toe detail of hold frame - bulk carrier

<table>
<tr><td colspan="3">Lower and upper hold frame connections</td></tr>
<tr><td colspan="2">Critical areas</td><td>Design standard N</td></tr>
<tr><td colspan="2">
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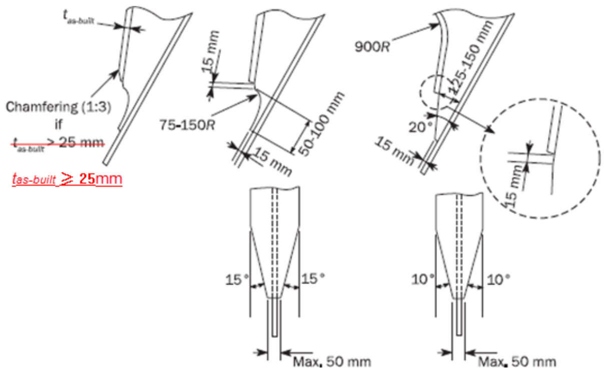
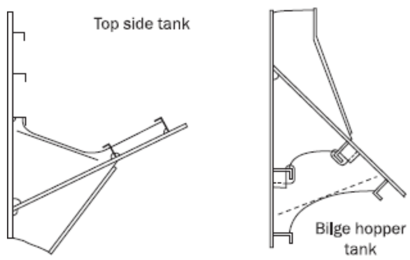
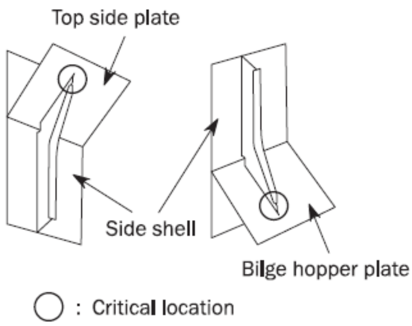
<td rowspan="3">

Examples of the soft and extended toes at the end of hold frames.


Connection of lower and upper end bracket of hold frame.</td></tr>
<tr><td colspan="2">Critical locations</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Minimum requirement</td><td colspan="2">As a minimum the detail design standard N is to be applied. Tapered extended toes are more effective and are to be considered for high tensile steel side shell frame.</td></tr>
<tr><td>Critical location</td><td colspan="2">Toe connection of side shell frame lower and upper brackets to the hopper and topside sloping plates, including face plate terminations.</td></tr>
</table>

Lower and upper hold frame connections	
Detail design standard	Alternative geometries than stipulated above are permissible subject to demonstration of satisfactory fatigue performance. However, the maximum angles shown on the figures for thickness chamfering and face width tapering are not to be exceeded. Bracket toe height and the distance between the face plate termination and start of the toe radius (or toe taper) are to be kept to a minimum. The face plates of hold frames at lower or upper brackets are to be tapered and chamfered as shown. While chamfering may be dispensed with if the thickness of the face plates is less than 25 mm, it is nevertheless a recommended practice, with a larger gradient if necessary. Frames are to be built-up symmetrical sections with integral upper and lower brackets and are to be arranged with soft or elongated toes as shown. The side frame flange is to be curved (not knuckled) at the connection with the end brackets. Where the frame upper brackets are not positioned directly below a ring web, supporting brackets are to be provided. In the design ensure that if a topside tank stiffener is positioned above the end of frame upper bracket, the stiffener cut-out is avoided or closed with a full collar. Increasing the size of supporting brackets will reduce stress concentrations in the critical area. Where the frame lower brackets are not positioned directly above a ring web, supporting brackets are to be provided. In the design ensure that if a hopper tank stiffener is positioned below the end of the frame lower bracket, the stiffener cut-out is avoided or closed with a full collar. Increasing the size of supporting brackets will reduce stress concentrations in the critical area.
Building tolerances	Ensure alignment between side shell frame lower and upper bracket and transverse ring webs or supporting brackets according to IACS Recommendation No. 47. Maximum misalignment is to be not greater than $t_{as\text{-}built}$ /3 where $t_{as\text{-}built}$ is the thinner as-built thickness of the webs to be aligned and misalignment is the overhang of the as-built thinner thickness.
Welding requirement	Welding is to comply with Ch 12, Sec 3, [3]. In way of the wrap around weld at the face plate termination, care should be taken to ensure no over-run onto the radius part and the toe is free from notches and undercut.

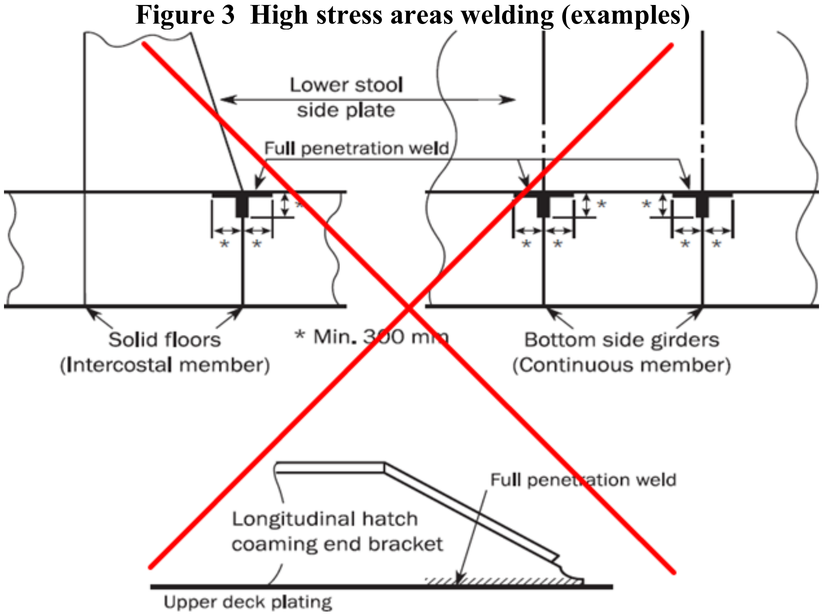
CHAPTER 12 CONSTRUCTION

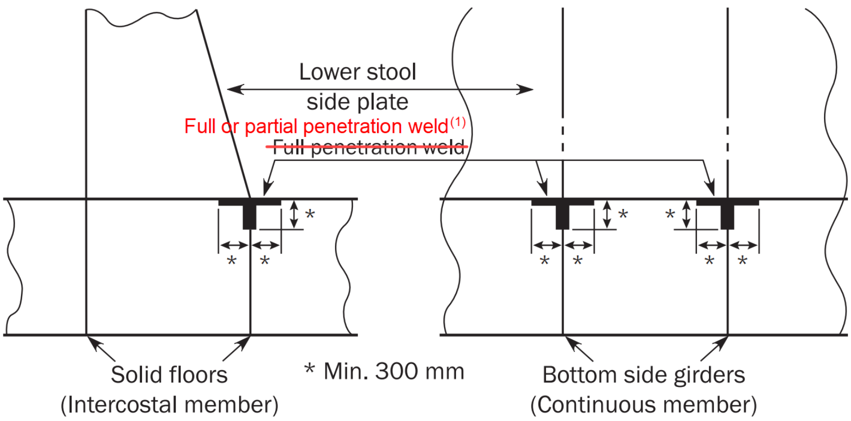
SECTION 3 DESIGN OF WELD JOINTS

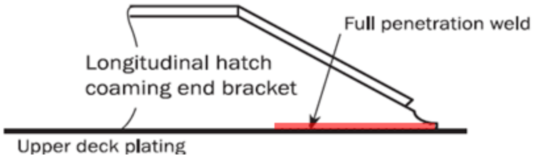
2 TEE OR CROSS JOINT

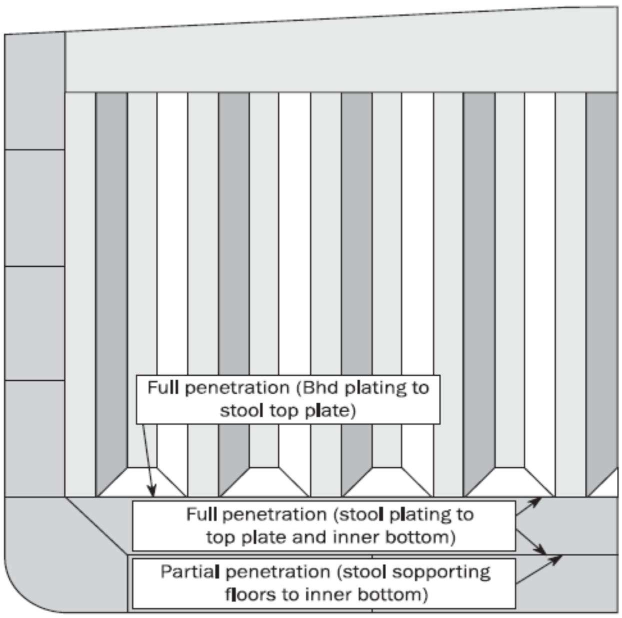
2.4 Partial or full penetration welds

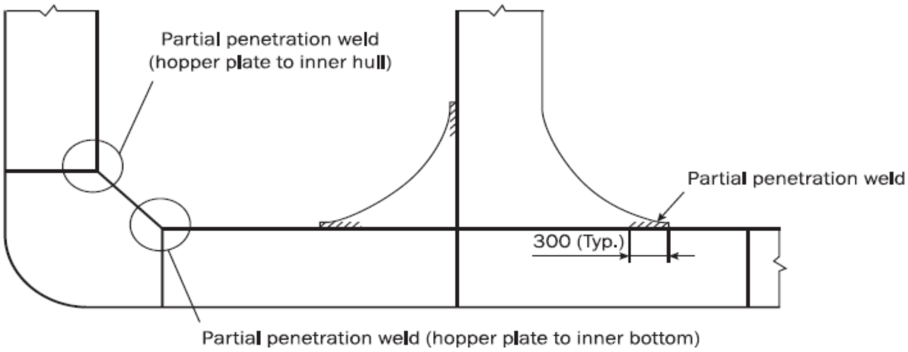
Figure 3 High stress areas welding (examples)











Note:

(1) Full penetration weld is to be applied in case of Ch 12, Sec 3, [2.4.5] i). Partial penetration weld is to be applied in case of Ch 12, Sec 3, [2.4.6] f).