Common Structural Rules for Bulk Carriers and Oil Tankers

Draft Rule Change Proposal 1 to 01 JAN 2019 version

Notes: (1) These Rule Changes enter into force on 1st July 2020.
COMMON STRUCTURAL RULES FOR BULK CARRIERS AND OIL TANKERS

RULE CHANGE PROPOSAL 1

This proposal contains amendments within the following Parts and chapters of the Common Structural Rules for Bulk Carriers and Oil Tankers, 1 January 2019. The amendments are effective on 1 July 2020.

For technical background for Rule Changes in this present document, reference is made to separate document Technical Background for this Rule Change Proposal.
Contents

PART 1 GENERAL RULE REQUIREMENTS ......................................................................................................... 4

CHAPTER 1 RULE GENERAL PRINCIPLE ........................................................................................................ 4
   SECTION 2 RULE PRINCIPLES ........................................................................................................... 4
   SECTION 3 VERIFICATION OF COMPLIANCE ................................................................................... 5
   SECTION 4 SYMBOLS AND DEFINITIONS ..................................................................................... 5

CHAPTER 2 GENERAL ARRANGEMENT DESIGN ...................................................................................... 6
   SECTION 1 GENERAL........................................................................................................................ 6
   SECTION 4 ACCESS AND ESCAPE ARRANGEMENT .................................................................... 6

CHAPTER 3 STRUCTURAL DESIGN PRINCIPLE .................................................................................... 8
   SECTION 6 STRUCTURAL DETAILS PRINCIPLE ......................................................................... 8
   SECTION 7 STRUCTURAL IDEALISATION .................................................................................... 9

CHAPTER 4 LOADS ......................................................................................................................................... 11
   SECTION 4 HULL GIRDER LOADS .................................................................................................. 11
   SECTION 8 LOADING CONDITIONS ........................................................................................... 11

CHAPTER 7 DIRECT STRENGTH ANALYSIS .......................................................................................... 12
   SECTION 2 CARGO HOLD STRUCTURAL STRENGTH ANALYSIS .............................................. 12
   SECTION 3 LOCAL STRUCTURAL STRENGTH ANALYSIS ............................................................ 16

PART 2 SHIP TYPES .......................................................................................................................................... 17

CHAPTER 1 BULK CARRIERS .................................................................................................................... 17
   SECTION 1 GENERAL ARRANGEMENT DESIGN ........................................................................ 17
PART 1 GENERAL RULE REQUIREMENTS

CHAPTER 1
RULE GENERAL PRINCIPLE

SECTION 2 RULE PRINCIPLES

2 General Assumptions

2.2 Application and implantation of the Rules

2.2.2

.... Part shown only ....

b) Design aspects:

• The owner specifies the intended use of the ship, and the ship is designed according to operational requirements as well as the structural requirements given in the Rules.

• The builder identifies and documents the operational limits for the ship so that the ship can be safely and efficiently operated within these limits.

• Verification of the design is performed by the builder to check compliance with provisions contained in the Rules in addition to national and international regulations.

• The design is performed by appropriately qualified, competent and experienced personnel.

• The Society performs a technical appraisal of the design plans and related documents for a ship to verify compliance with the appropriate classification Rules.

• For spaces where lighting and ventilation are to be fitted, the builder is to give consideration to the influence on the structural design and arrangement from the relevant requirements of International Conventions such as SOLAS and MLC2006 Regulation 3.1 - Accommodation and recreational facilities, and Society's rules if any. **For general guidance, human element factors may be considered based on IACS Recommendation No. 132 and/or an ergonomic standard accepted by the Society. Human element considerations, including enhanced safety and productivity, may be considered using Recommendation No. 132 or other ergonomic standards accepted by the Society.**

• For **continually manned** spaces normally occupied or manned by shipboard personnel where noise is to be minimised, the builder is to give consideration to the influence on the structural design and arrangement from the relevant requirements of SOLAS Ch II-1, Reg.3-12 and "The Code on Noise Levels Onboard Ships" adopted at MSC.337(91).

• For **continually manned** spaces normally occupied or manned by shipboard personnel where vibration is to be minimised, the builder is to give consideration to the influence on the structural design and arrangement from the relevant requirements of relevant statutory requirements such as MLC 2006 Regulation 3.1 - Accommodation and recreational facilities. **For general guidance, human element factors may be considered based on IACS Recommendation No. 132 or on an ergonomic standard accepted by the Society. Human element considerations, including enhanced safety and productivity, may be considered using Recommendation No. 132 or other ergonomic standards accepted by the Society.**
SECTION 3 VERIFICATION OF COMPLIANCE

1 General

1.1 Newbuilding

1.1.5

Through all stages of ship construction, it is the builder’s responsibility to promptly inform promptly
the Society of the modifications or departures from approved arrangements and to deal with as
necessary plans. The builder is to ensure that any deviations from the requirements of the Rules or
approved plans, other than those of a minor nature not affecting the structural strength of the vessel,
are, in any case, accepted by the Society’s approval office.

SECTION 4 SYMBOLS AND DEFINITIONS

3 Definitions

3.8 Glossary

3.8.1

Table 7: Definition of terms

<table>
<thead>
<tr>
<th>Terms</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compartment</td>
<td>An internal space bounded by bulkheads or plating.</td>
</tr>
<tr>
<td>Confined space</td>
<td>A space identified by one of the following characteristics: limited openings for entry and exit, unfavourable natural ventilation or not designed for continuous worker occupancy.</td>
</tr>
<tr>
<td>Continuously manned space</td>
<td>A space in which the continuous or prolonged presence of seafarers is necessary for normal operational periods. This includes spaces routinely occupied for a period of 20 minutes or more during normal operational periods.</td>
</tr>
<tr>
<td>Corrugated bulkhead</td>
<td>A bulkhead including corrugations and usually fitted with lower and upper stools.</td>
</tr>
</tbody>
</table>

……

<table>
<thead>
<tr>
<th>Terms</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normally unmanned space</td>
<td>A space not normally manned (without the continuous or prolonged presence of seafarers) during normal operational periods. This includes spaces routinely occupied for a period of less than 20 minutes during normal operational periods.</td>
</tr>
<tr>
<td>Notch</td>
<td>A discontinuity in a structural member caused by welding.</td>
</tr>
<tr>
<td>Oil fuel tank</td>
<td>A tank used for the storage of fuel oil.</td>
</tr>
</tbody>
</table>
CHAPTER 2
GENERAL ARRANGEMENT DESIGN

SECTION 1 GENERAL

1.1 General

1.1.1 This chapter covers the general structural arrangement requirements for the ship.

1.1.2 Arrangements for continually manned spaces are to include consideration of ventilation, lighting, noise and whole-body vibration in accordance with industry standards accepted by the Society. See also Sec 4, [1.1.1] to [1.1.3].

1.1.3 Arrangements for normally unmanned spaces are to include consideration of lighting and ventilation for periodic inspections, survey and maintenance in accordance with industry standards accepted by the Society. See also Sec 4, [1.1.1] to [1.1.5].

SECTION 4 ACCESS AND ESCAPE ARRANGEMENT

1 ENCLOSED SPACES

1.1 General

1.1.1 Special considerations

Human element considerations, including enhanced safety and productivity, may be considered using Recommendation No. 132 or other ergonomic standards accepted by the Society.

Where spaces have special considerations or requirements for access; e.g. security restrictions for the CO2 room to prevent unintentional release, these are to be considered in conjunction with the requirements of this section, and any conflicts should be raised as soon as possible for consideration by the Society.

1.1.2 Enclosed spaces

All enclosed spaces are to be accessible with appropriate access arrangements for easy inspection, survey and maintenance i.e. access is to allow unobstructed passage to items for inspection for personnel wearing the appropriate clothing, including personal protective equipment, and using all necessary tools and test equipment. Special measures for inspection and maintenance are to be put in place for small enclosed spaces for which the design causes impracticality for the access.

Provision is also to be made for appropriate arrangements to facilitate emergency egress of inspection personnel or ships’ crew in accordance with industry standards accepted by the Society.

1.1.2.3 Spaces not explicitly covered by SOLAS

For areas spaces which are not explicitly covered by SOLAS, Ch II-1, Reg 3-6, the builder is to provide appropriate accesses arrangements for easy inspection, survey and maintenance in accordance with industry standards accepted by the Society. See also [1.1.5]. For general guidance, human element factors may be considered based on IACS Recommendation No. 132 or with an ergonomic standard accepted by the Society.
Provision is also to be made for appropriate arrangements to facilitate emergency egress of inspection personnel or ships’ crew in accordance with industry standards accepted by the Society.

1.1.4 Ventilation of normally unmanned spaces

Unless otherwise specifically detailed in these Rules, normally unmanned spaces are to be capable of being ventilated through natural or forced ventilation. Such ventilation could be achieved through the inclusion of mushroom ventilators, gooseneck ventilators, ventilators with weather proof covers etc. Exchange air may be provided through permanent or temporary mechanical ventilation and air trunk systems or a suitable air exchange path through tank openings and ventilators.

1.1.5 Permanent means of access to normally unmanned spaces

Unless otherwise specifically detailed in these Rules, permanent means of access to normally unmanned spaces is to be provided in accordance with SOLAS, Ch II-1, Reg. 3-6.

For enclosed spaces, which are not explicitly covered by SOLAS, Ch II-1, Reg. 3-6, the requirements of the Convention and associated Resolutions should be applied as far as practicable. The size of openings providing access to or emergency egress from spaces not entered during operation, entered for maintenance or entered for regular inspections shall not be less than 600mm x 400mm if ovoid or in accordance with industry standards accepted by the Society if circular.
CHAPTER 3
STRUCTURAL DESIGN PRINCIPLE

SECTION 6 STRUCTURAL DETAILS PRINCIPLE

5 Intersection of stiffeners and primary supporting members

5.2 Connection of stiffeners to PSM

5.2.1 General

For connection of stiffeners to PSM in case of lateral pressure other than bottom slamming and bow impact loads, [5.2.2] and [5.2.3] are to be applied. In case of bottom slamming or bow impact loads, [5.2.4] is to be applied.

The cross sectional areas of the connections are to be determined from the proportion of load transmitted through each component in association with its appropriate permissible stress.

5.2.2

The load, W1, in kN, transmitted through the shear connection is to be taken as follows.

- If the web stiffener is connected to the intersecting stiffener:

\[ W_1 = W (\alpha_a + \frac{A_1}{4f_c A_w + A_1}) \]

- If the web stiffener is not connected to the intersecting stiffener:

\[ W_1 = W \]

Where:

\[ W \]: Total load, in kN, transmitted through the stiffener connection to the PSM taken equal to:

\[ W = \frac{P_1 s_1 (S_1 - \frac{s_1}{2000}) + P_2 s_2 (S_2 - \frac{s_2}{2000})}{2 \sin \phi_w} \times 10^{-3} \]

\( P_1, P_2 \): Design pressure applied on the stiffener for the design load set being considered, in kN/m², on each side of the considered connection. For bottom slamming or bow impact loads, \( P_1 \) and \( P_2 \) are the design pressure as defined in Ch 4, Sec 5, [3.2] and [3.3] respectively.

\( S_1, S_2 \): Spacing between the considered and the adjacent PSM on each side of the considered connection, in m.

\( s_1, s_2 \): Spacing of the stiffener, in mm, on each side of the considered connection.

\( \alpha_a \): Panel aspect ratio, not to be taken greater than 0.25.

\( \phi_w \): angle, in deg, as defined in Ch 3, Sec 7.

5.2.3

\[ \sigma_{perm}, \tau_{perm} \]: Permissible direct stress given in Table 1 for AC-S and AC-SD, AC-I, in N/mm². Permissible shear stress given in Table 1 for AC-S and AC-SD, AC-I, in N/mm².
5.2.4 Bottom slamming and bow impact loads

For bottom slamming or bow impact loads, the load \(W\), in kN, transmitted through the PSM web stiffener is to comply with [5.2.2] and [5.2.3]

\[
0.9 W \leq \left( A_{1} \sigma_{\text{perm}} + A_{w} \tau_{\text{perm}} \right) \frac{10}{10}
\]

where:

- \(W\) : Load, in kN, as defined in [5.2.2].
- \(A_{1}\) : Effective net shear area, in cm², as defined in [5.2.2].
- \(A_{w}\) : Effective net cross sectional area, in cm², as defined in [5.2.2].
- \(\sigma_{\text{perm}}\) : Permissible direct stress given in Table 1 for AC-I, in N/mm².
- \(\tau_{\text{perm}}\) : Permissible shear stress given in Table 1 for AC-I, in N/mm².

5.2.9

The size of the fillet welds is to be calculated according to Ch 12, Sec 3, [2.5] based on the weld factors given in Table 2. For the welding in way of the shear connection the size is not to be less than that required for the PSM web plate for the location under consideration.

| Table 2: Weld factors for connection between stiffeners and PSMs |
|-----------------------------|-----------------|------------------|
| Item                        | Acceptance criteria | Weld factor                 |
| PSM stiffener to intersecting stiffener | AC-S, AC-SD, AC-I | \(0.6 \sigma_{W} / \sigma_{\text{perm}}\) not to be less than 0.38 |
| Shear connection inclusive of lug or collar plate | AC-S, AC-SD, AC-I | 0.38 |
| Shear connection inclusive of lug or collar plate, where the web stiffener of the PSM is not connected to the intersection stiffener | AC-S, AC-SD, AC-I | \(0.6 \tau_{W} / \tau_{\text{perm}}\) not to be less than 0.44 |
| PSM stiffener to intersecting stiffener | AC-I | 0.6 \(\frac{10}{10}\) |

SECTION 7 STRUCTURAL IDEALISATION

1 Structural idealisation of stiffeners and primary supporting members

1.3 Effective breadth

1.3.3 Effective area of curved face plate and attached plating of primary supporting members

The effective net area given in a) and b) is only applicable to curved face plates and curved attached plating of primary supporting members. This is not applicable for the area of web stiffeners parallel to the face plate.

The effective net area is applicable to primary supporting members for the following calculations:

- Actual net section modulus used for comparison with the scantling requirements in Ch 6.
- Actual effective net area of curved face plates, modelled by beam elements, used in Ch 7.

a) The effective net area, \(A_{\text{eff,50}}\), in mm², is to be taken as:

\[A_{\text{eff,50}} = C \cdot f_{\text{a,50}} \cdot bf\]
Cf: Flange efficiency coefficient taken equal to is to be obtained from the following formula but not to be greater than 1.0:

\[ C_f = C_f = \frac{\frac{\sqrt{E}}{k_e}}{k_e} \text{ but not to be taken greater than 1.0} \]

\[ C_f = C_f, \frac{1.285}{\beta k_1} \text{ for symmetrical face plate} \]

\[ C_f = 0.18 + \frac{0.08}{\beta^2} \text{ for unsymmetrical face plate} \]

\[ C_f = C_f, \frac{1.285}{\beta} \text{ for attached plating of box girders} \]

\( C_f \): Coefficient taken equal to:

- For symmetrical and unsymmetrical face plates,

\[ C_{f_{1}} = \frac{0.643 (\sinh k_1 \beta \cosh k_1 \beta + \sin k_1 \beta \cos k_1 \beta)}{(\sinh k_1 \beta)^2 + (\sin k_1 \beta)^2} \]

- For attached plating of box girders with two webs,

\[ C_{f_{1}} = \frac{0.78 (\sinh \beta + \sin \beta)(\cosh \beta - \cos \beta)}{(\sinh \beta)^2 + \sin^2 \beta} \]

- For attached plating of box girders with multiple webs,

\[ C_{f_{1}} = \frac{1.56 (\cosh \beta - \cos \beta)}{\sinh \beta + \sin \beta} \]

\( k_1 \): Coefficient calculated as:

\[ k_1 = 1.4 + 1.25(1.4-\beta)^3 \text{ for } \beta < 1.4 \]

\[ k_1 = 1.4 \text{ for } \beta \geq 1.4 \]
CHAPTER 4
LOADS

SECTION 4 HULL GIRDER LOADS

2 VERTICAL STILL WATER HULL GIRDER LOADS

2.3 Vertical still water shear force

2.3.4 Permissible still water shear force in harbour/sheltered water and tank testing

The permissible vertical still water shear forces, $Q_{sw-p}$ for oil tankers and bulk carriers, in the harbour/sheltered water and tank testing condition at any longitudinal position are to envelop:

- The most severe still water shear forces, positive or negative, for the harbour/sheltered water loading conditions defined in Ch 4, Sec 8 after shear force correction in case of bulk carrier.
- The most severe still water shear forces for the harbour/sheltered water loading conditions defined in the loading manual after shear force correction in case of bulk carrier.
- The permissible vertical still water shear force defined in [2.3.3].
- For oil tankers, the minimum still water shear force for harbour/sheltered water conditions defined in [2.3.2].

The following value may be used as guidance at preliminary design stage:

$$Q_{SW-p} = Q_{SW} + 0.6 Q_{WV}$$

where:

$Q_{SW}$: Permissible still water shear force $Q_{sw}$, as defined in [2.3.3].

$Q_{WV}$: Vertical wave shear force for strength assessment $Q_{wv-pos}$ and $Q_{wv-neg}$ as defined in [3.2.1] using $f_p$ equal to 1.0.

SECTION 8 LOADING CONDITIONS

3 OIL TANKERS

3.2 Design load combinations for direct strength analysis

3.2.6 Tankers with two oil-tight longitudinal bulkheads except with a cross tie arrangement in the wing cargo tanks

For tankers with two oil-tight longitudinal bulkheads except with a cross tie arrangement in the wing cargo tanks, loading patterns A7 and A12 in Table 2, Table 4, Table 6 and Table 8 are to be examined for the possibility that unequal filling levels in transversely paired wing cargo tanks would result in a more onerous stress response. Loading pattern A7 is required to be analysed only if such a non-symmetric seagoing loading condition is included in the ship loading manual. The actual loading pattern, draught, GM and $k_r$ from the loading manual are to be used in the FE analysis. Where the GM and $k_r$ are not given in the ship’s loading manual, GM and $k_r$ are to be determined in accordance with Ch 4, Sec 3.
If loading patterns A7 and A12 are not considered, an operational restriction describing that the difference in filling level between corresponding port and starboard wing cargo tanks is not to exceed 25% of the filling height in the wing cargo tank, is to be added in the loading manual. Loading patterns A7 and A12 need not be examined for tankers with a cross tie arrangement in the wing cargo tanks.

CHAPTER 7
Direct Strength Analysis

SECTION 2 CARGO HOLD STRUCTURAL STRENGTH ANALYSIS

4 LOAD APPLICATION

4.4 Procedure to adjust hull girder shear forces and bending moments

4.4.5 Hull girder shear force adjustment procedure

The hull girder shear force adjustment procedure defined in this requirement applies to all FE load combinations given in Ch 4, Sec 8. The FE load combinations not directly covered by the load combination tables of Ch 4, Sec 8 are to be considered on a case by case basis.

The two following methods are to be used for the shear force adjustment:

- Method 1 (M1): for shear force adjustment at one bulkhead of the mid-hold as given in [4.4.6],
- Method 2 (M2): for shear force adjustment at both bulkheads of the mid-hold as given in [4.4.7].

For the considered FE load combination, the method to be applied is to be selected as follows:

- For maximum shear force load combination (Max SFLC), the method 1 applies at the bulkhead mentioned in Table 4 if the shear force after the adjustment with method 1 at the other bulkhead does not exceed the target value. Otherwise, the method 2 applies.
- For other shear force load combination:
  - The shear force adjustment is not requested when the shear forces at both bulkheads are lower or equal to the target values. *This applies to cargo hold analysis in whole cargo area except for aft most and foremost cargo hold.*
  - For aft most and foremost cargo hold analyses, the shear force adjustment is to be applied with method 1. The target hull girder vertical shear force at the aft and forward transverse bulkheads, $Q_{targ-aft}$ and $Q_{targ-fwd}$, are to be set to values of vertical shear force due to local loads $Q_{aft}$ and $Q_{fwd}$ accordingly:
    
    \[
    Q_{targ-fwd} = Q_{fwd} \\
    Q_{targ-aft} = Q_{aft}
    \]
  - The method 1 applies when the shear force exceeds the target at one bulkhead and the shear force at the other bulkhead after the adjustment with method 1 does not exceed the target value. Otherwise the method 2 applies,
  - The method 2 applies when the shear forces at both bulkheads exceed the target values,
The “maximum shear force load combinations” are marked as “Max SFLC” in the load combination tables of Ch 4, Sec 8. The “other shear force load combinations” are those which are not the maximum shear force load combinations. They are not marked in the load combination tables of Ch 4, Sec 8.

4.4.6 Method 1 for vertical shear force adjustment at one bulkhead

The required adjustments in shear force at aft or forward transverse bulkhead of the mid-hold are to be made by applying vertical bending moments, \( M_{Y,aft} \) and \( M_{Y,fore} \) at model ends. For aft most cargo and foremost cargo hold models, the following additional vertical loads are to be applied at the transverse frame positions as shown in Table 7:

- \( \delta w'_{1} - \) for aft most cargo hold model
- \( \delta w'_{3} - \) for foremost cargo hold model

The required adjustments in shear force at following transverse bulkheads of the mid-hold are given by:

- Aft bulkhead:

\[
M_{Y,aft} = M_{Y,fore} = \frac{(x_{fore} - x_{aft})}{2} (Q_{targ-aft} - Q_{aft}) - M'_{1-aft}
\]

\[
\Delta Q_{aft} = \Delta Q_{fwd} = 0
\]

\[
\delta w'_{1} = \frac{Q_{targ-aft} - Q_{aft} + R_{v,aft}}{(n_{1} - 1)} \quad \text{for aftmost cargo hold model only}
\]

\[
\delta w'_{3} = \frac{Q_{targ-aft} - Q_{aft} + R_{v,fore}}{(n_{3} - 1)} \quad \text{for foremost cargo hold model only}
\]

- Forward bulkhead

\[
M_{Y,aft} = M_{Y,fore} = \frac{(x_{fore} - x_{aft})}{2} (Q_{targ-fwd} - Q_{fwd}) - M'_{1-fwd}
\]

\[
\Delta Q_{aft} = \Delta Q_{fwd} = 0
\]

\[
\delta w'_{1} = \frac{Q_{targ-fwd} - Q_{fwd} + R_{v,aft}}{(n_{1} - 1)} \quad \text{for aftmost cargo hold model only}
\]

\[
\delta w'_{3} = \frac{Q_{targ-fwd} - Q_{fwd} + R_{v,fore}}{(n_{3} - 1)} \quad \text{for foremost cargo hold model only}
\]

where:

- \( M_{Y,aft}, M_{Y,fore} \): Vertical bending moment, in kNm, to be applied at the aft and fore ends in accordance with [4.4.10], to enforce the hull girder vertical shear force adjustment as shown in Table 5. The sign convention is that of the FE model axis.
- \( Q_{aft} \): Vertical shear force, in kN, due to local loads at aft bulkhead location of mid-hold, resulting from the local loads calculated according to [4.4.3]. Since the vertical shear force is discontinued at the transverse bulkhead location, \( Q_{aft} \) is the maximum absolute shear force between the stations located right after and right forward of the aft bulkhead of mid-hold.
Q_{fwd} : Vertical shear force, in kN, due to local loads at the forward bulkhead location of mid-hold, \( x_{b-fwd} \), resulting from the local loads calculated according to [4.4.3]. Since the vertical shear force is discontinued at the transverse bulkhead location, Q_{fwd} is the maximum absolute shear force between the stations located right after and right forward of the forward bulkhead of mid-hold.

\[ M'_{1\text{-aft}}, M'_{1\text{-fwd}} : \text{Additional vertical bending moment, in kNm, applicable for aftmost and foremost cargo hold analysis only, taken as:} \]

- **Aft most cargo hold model**
  \[ M'_{1\text{-aft}} = \frac{l_1}{4} \left( Q_{\text{targ-aft}} - Q_{\text{aft}} + R_{V,\text{aft}} \right) \]
  \[ M'_{1\text{-fwd}} = \frac{l_1}{4} \left( Q_{\text{targ-fwd}} - Q_{\text{fwd}} + R_{V,\text{aft}} \right) \]

- **Foremost cargo hold model**
  \[ M'_{1\text{-aft}} = \frac{l_2}{4} \left( Q_{\text{targ-aft}} - Q_{\text{aft}} + R_{V,\text{fore}} \right) \]
  \[ M'_{1\text{-fwd}} = \frac{l_2}{4} \left( Q_{\text{targ-fwd}} - Q_{\text{fwd}} + R_{V,\text{fore}} \right) \]

\( \delta w'_{1} \) : Distributed load, in kN, at frame in the modelled engine room of aftmost cargo hold model, see also Table 8.

\( \delta w'_{3} \) : Distributed load, in kN, at frame in the modelled forepeak of foremost cargo hold model, see also Table 8.

\( \Delta Q_{\text{aft}}, \Delta Q_{\text{fwd}} \) : Shear force adjustments, as given in Table 8

\( R_{V,\text{aft}}, R_{V,\text{fore}} \) : Reaction forces at the aft and fore ends, in kN, as defined in [4.4.3].

\( l_1, l_2 \) : Length of the modelled engine room in aftmost cargo hold model, in m. See also Table 8.

\( l_3, n_3 \) : Length of the modelled forepeak in foremost cargo hold model, in m. See also Table 8.

Table 6 shows examples of the shear adjustment application due to the vertical bending moments and to vertical loads.

\[ M_{Y,\text{aft}} = M_{Y,\text{fore}} = \frac{(x_{\text{fore}} - x_{\text{aft}})}{2} \left( \frac{Q_{\text{targ-fwd}} - Q_{\text{fwd}} + Q_{\text{targ-aft}} - Q_{\text{aft}}}{2} \right) - M'_{2} \]

\[ \Delta Q_{\text{fwd}} = \frac{Q_{\text{targ-fwd}} - Q_{\text{fwd}} - (Q_{\text{targ-aft}} - Q_{\text{aft}})}{2} + \]

\[ \Delta Q_{\text{aft}} = -\Delta Q_{\text{fwd}} \]
• Aft most cargo hold model
\[
\delta w'_1 = \frac{(Q_{\text{targ-aft}} - Q_{\text{aft}})(l - l_2 - l_3) + (Q_{\text{targ-fwd}} - Q_{\text{fwd}})(l - l_2 - l_3)}{2l - l_1 - 2l_2 - l_3} + R_{\text{aft}} \frac{1}{n_1 - 1}
\]

• Foremost cargo hold model
\[
\delta w'_3 = \frac{(Q_{\text{targ-fwd}} - Q_{\text{fwd}})(l - l_2 - l_3) + (Q_{\text{targ-aft}} - Q_{\text{aft}})(l - l_2 - l_3)}{2l - l_1 - 2l_2 - l_3} + R_{\text{fwd}} \frac{1}{n_3 - 1}
\]

where:
- \( M_{Y_{\text{aft}}, Y_{\text{fore}}} \): Vertical bending moment, in kNm, to be applied at the aft and fore ends in accordance with [4.4.10], to enforce the hull girder vertical shear force adjustment. The sign convention is that of the FE model axis.
- \( \Delta Q_{\text{aft}} \): Adjustment of shear force, in kN, at aft bulkhead of mid-hold.
- \( \Delta Q_{\text{fwd}} \): Adjustment of shear force, in kN, at fore bulkhead of mid-hold.
- \( M'_2 \): Additional vertical bending moment, in kNm, applicable for aftmost and foremost cargo hold analysis only, taken as:
  - Aftmost cargo hold model
    \[
    M'_2 = \frac{l_1(n_1 - 1)\delta w'_1}{4}
    \]
  - Foremost cargo hold model
    \[
    M'_2 = \frac{l_3(n_3 - 1)\delta w'_3}{4}
    \]
- \( \delta w'_1 \): Distributed load, in kN, at frame in the modelled engine room of aftmost cargo hold model, see also Table 8.
- \( \delta w'_3 \): Distributed load, in kN, at frame in the modelled forepeak of foremost cargo hold model, see also Table 8.
- \( R_{\text{aft}}, R_{\text{fwd}} \): Reaction forces at the aft and fore ends, in kN, as defined in [4.4.3].
- \( l_1 \): Length of the modelled engine room in aftmost cargo hold model, in m. See also Table 8.
- \( l_3 \): Length of the modelled forepeak in foremost cargo hold model, in m. See also Table 8.
- \( n_1, n_3 \): Number of frame spaces, see Table 8.

\[\begin{array}{|c|}
\hline
\text{Table 8 : Formulae for calculation of vertical loads for adjusting vertical shear forces} \\
\hline
\hline
\delta w_1 &= \frac{\Delta Q_{\text{aft}}(2l - l_2 - l_3) + \Delta Q_{\text{fwd}}(l_2 + l_3)}{(n_1 - 1)(2l - l_1 - 2l_2 - l_3)} + \delta w'_1 \\
\hline
\delta w_2 &= \frac{(W_1 + W_3)}{(n_2 - 1)} = \frac{(\Delta Q_{\text{aft}} - \Delta Q_{\text{fwd}})}{(n_2 - 1)} \\
\hline
\delta w_3 &= -\frac{\Delta Q_{\text{fwd}}(2l - l_1 - l_2) - \Delta Q_{\text{aft}}(l_1 + l_2)}{(n_3 - 1)(2l - l_1 - 2l_2 - l_3)} - \delta w'_3 \\
\hline
\end{array}\]

\[F = F_{\text{aft}} = F_{\text{fwd}} = 0.5 \left( \frac{W_1(l_2 + l_3) - W_3(l_2 + l_3)}{l} \right)\]
For aftmost and foremost cargo hold FE model

\[ F = F_{aft} = \left( \frac{W1(l_f + l_3 + 0.5l_1) + W2(l_f + 0.5l_2) + W3(l_f + 0.5l_3)}{l} \right) \]

where:

- \( l_1 \): Length of aft cargo hold of model, in m.
- \( l_2 \): Length of mid-hold of model, in m.
- \( l_3 \): Length of forward cargo hold of model, in m.
- \( \Delta Q_{aft} \): Required adjustment in shear force, in kN, at aft bulkhead of middle hold, see [4.4.7].
- \( \Delta Q_{fwd} \): Required adjustment in shear force, in kN, at fore bulkhead of middle hold, see [4.4.7].
- \( F \): End reactions, in kN, due to application of vertical loads to frames.
- \( W1 \): Total evenly distributed vertical load, in kN, applied to aft hold of FE model, \((n_1 - 1) \delta w_1\).
- \( W2 \): Total evenly distributed vertical load, in kN, applied to mid-hold of FE model, \((n_2 - 1) \delta w_2\).
- \( W3 \): Total evenly distributed vertical load, in kN, applied to forward hold of FE model, \((n_3 - 1) \delta w_3\).
- \( n_1 \): Number of frame spaces in aft cargo hold of FE model.
- \( n_2 \): Number of frame spaces in mid-hold of FE model.
- \( n_3 \): Number of frame spaces in forward cargo hold of FE model.
- \( \delta w_1 \): Distributed load, in kN, at frame in aft cargo hold of FE model.
- \( \delta w_2 \): Distributed load, in kN, at frame in mid-hold of FE model.
- \( \delta w_3 \): Distributed load, in kN, at frame in forward cargo hold of FE model.
- \( \delta w'\_a \): Additional distributed load, in kN, at frame in the modelled engine room of aftmost cargo hold model. Formulae of \( \delta w'\_a \) are given in [4.4.6] and [4.4.7] for shear force adjustment method 1 and method 2 accordingly.
- \( \delta w'\_f \): Additional distributed load, in kN, at frame in the modelled forepeak of foremost cargo hold model. Formulae of \( \delta w'\_f \) are given in [4.4.6] and [4.4.7] for shear force adjustment method 1 and method 2 accordingly.
- \( \Delta l_{end} \): Distance, in m, between end bulkhead of aft cargo hold to aft end of FE model.
- \( \Delta l_{fwd} \): Distance, in m, between fore bulkhead of forward cargo hold to forward end of FE model.
- \( l \): Total length, in m, of FE model including portions beyond end bulkheads:
  \[ l = l_1 + l_2 + l_3 + \Delta l_{end} + \Delta l_{fwd} \]

Note 1: Positive direction of loads, shear forces and adjusting vertical forces in the formulae is in accordance with Table 6 and Table 7.

Note 2: \( W1 + W3 = W2 \) (not applicable for aftmost and foremost cargo FE model).

Note 3: The above formulae are only applicable if uniform frame spacing is used within each hold. The length and frame spacing of individual cargo holds may be different.

---

### SECTION 3 LOCAL STRUCTURAL STRENGTH ANALYSIS

#### 6 ANALYSIS CRITERIA

6.2 Acceptance criteria

6.2.1 \( \lambda_{perm} \): Permissible fine mesh utilisation factor, taken as:

- Element not adjacent to weld:
• $\lambda_{fperm} = 1.70 f_f$ for S+D
• $\lambda_{fperm} = 1.36 f_f$ for S

Element adjacent to weld:
• $\lambda_{fperm} = 1.50 f_f$ for S+D
• $\lambda_{fperm} = 1.20 f_f$ for S

$f_f$: Fatigue factor, taken as:
• $f_f = 1.0$ in general, including the free edge of base material,
• $f_f = 1.2$ for details assessed by very fine mesh analysis complying with the fatigue assessment criteria given in Ch 9, Sec 2.

PART 2 SHIP TYPES

CHAPTER 1
BULK CARRIERS

SECTION 1 GENERAL ARRANGEMENT DESIGN

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 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; where pipe tunnels are entered from the engine room, the engine room ventilation system may be used as the mechanical ventilation method.

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 and the following additional requirements:

a) The watertight door is to be capable of being manually closed from outside the adjacent spaces and remotely from the bridge.

b) A means of indicating whether the door is open or closed is to be provided locally and on the bridge.

c) 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.