Guide on Finite Element Analysis of Oil Tankers and Bulk Carriers having length between 90 m and 150 m

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GENERAL CONDITIONS

Definitions:

"*Administration*" means the Government of the State whose flag the Ship is entitled to fly or under whose authority the Ship is authorised to operate in the specific case.

"IACS" means the International Association of Classification Societies.

"*Interested Party*" means the party, other than the Society, having an interest in or responsibility for the Ship, product, plant or system subject to classification or certification (such as the owner of the Ship and his representatives, the ship builder, the engine builder or the supplier of parts to be tested) who requests the Services or on whose behalf the Services are requested.

"*Owner*" means the registered owner, the ship owner, the manager or any other party with the responsibility, legally or contractually, to keep the ship seaworthy or in service, having particular regard to the provisions relating to the maintenance of class laid down in Part A, Chapter 2 of the Rules for the Classification of Ships or in the corresponding rules indicated in the specific Rules.

"Rules" in these General Conditions means the documents below issued by the Society:

- (i) Rules for the Classification of Ships or other special units;
- (ii) Complementary Rules containing the requirements for product, plant, system and other certification or containing the requirements for the assignment of additional class notations;
- (iii) Rules for the application of statutory rules, containing the rules to perform the duties delegated by Administrations;
- (iv) Guides to carry out particular activities connected with Services;
- (v) Any other technical document, as for example rule variations or interpretations.

"*Services*" means the activities described in Article 1 below, rendered by the Society upon request made by or on behalf of the Interested Party.

"Ship" means ships, boats, craft and other special units, as for example offshore structures, floating units and underwater craft.

"*Society*" or *"TASNEEF"* means Tasneef and/or all the companies in the Tasneef Group which provide the Services.

"*Surveyor*" means technical staff acting on behalf of the Society in performing the Services.

Article 1

1.1. The purpose of the Society is, among others, the classification and certification of ships and the certification of their parts and components. In particular, the Society:
- (i) sets forth and develops Rules;
- (ii) publishes the Register of Ships;
- (iii) issues certificates, statements and reports based on its survey activities.

1.2. The Society also takes part in the implementation of national and international rules and standards as delegated by various Governments.

1.3. The Society carries out technical assistance activities on request and provides special services outside the scope of classification, which are regulated by these general conditions, unless expressly excluded in the particular contract.

Article 2

2.1. The Rules developed by the Society reflect the level of its technical knowledge at the time they are published. Therefore, the Society, although committed also through its research and development services to continuous updating of the Rules, does not guarantee the Rules meet state-of-the-art science and technology at the time of publication or that they meet the Society's or others' subsequent technical developments.

2.2. The Interested Party is required to know the Rules on the basis of which the Services are provided. With particular reference to Classification Services, special attention is to be given to the Rules concerning class suspension, withdrawal and reinstatement. In case of doubt or inaccuracy, the Interested Party is to promptly contact the Society for clarification.
The Rules for Classification of Ships are published on the Society's website: www.tasneef.ae.

2.3. The Society exercises due care and skill:
- (i) in the selection of its Surveyors
- (ii) in the performance of its Services, taking into account the level of its technical knowledge at the time the Services are performed.

2.4. Surveys conducted by the Society include, but are not limited to, visual inspection and non-destructive testing. Unless otherwise required, surveys are conducted through sampling techniques and do not consist of comprehensive verification or monitoring of the Ship or of the items subject to certification. The surveys and checks made by the Society on board ship do not necessarily require the constant and continuous presence of the Surveyor. The Society may also commission laboratory testing, underwater inspection and other checks carried out by and under the responsibility of qualified service suppliers. Survey practices and procedures are selected by the Society based on its experience and knowledge and according to generally accepted technical standards in the sector.

Article 3

3.1. The class assigned to a Ship, like the reports, statements, certificates or any other document or information issued by the Society, reflects the opinion of the Society concerning compliance, at the time the Service is provided, of the Ship or product subject to certification, with the applicable Rules (given the intended use and within the relevant time frame).
The Society is under no obligation to make statements or provide information about elements or facts which are not part of the specific scope of the Service requested by the Interested Party or on its behalf.

3.2. No report, statement, notation on a plan, review, Certificate of Classification, document or information issued or given as part of the Services provided by the Society shall have any legal effect or implication other than a representation that, on the basis of the checks made by the Society, the Ship, structure, materials, equipment, machinery or any other item covered by such document or information meet the Rules. Any such document is issued solely for the use of the Society, its committees and clients or other duly authorised bodies and for no other purpose. Therefore, the Society cannot be held liable for any act made or document issued by other parties on the basis of the statements or information given by the Society. The validity, application, meaning and interpretation of a Certificate of Classification, or any other document or information issued by the Society in connection with its Services, is governed by the Rules of the Society, which is the sole subject entitled to make such interpretation. Any disagreement on technical matters between the Interested Party and the Surveyor in the carrying out of his functions shall be raised in writing as soon as possible with the Society, which will settle any divergence of opinion or dispute.

3.3. The classification of a Ship, or the issuance of a certificate or other document connected with classification or certification and in general with the performance of Services by the Society shall have the validity conferred upon it by the Rules of the Society at the time of the assignment of class or issuance of the certificate; in no case shall it amount to a statement or warranty of seaworthiness, structural integrity, quality or fitness for a particular purpose or service of any Ship, structur e, material, equipment or machinery inspected or tested by the Society.

3.4. Any document issued by the Society in relation to its activities reflects the condition of the Ship or the subject of certifi cation or other activity at the time of the check.

3.5. The Rules, surveys and activities performed by the Society, reports, certificates and other documents issued by the Society are in no way intended to replace the duties and responsibilities of other parties such as Governments, designers, ship builders, manufacturers, repairers, suppliers, contractors or sub-contractors, Owners, operators, charterers, underwriters, sellers or intended buyers of a Ship or other product or system surveyed.
These documents and activities do not relieve such parties from any fulfilment, warranty, responsibility, duty or obligation (also of a contractual nature) expressed or implied or in any case incumbent on them, nor do they confer on such parties any right, claim or cause of action against the Society. With particular regard to the duties of the ship Owner, the Services undertaken by the Society do not relieve the Owner of his duty to ensure proper maintenance of the Ship and ensure seaworthiness at all times. Likewise, t he Rules, surveys performed, reports, certificates and other documents issued by the Society are intended neither to guarantee the buyers of the Ship, its components or any other surveyed or certified item, nor to relieve the seller of the duties arising out of the law or the contract, regarding the quality, commercial value or characteristics of the item which is the subject of transaction.
In no case, therefore, shall the Society assume the obligations incumbent upon the above-mentioned parties, even when it is consulted in connection with matters not covered by its Rules or other documents.
In consideration of the above, the Interested Party undertakes to relieve and hold harmless the Society from any third party claim, as well as from any liability in relation to the latter concerning the Services rendered.
Insofar as they are not expressly provided for in these General Conditions, the duties and responsibilities of the Owner and Interested Parties with respect to the services rendered by the Society are described in the Rules applicable to the specific Service rendered.

Article 4

4.1. Any request for the Society's Services shall be submitted in writing and signed by or on behalf of the Interested Party. Such a request will be considered irrevocable as soon as received by the Society and shall entail acceptance by the applicant of all relevant requirements of the Rules, including these General Conditions. Upon acceptance of the written request by the Society, a contract between the Society and the Interested Party is entered into, which is regulated by the present General Conditions.

4.2. In consideration of the Services rendered by the Society, the Interested Party and the person requesting the service shall be jointly liable for the payment of the relevant fees, even if the service is not concluded for any cause not pertaining to the Society. In the latter case, the Society shall not be held liable for non-fulfilment or partial fulfilment of the Services requested. In the event of late payment, interest at the legal current rate increased by 1.5% may be demanded.

4.3. The contract for the classification of a Ship or for other Services may be terminated and any certificates revoked at the request of one of the parties, subject to at least 30 days' notice to be given in writing. Failure to pay, even in part, the fees due for Services carried out by the Society will entitle the Society to immediately terminate the contract and suspend the Services.
For every termination of the contract, the fees for the activities performed until the time of the termination shall be owed to the Society as well as the expenses incurred in view of activities already programmed; this is without prejudice to the right to compensation due to the Society as a consequence of the termination.
With particular reference to Ship classification and certification, unless decided otherwise by the Society, termination of the contract implies that the assignment of class to a Ship is withheld or, if already assigned, that it is suspended or withdrawn; any st atutory certificates issued by the Society will be withdrawn in those cases where provided for by agreements between the Society and the flag State.

Article 5

5.1. In providing the Services, as well as other correlated information or advice, the Society, its Surveyors, servants or agents operate with due diligence for the proper execution of the activity. However, considering the nature of the activities performed (see art. 2.4), it is not possible to guarantee absolute accuracy, correctness and completeness of any information or advice supplied. Express and implied warranties are specifically disclaimed.
Therefore, except as provided for in paragraph 5.2 below, and also in the case of activities carried out by delegation of Governments, neither the Society nor any of its Surveyors will be liable for any loss, damage or expense of whatever nature sustained by any person, in tort or in contract, derived from carrying out the Services.

5.2. Notwithstanding the provisions in paragraph 5.1 above, should any user of the Society's Services prove that he has suffered a loss or damage due to any negligent act or omission of the Society, its Surveyors, servants or agents, then the Society will pay compensation to such person for his proved loss, up to, but not exceeding, five times the amount of the fees charged for the specific services, information or opinions from which the loss or damage derives or, if no fee has been charged, a maximum of AED5,000 (Arab Emirates Dirhams Five Thousand only). Where the fees charged are related to a number of Services, the amount of the fees will be apportioned for the purpose of the calculation of the maximum compensation, by reference to the estimated time involved in the performance of the Service from which the damage or loss derives. Any liability for indirect or consequential loss, damage or expense is specifically excluded. In any case, irrespective of the amount of the fees charged, the maximum damages payable by the Society will not be more than AED5,000,000 (Arab Emirates Dirhams Five Millions only). Payment of compensation under this paragraph will not entail any admission of responsibility and/or liability by the Society and will be made without prejudice to the disclaimer clause contained in paragraph 5.1 above.

5.3. Any claim for loss or damage of whatever nature by virtue of the provisions set forth herein shall be made to the Society in writing, within the shorter of the following periods: (i) THREE (3) MONTHS from the date on which the Services were performed, or (ii) THREE (3) MONTHS from the date on which the damage was discovered. Failure to comply with the above deadline will constitute an absolute bar to the pursuit of such a claim against the Society.

Article 6

6.1. These General Conditions shall be governed by and construed in accordance with United Arab Emirates (UAE) law, and any dispute arising from or in connection with the Rules or with the Services of the Society, including any issues concerning responsibility, liability or limitations of liability of the Society, shall be determined in accordance with UAE law. The courts of the Dubai International Financial Centre (DIFC) shall have exclusive jurisdiction in relation to any claim or dispute which may arise out of or in connection with the Rules or with the Services of the Society.

6.2. However,

(i) In cases where neither the claim nor any counterclaim exceeds the sum of AED300,000 (Arab Emirates Dirhams Three Hundred Thousand) the dispute shall be referred to the jurisdiction of the DIFC Small Claims Tribunal; and

(ii) for disputes concerning non-payment of the fees and/or expenses due to the Society for services, the Society shall have the right to submit any claim to the jurisdiction of the Courts of the place where the registered or operating office of the Interested Party or of the applicant who requested the Service is located.

In the case of actions taken against the Society by a third party before a public Court, the Society shall also have the right to summon the Interested Party or the subject who requested the Service before that Court, in order to be relieved and held harmless according to art. 3.5 above.

Article 7

7.1. All plans, specifications, documents and information provided by, issued by, or made known to the Society, in connection with the performance of its Services, will be treated as confidential and will not be made available to any other party other than the Owner without authorisation of the Interested Party, except as provided for or required by any applicable international, European or domestic legislation, Charter or other IACS resolutions, or order from a competent authority. Information about the status and validity of class and statutory certificates, including transfers, changes, suspensions, withdrawals of class, recommendations/conditions of class, operating conditions or restrictions issued against classed ships and other related information, as may be required, may be published on the website or released by other means, without the prior consent of the Interested Party.

Information about the status and validity of other certificates and statements may also be published on the website or released by other means, without the prior consent of the Interested Party.

7.2. Notwithstanding the general duty of confidentiality owed by the Society to its clients in clause 7.1 above, the Society's clients hereby accept that the Society may participate in the IACS Early Warning System which requires each Classification Society to provide other involved Classification Societies with relevant technical information on serious hull structural and engineering systems failures, as defined in the IACS Early Warning System (but not including any drawings relating to the ship which may be the specific property of another party), to enable such useful information to be shared and used to facilitate the proper working of the IACS Early Warning System. The Society will provide its clients with written details of such information sent to the involved Classification Societies.

7.3. In the event of transfer of class, addition of a second class or withdrawal from a double/dual class, the Interested Party undertakes to provide or to permit the Society to provide the other Classification Society with all building plans and drawings, certificates, documents and information relevant to the classed unit, including its history file, as the other Classification Society may require for the purpose of classification in compliance with the applicable legislation and relative IACS Procedure. It is the Owner's duty to ensure that, whenever required, the consent of the builder is obtained with regard to the provision of plans and drawings to the new Society, either by way of appropriate stipulation in the building contract or by other agreement.

In the event that the ownership of the ship, product or system subject to certification is transferred to a new subject, the latter shall have the right to access all pertinent drawings, specifications, documents or information issued by the Society or which has come to the knowledge of the Society while carrying out its Services, even if related to a period prior to transfer of ownership.

Article 8

8.1. Should any part of these General Conditions be declared invalid, this will not affect the validity of the remaining provisions.

INDEX

CHAPTER 1 – OIL TANKERS

INDEX

CHAPTERT 2 - BULK CARRIERS

CHAPTER 1 – OIL TANKERS

1 GENERAL

1.1 The purpose of Part 1 of this guide is to detail the procedure for the finite element analysis based on three-dimensional models extended over three cargo tanks, for ships with the service notation Oil Tanker having rule length L between 90 m and 150 m.

1.2 Ships with service notation Oil Tanker having rule length L between 90 m and 150 m are to comply with Tasneef Rules, i.e. they are not covered by Common Structural Rules for Bulk Carriers and Oil Tankers (CSR BC&OT).

It is worth noting that according to Tasneef Rules Pt B, Ch 7, Sec 3, [1.1.3], a three dimensional model is to be adopted for the analysis of primary supporting members of ships greater than 120 m in length.

1.3 The structural analysis is aimed at:

- Calculating the stress of longitudinal hull girder structural members, primary supporting members and bulkheads in the midship area and, when deemed necessary by the designer, in other areas, which are to be used in the yielding and buckling checks
- Calculating the stress gradients at structural detail level with the refined local mesh models in the highly stressed area, which are to be used in the yielding checks
- Calculating hot spot stress ranges in the structural details, which are to be used in the fatigue checks, if required.

1.4 The yielding and buckling checks of primary supporting members are to be carried out according to [8.3.1] and [8.4].

The structural details check is to be carried out according to [8.3.2]

The fatigue check of structural details is to be carried out according to [8.5].

1.5 The structural assessment is to be based on linear finite element analysis of three-dimensional structural models. The general types of finite elements to be used in the finite element analysis are given in Table 1.

Table 1: Types of finite elements

Type of finite element	Description
Rod (or truss) element	Line element with axial stiffness only and constant cross sectional area along the length of the element.
Beam element	Line element with axial, torsional and bi-directional shear and bending stiffness and with constant properties along the length of the element.
Shell (or plate) element	Shell element with in-plane stiffness and out-of-plane bending stiffness with constant thickness.

2 STRUCTURAL MODEL

2.1 General

2.1.1 The Finite Element Models used for the strength checks of primary supporting members are generally to extend in the longitudinal direction over at least three adjacent cargo tanks, the structures to be analysed belonging to the central one (mid-tank).

To account for the non modelled parts of the hull, appropriate loads and constraints are applied at the model boundaries, as specified in [2.7], in such a way that the hull girder loads are correctly reproduced in the area under investigation. Furthermore, some adjustment loads are applied to the fore end of the model in order to reach the target values of bending moments and shear force, as specified in [4.3].

2.1.2 The analysis is to address all the possible tank structural arrangements in the cargo tank central area. This means that, if the design contemplates different structural arrangements in this area, several FE models are to be built in such a way that each arrangement is represented in the central part of a model extended over at least three cargo tanks.

2.1.3 When the primary supporting member arrangement is such that the Society can accept that the results obtained for the midship region are extrapolated to other regions, no additional analyses are required. Otherwise, analyses of the other regions are to be carried out.

2.1.4 In general the use of the "fine mesh" as described in Tasneef Rules Pt B, Ch 7, App 1, [3.4.3] is to be adopted for the finite element model, as better explained in [2.6]. In practice the provisions of CSR BC&OT are to be used for the modelling**.**

2.2 Net scantlings

All the elements in [2.3] are to be modelled based on gross offered thickness reduced by 0.5 t_c according to Tasneef Rules Pt B, Ch 4, Sec 2, [2.1.5].

2.3 Members to be modelled

All main longitudinal and transverse structural elements are to be modelled. These include:

- Inner and outer shell
- Deck
- Double bottom floors and girders
- Transverse and vertical web frames
- Stringers
- Transverse and longitudinal bulkhead structures
- Other primary supporting members
- Other structural members which contribute to hull girder strength

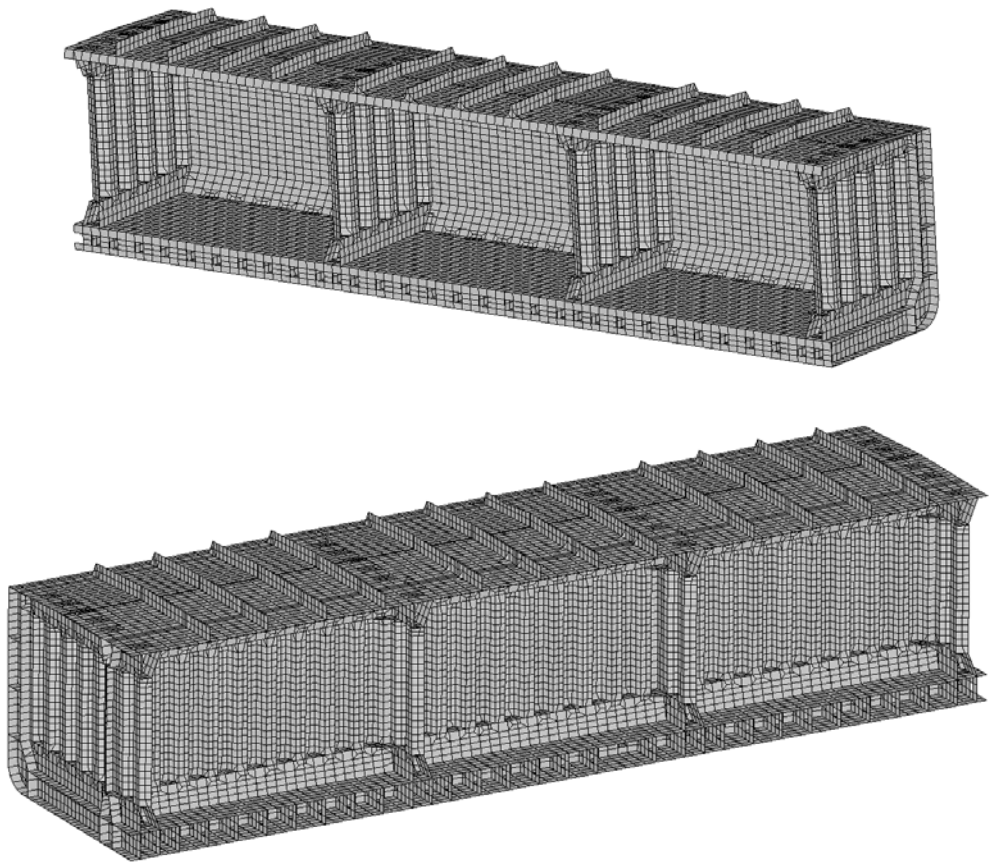
All plates and stiffeners on the structure, including web stiffeners, are to be modelled. Brackets which contribute to primary supporting member strength and the size of which is not less than the typical mesh size (s-by-s) described in [2.6.2] are to be modelled.

2.4 Extent of model

2.4.1 Longitudinal extent

The longitudinal extent of the cargo tank FE model is to cover three-cargo tank lengths. The transverse bulkheads at the ends of the model are to be modelled. Where corrugated transverse bulkheads are fitted, the model is to include the extent of the bulkhead stool structure forward and aft of the tanks at the model ends. The web frames at the ends of the model are to be modelled. A Typical finite element model representing the midship cargo tank region of a product carrier is shown in Figure 1.
In general, the finite element model is to represent the geometry of the hull form. In the midship cargo tank region, the finite element model may be prismatic provided the mid-tank has a prismatic shape.

Figure 1: Example of three-cargo tank model of an oil tanker



2.4.2 Transverse extent

Both port and starboard sides of the ship are to be modelled.

2.4.3 Vertical extent

The full depth of the ship is to be modelled including primary supporting members above the upper deck.

2.5 Finite element types

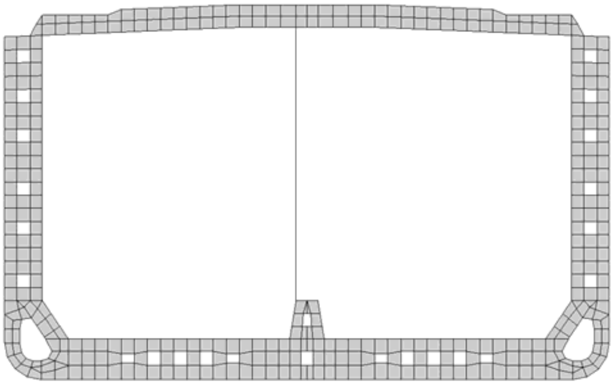
Shell elements are to be used to represent plates.
All stiffeners are to be modelled with beam elements having axial, torsional, bi-directional shear and bending stiffness. The eccentricity of the neutral axis is to be modelled.
Face plates of primary supporting members and brackets are to be modelled using rod or beam elements.

2.6 Structural modelling

2.6.1 Aspect ratio

The ratio between the longer and the shorter side of elements is to be less than 3. The use of triangular shell elements is to be kept to a minimum. Where possible, the aspect ratio of shell elements in areas where there are likely to be high stresses or a high stress gradient is to be kept close to 1 and the use of triangular elements is to be avoided.

Figure 2: Typical finite element mesh on web frame



2.6.2 Mesh

The shell element mesh is to follow the stiffening system as far as practicable, hence representing the actual plate panels between stiffeners. In general, the shell element mesh is to satisfy the following requirements:

- One element between every longitudinal stiffener, see Figure 2. Longitudinally, the element length is not to be greater than 2 longitudinal spaces with a minimum of three elements between primary supporting members.
- One element between every stiffener on transverse bulkheads.
- One element between every web stiffener on transverse and vertical web frames, cross ties and stringers, see Figure 2.
- At least 3 elements over the depth of double bottom girders, floors, transverse web frames, vertical web frames and horizontal stringers on transverse bulkheads. For cross ties, deck transverse and horizontal stringers on transverse wash bulkheads and longitudinal bulkheads with a smaller web depth, modelling using 2 elements over the depth is acceptable provided that there is at least 1 element between every web stiffener.
- The mesh on the hopper tank web frame and the topside web frame is to be fine enough to represent the shape of the web ring opening, as shown in Figure 2.
- The curvature of the free edge on large brackets of primary supporting members is to be modelled to avoid unrealistic high stress due to geometry discontinuities. In general, a mesh size equal to the stiffener spacing is acceptable. The bracket toe may be terminated at the nearest nodal point provided that the modelled length of the bracket arm does not exceed the actual bracket arm length. The bracket flange is not to be connected to the plating.

2.6.3 Corrugated bulkhead

Diaphragms in the stools, supporting structure of corrugated bulkheads and internal longitudinal and vertical stiffeners on the stool plating are to be included in the model. Modelling is to be carried out as follows:

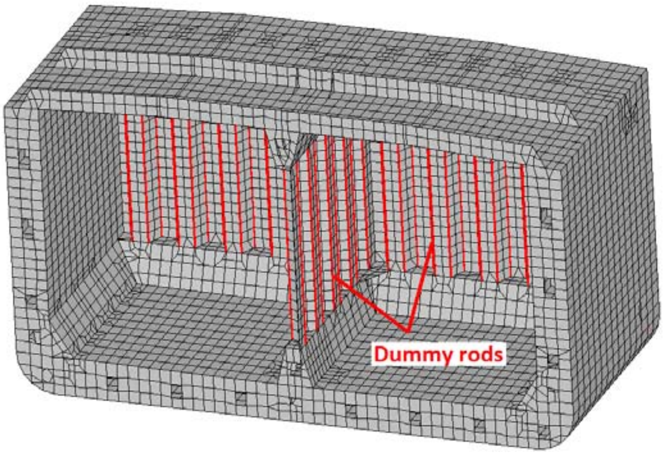
a) The corrugation is to be modelled with its geometric shape.
b) The mesh on the flange and web of the corrugation is in general to follow the stiffener spacing inside the bulkhead stool.
c) The aspect ratio of the mesh in the corrugation is not to exceed 2 with a minimum of 2 elements for the flange breadth and the web height.
d) Where difficulty occurs in matching the mesh on the corrugations directly with the mesh on the stool, it is acceptable to adjust the mesh on the stool in way of the corrugations.
e) For a corrugated bulkhead without an upper stool and/or lower stool, it may be necessary to adjust the geometry in the model. The adjustment is to be made such that the shape and position of the corrugations and primary supporting members are retained. Hence, the adjustment is to be made on stiffeners and plate seams if necessary.
f) When corrugated bulkhead is subjected to liquid cargo or ballast, dummy rod elements with a cross sectional area of 1 mm^2 are to be modelled at the corrugation knuckle between the flange and the web (see Figure 3). Dummy rod elements are to be

used as minimum at the two corrugation knuckles closest to the intersection between:

- Transverse and longitudinal bulkheads,
- Transverse bulkhead and inner hull,
- Transverse bulkhead and side shell.

g) Manholes in diaphragms are to be modelled according to [2.6.7]

Figure 3: Dummy rod elements at the corrugation knuckle



2.6.4 Example of mesh arrangements of the cargo tank structure are shown in Figure 4 and Figure 5.

Figure 4: Example of FE mesh on transverse corrugated bulkhead structure for a product tanker

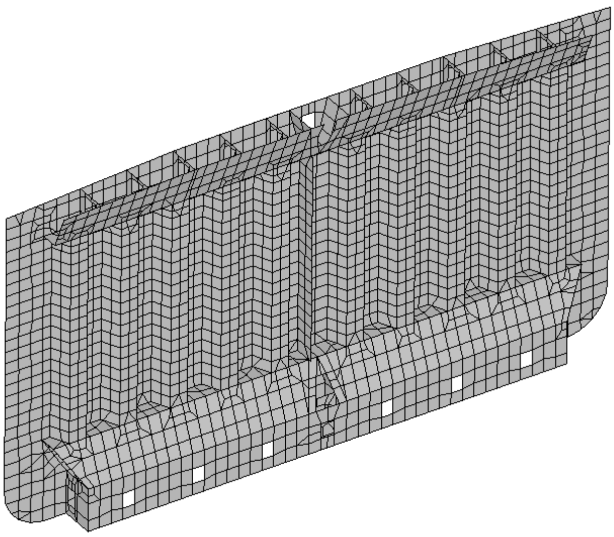
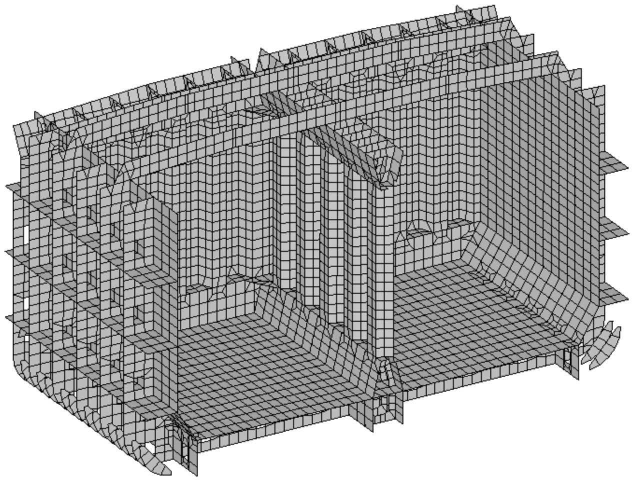


Figure 5: Example of FE mesh arrangements of cargo tank structure for a product carrier



2.6.5 Sniped end stiffener

Non continuous stiffeners are to be modelled as continuous stiffeners, i.e. the height web reduction in way of the snip ends are not to be modelled.

2.6.6 Web stiffeners of primary supporting members

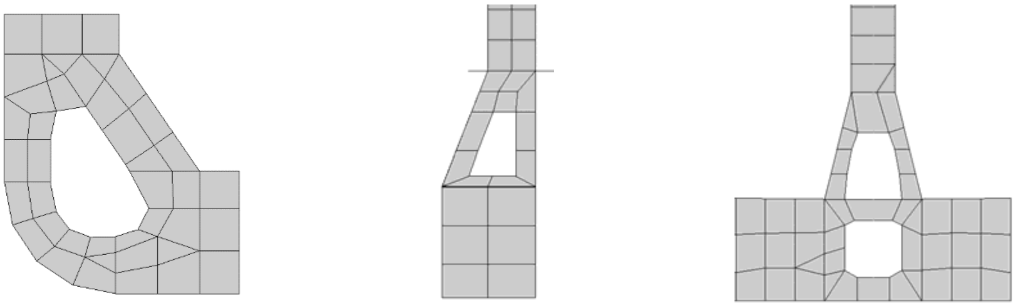
Web stiffeners of primary supporting members are to be modelled. Where these stiffeners are not in line with the primary FE mesh, it is sufficient to place the line element along the nearby nodal points provided that the adjusted distance does not exceed 0.2 times the stiffener spacing under consideration. The stresses obtained need not be corrected for the adjustment. Buckling stiffeners on large brackets, deck transverses and stringers parallel to the flange are to be modelled. These stiffeners may be modelled using rod elements.

2.6.7 Openings

Methods of representing openings and manholes in webs of primary supporting members are to be as follows:

- Manholes are to be modelled by removing the appropriate elements
- Small openings (openings smaller than manholes) do not need to be modelled
- Large opening (openings larger than manholes) are to be modelled representing the actual geometry of the hole (see Figure 6).

Figure 6: Example of large openings to be modelled



2.7 Boundary conditions

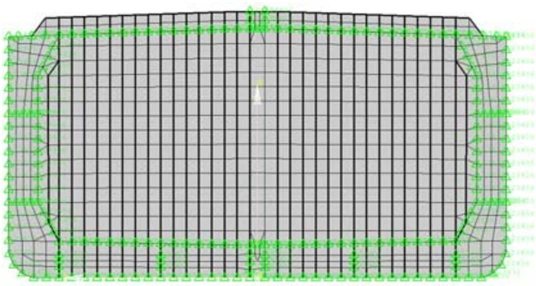
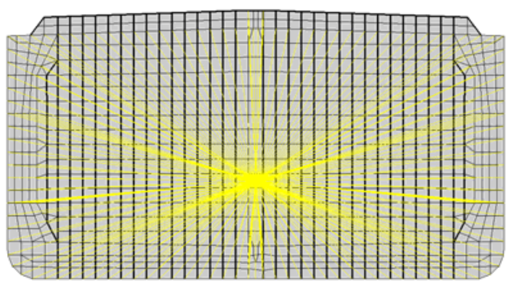
2.7.1 The model is assumed to be fixed at its aft end and free at its fore end.

All the degrees of freedom of the nodes on the longitudinal members at aft end of the model are to be constrained.

At the fore end section, rigid links are to be applied to all nodes located on longitudinal members, in such a way that the transverse section remains plane after deformation (see Table 2).

Shear forces and bending moments adjustment are applied at its fore end to reach the target values as described in [4.4.4] and [4.4.5].

Table 2: Boundary conditions applied at the model end sections

AFT END SECTION: all nodes on longitudinal members constrained	FORE END SECTION: rigid links applied to all nodes on longitudinal members
	

3 FE LOAD COMBINATION

3.1 Design Load combinations

3.1.1 FE load combination definition

A FE load combination is defined as a loading distribution, a draught, a value of still water bending moment and shear force, associated with the relevant load cases.

The design load combinations to be considered are reported in Table 3.

3.1.2 Load cases

In Table 3, some of the load cases “a”, “b”, “c” and “d” (Tasneef Rules reference Pt B, Ch 5, Sec 4) are marked with M or Q. This refers to association where either the maximal bending moments condition M or maximal shear force condition Q are to be reproduced in the model area under investigation for the relevant loading distribution, according to [4.3.2] for the bending moment and [4.3.3] for the shear force.

3.1.3 Ships with non-symmetrical structure about the centreline

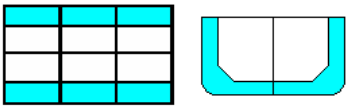
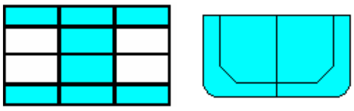
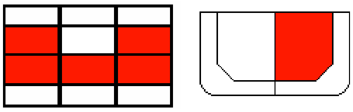
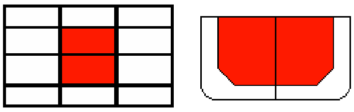
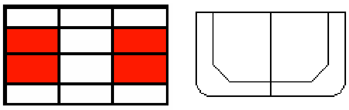
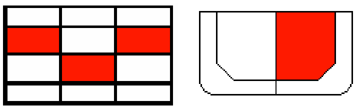
For ships with non-symmetrical structure about the centreline, the loading distributions with non-symmetrical load, e.g. No. 3 and 6 in Table 3 are to be duplicated in order to consider also the mirrored loading distribution about the centreline.

3.1.4 Ballast conditions

Where a ballast condition is specified in the ship loading manual with ballast water filled in one or more cargo tanks, loading distribution No. 2 in Table 3 is to be examined.

If the actual loading distribution as specified in the loading manual is different from loading distribution No. 2 then the actual loading distribution is to be considered in addition to loading distribution No. 2. Values of draught, still water bending moment and shear force are to be taken as indicated in the loading distribution No. 2 of Table 3 in combination with all the load cases.

Table 3: Oil tanker loading combinations

No.	Loading distribution	Draught	Still water bending moment	Still water shear force	Load case
1		Light ballast draught	Design hogging	Not to be considered	a crest M a trough M b crest M c pos M & Q c neg M & Q
2		Heavy ballast condition	Design sagging	Design	a crest M a trough M b crest M c pos M & Q c neg M & Q
3		Scantling draught	Design sagging	Not to be considered	a trough M b crest M
			Design hogging	Not to be considered	a trough M b crest M
4		60% of scantling draught	Max. sagging in non-homog. Loading condition **(1)**	Max. in non-homog. Loading condition **(1)**	a crest Q a trough M b crest M d pos M & Q d neg M & Q
5		90% of scantling draught	Max. hogging in non-homog. Loading condition **(1)**	Max. in non-homog. Loading condition **(1)**	a crest Q a trough M b crest M d pos M & Q d neg M & Q
6		60% of scantling draught	Design sagging	Of the corresponding loading condition **(1)**	a crest M a trough Q b crest M b crest Q c pos M & Q c neg M & Q d pos M & Q d neg M & Q

(1) As an alternative, the design still water bending moment and shear force values can be used.

4 LOAD APPLICATION

4.1 General

4.1.1 Structural weight

Effect of the weight of hull structure is to be included in static loads, but is not to be included in dynamic loads. Density of steel is to be taken as 7,85 t/m^3.

4.1.2 Sign convention

Unless otherwise mentioned in this Section, the sign of moments and shear force is to be in accordance with the sign convention defined in Tasneef Rules Pt B, Ch 5, Sec 2, [1.2]

4.2 Local loads

4.2.1 Still water loads

Still water loads include:

- The still water sea pressure, defined in Tasneef Rules Pt B, Ch 5, Sec 5, [1]
- The still water internal loads, defined in Tasneef Rules Pt B, Ch 5, Sec 6 for the various types of cargoes and for ballast.

4.2.2 Wave loads

Wave loads include:

- The wave pressure, obtained at any point of the model from the formulae in Tasneef Rules Pt B, Ch 7, App 1, Tab 4 for upright ship conditions (load cases “a” and “b”) and Tab 5 for inclined ship conditions (load cases “c” and “d”)
- The inertial loads, defined in Tasneef Rules Pt B, Ch 5, Sec 6 for the various types of cargoes and for ballast, and for each load case “a”, “b”, “c” and “d”.

4.2.3 Pressure application on FE element

Constant pressure, calculated at the element’s centroid, is applied to the shell element of the loaded surfaces, e.g. outer shell and deck for external pressure and tank boundaries for internal pressure. Alternatively, pressure can be calculated at element nodes applying linear pressure distribution within elements.

In Figure 7 and Figure 8 examples of application of local loads are shown.

Figure 7: Example of local loads for loading condition homogeneous full load in association with different load cases

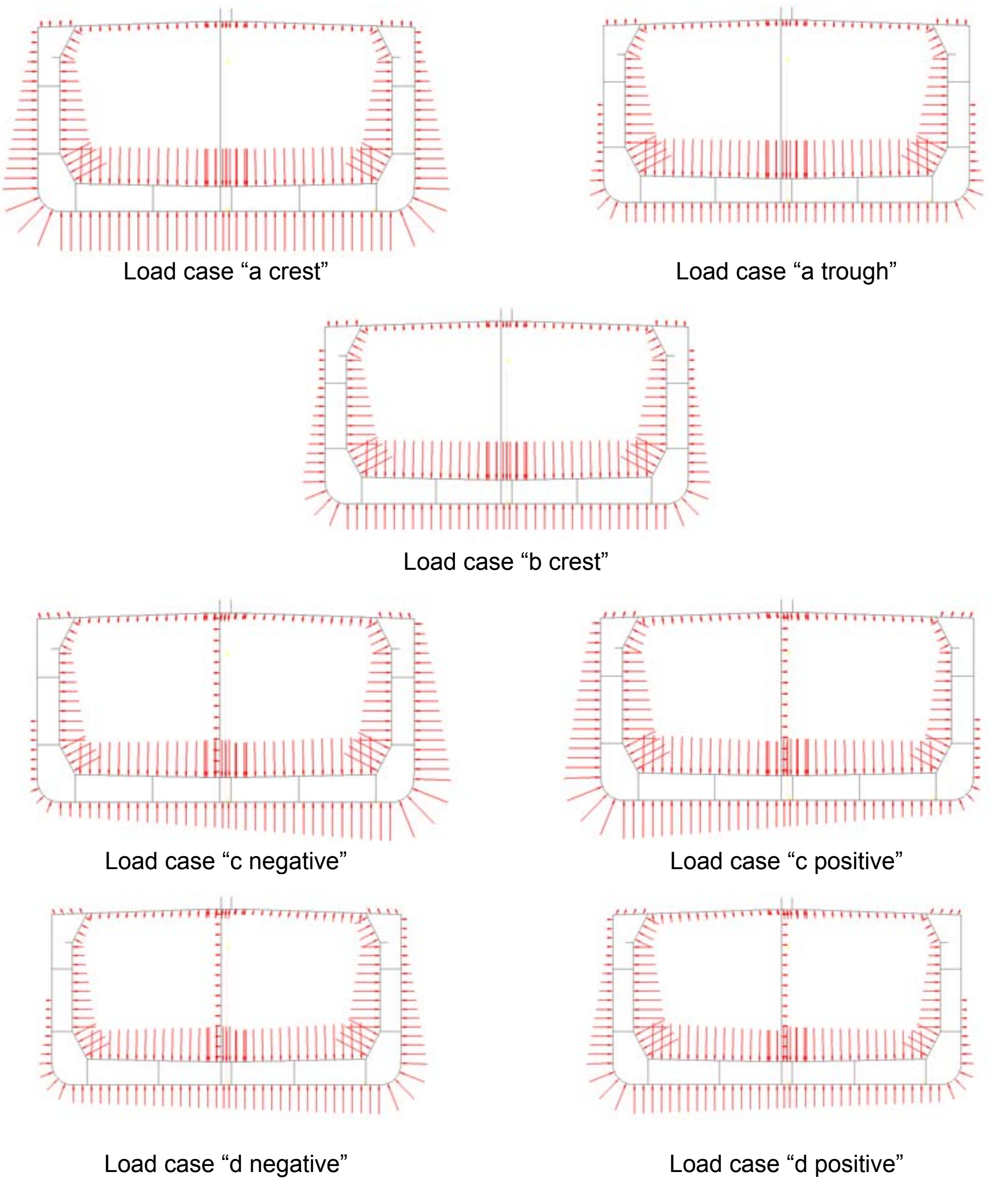
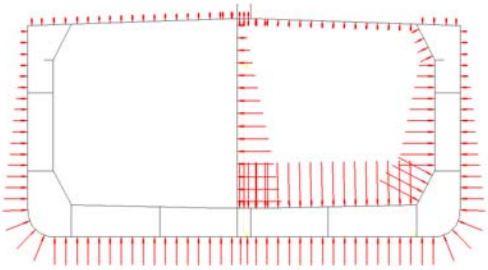
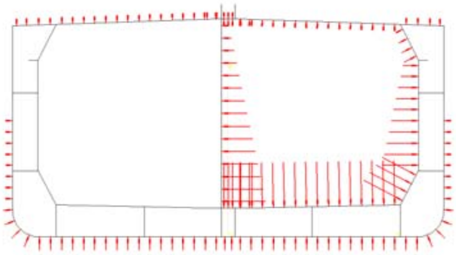


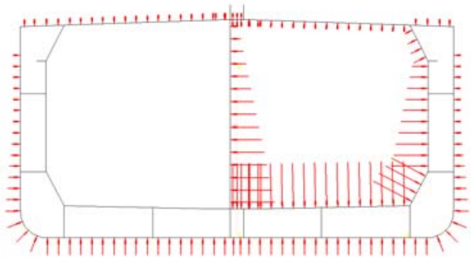
Figure 8: Example of local loads for loading condition chess load in association with different load cases



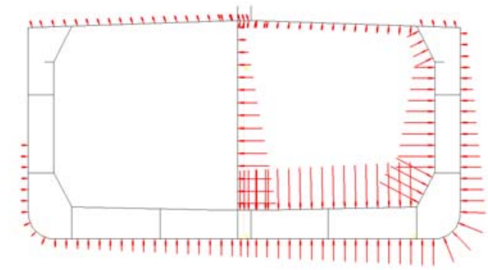
Load case “a crest”



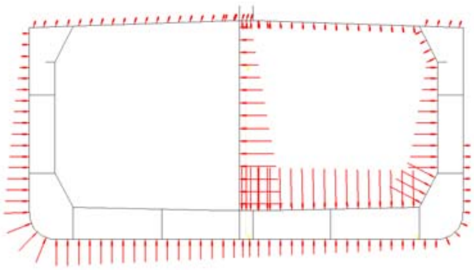
Load case “a trough”



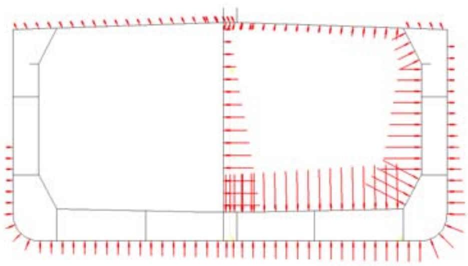
Load case “b crest”



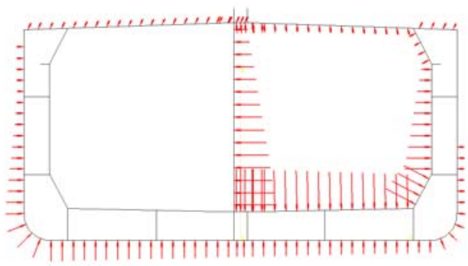
Load case “c negative”



Load case “c positive”



Load case “d negative”



Load case “d positive”

4.3 Hull girder loads

4.3.1 General

Each loading condition is to be associated with its corresponding hull girder loads which is to be applied to the model according to the procedure described in [4.4].

The hull girder loads are constituted by:

- The still water and wave vertical bending moments
- The horizontal wave bending moment
- The still water and wave vertical shear forces

Target values of hull girder loads are to be reached at the middle of the central tank and in way of the aft transverse bulkhead of the central tank, as specified respectively in [4.3.2] and [4.3.3], in order to maximize respectively the bending moments and the shear force.

4.3.2 Target hull girder loads at the middle of the central tank

The target values of hull girder loads at the middle of the central tank (maximal bending moments condition) are to be taken as given in Table 4 (Tasneef Rules reference Pt B, Ch 7, App 1, Tab 6) and are to be
obtained by means of the procedure described in [4.4.4].
The FE analysis results are applicable to the evaluation area as defined in [8.1.1].

4.3.3 Target hull girder loads in way of the aft transverse bulkhead of the central tank

The target values of hull girder loads in way of the aft transverse bulkhead of the central tank (maximal shear force condition) are to be taken as given in Table 5 (Tasneef rules reference Pt B, Ch 7, App 1, Tab
7) and are to be obtained by means of the procedure described in [4.4.5].
The FE analysis results are applicable to the evaluation area as defined in [8.1.1].

Table 4: Target values of hull girder loads at the middle of the central tank (maximal bending moments condition)

LOAD CASE		STILL WATER VERTICAL BENDING MOMENT			WAVE VERTICAL BENDING MOMENT			HORIZONTAL WAVE BENDING MOMENT			STILL WATER VERTICAL SHEAR FORCE			WAVE VERTICAL SHEAR FORCE			
		C_{FMSW}	γ_{s1}		C_{FMWV}	γ_{w1}		C_{FMWH}	γ_{w1}		C_{FQSW}	γ_{w1}		C_{FQWV}	γ_{w1}		
																x < 0.5L	x >= 0.5L
A crest	$M_{SW}<>0$	1	1,05	M_{SW}	0,625	1,05	$M_{WV,H}$	0	1,05	M_{WH}	0	1,05	Q_{SW}	0	1,05	Q_{WV}	$-Q_{WV}$
A trough	$M_{SW}<>0$	1	1,05	M_{SW}	0,625	1,05	$M_{WV,S}$	0	1,05	M_{WH}	0	1,05	Q_{SW}	0	1,05	$-Q_{WV}$	Q_{WV}
B crest	$M_{SW}<>0$	1	1,05	M_{SW}	0,625	1,05	$M_{WV,S}$	0	1,05	M_{WH}	0	1,05	Q_{SW}	0	1,05	$-Q_{WV}$	Q_{WV}
B trough	$M_{SW}<>0$	1	1,05	M_{SW}	0,625	1,05	$M_{WV,H}$	0	1,05	M_{WH}	0	1,05	Q_{SW}	0	1,05	Q_{WV}	$-Q_{WV}$
C Pos	$M_{SW}>0$	1	1,05	M_{SW}	0,25	1,05	$M_{WV,H}$	0,625	1,05	M_{WH}	0	1,05	Q_{SW}	0	1,05	Q_{WV}	$-Q_{WV}$
C Neg	$M_{SW}>0$	1	1,05	M_{SW}	0,25	1,05	$M_{WV,H}$	0,625	1,05	$-M_{WH}$	0	1,05	Q_{SW}	0	1,05	Q_{WV}	$-Q_{WV}$
C Pos	$M_{SW}<0$	1	1,05	M_{SW}	0,25	1,05	$M_{WV,S}$	0,625	1,05	M_{WH}	0	1,05	Q_{SW}	0	1,05	$-Q_{WV}$	Q_{WV}
C Neg	$M_{SW}<0$	1	1,05	M_{SW}	0,25	1,05	$M_{WV,S}$	0,625	1,05	$-M_{WH}$	0	1,05	Q_{SW}	0	1,05	$-Q_{WV}$	Q_{WV}
D Pos	$M_{SW}>0$	1	1,05	M_{SW}	0,25	1,05	$M_{WV,H}$	0,625	1,05	M_{WH}	0	1,05	Q_{SW}	0	1,05	Q_{WV}	$-Q_{WV}$
D Neg	$M_{SW}>0$	1	1,05	M_{SW}	0,25	1,05	$M_{WV,H}$	0,625	1,05	$-M_{WH}$	0	1,05	Q_{SW}	0	1,05	Q_{WV}	$-Q_{WV}$
D Pos	$M_{SW}<0$	1	1,05	M_{SW}	0,25	1,05	$M_{WV,S}$	0,625	1,05	M_{WH}	0	1,05	Q_{SW}	0	1,05	$-Q_{WV}$	Q_{WV}
D Neg	$M_{SW}<0$	1	1,05	M_{SW}	0,25	1,05	$M_{WV,S}$	0,625	1,05	$-M_{WH}$	0	1,05	Q_{SW}	0	1,05	$-Q_{WV}$	Q_{WV}

C_{FMSW}: combination factor for still water vertical bending moment
C_{FMWV}: combination factor for wave vertical bending moment
C_{FMWH}: combination factor for horizontal wave bending moment
C_{FQSW}: combination factor for still water vertical shear force
C_{FQWV}: combination factor for wave vertical shear force

Table 1: Target values of hull girder loads in way of the aft transverse bulkhead of the central tank (maximal shear forces condition)

LOAD CASE		STILL WATER VERTICAL BENDING MOMENT			WAVE VERTICAL BENDING MOMENT			HORIZONTAL WAVE BENDING MOMENT			STILL WATER VERTICAL SHEAR FORCE			WAVE VERTICAL SHEAR FORCE			
		C_{FMSW}	γ_{s1}		C_{FMWV}	γ_{w1}		C_{FMWH}	γ_{w1}		C_{FQSW}	γ_{w1}		C_{FQWV}	γ_{w1}		
																x < 0.5L	x >= 0.5L
A crest	$M_{SW}<>0$	1	1,05	M_{SW}	0,4	1,05	$M_{WV,H}$	0	1,05	M_{WH}	1	1,05	Q_{SW}	0,625	1,05	Q_{WV}	$-Q_{WV}$
A trough	$M_{SW}<>0$	1	1,05	M_{SW}	0,4	1,05	$M_{WV,S}$	0	1,05	M_{WH}	1	1,05	Q_{SW}	0,625	1,05	$-Q_{WV}$	Q_{WV}
B crest	$M_{SW}<>0$	1	1,05	M_{SW}	0,4	1,05	$M_{WV,S}$	0	1,05	M_{WH}	1	1,05	Q_{SW}	0,625	1,05	$-Q_{WV}$	Q_{WV}
B trough	$M_{SW}<>0$	1	1,05	M_{SW}	0,4	1,05	$M_{WV,H}$	0	1,05	M_{WH}	1	1,05	Q_{SW}	0,625	1,05	Q_{WV}	$-Q_{WV}$
C Pos	$M_{SW}>0$	1	1,05	M_{SW}	0,25	1,05	$M_{WV,H}$	0	1,05	M_{WH}	1	1,05	Q_{SW}	0,25	1,05	Q_{WV}	$-Q_{WV}$
C Neg	$M_{SW}>0$	1	1,05	M_{SW}	0,25	1,05	$M_{WV,H}$	0	1,05	$-M_{WH}$	1	1,05	Q_{SW}	0,25	1,05	Q_{WV}	$-Q_{WV}$
C Pos	$M_{SW}<0$	1	1,05	M_{SW}	0,25	1,05	$M_{WV,S}$	0	1,05	M_{WH}	1	1,05	Q_{SW}	0,25	1,05	$-Q_{WV}$	Q_{WV}
C Neg	$M_{SW}<0$	1	1,05	M_{SW}	0,25	1,05	$M_{WV,S}$	0	1,05	$-M_{WH}$	1	1,05	Q_{SW}	0,25	1,05	$-Q_{WV}$	Q_{WV}
D Pos	$M_{SW}>0$	1	1,05	M_{SW}	0,25	1,05	$M_{WV,H}$	0	1,05	M_{WH}	1	1,05	Q_{SW}	0,25	1,05	Q_{WV}	$-Q_{WV}$
D Neg	$M_{SW}>0$	1	1,05	M_{SW}	0,25	1,05	$M_{WV,H}$	0	1,05	$-M_{WH}$	1	1,05	Q_{SW}	0,25	1,05	Q_{WV}	$-Q_{WV}$
D Pos	$M_{SW}<0$	1	1,05	M_{SW}	0,25	1,05	$M_{WV,S}$	0	1,05	M_{WH}	1	1,05	Q_{SW}	0,25	1,05	$-Q_{WV}$	Q_{WV}
D Neg	$M_{SW}<0$	1	1,05	M_{SW}	0,25	1,05	$M_{WV,S}$	0	1,05	$-M_{WH}$	1	1,05	Q_{SW}	0,25	1,05	$-Q_{WV}$	Q_{WV}

C_{FMSW}: combination factor for still water vertical bending moment
C_{FMWV}: combination factor for wave vertical bending moment
C_{FMWH}: combination factor for horizontal wave bending moment
C_{FQSW}: combination factor for still water vertical shear force
C_{FQWV}: combination factor for wave vertical shear force

4.4 Procedure to adjust hull girder loads

4.4.1 General

The procedure given in this sub-article [4.4] describes how to adjust the hull girder horizontal bending moment, vertical shear force and vertical bending moment distribution on the three-cargo tank FE model to achieve the required target values at required locations. The hull girder load target values are specified in [4.3].

4.4.2 Local load distribution

The following local loads are to be applied for the calculation of hull girder shear and bending moments:

a) Ship structural steel weight distribution over the length of the cargo tank model (static loads). The structural steel weight is to be calculated based on the FE model with the net thickness as specified in [2.2]
b) Weight of cargo and ballast (static loads).
c) Static sea pressure and dynamic wave pressure.
d) Dynamic cargo and ballast loads for seagoing load cases.

4.4.3 Hull girder forces and bending moment due to local loads

Hull girder bending and torsion moments, and shear (vertical and horizontal) and longitudinal forces at a given X section, generated by the local loads applied to the model and its steel weight, are to be calculated by integration of these loads by elements and nodes of the model located on the positive side from this section ($x_i > X$):

$$M_L(X) = \sum_{i,\ x_i > X} M_i$$

$$Q_L(X) = \sum_{i,\ x_i > X} Q_i$$

The contribution of local load on element i to the vertical and horizontal bending moments (M_{LV}, M_{LH}), torsion moment (M_{LT}), shear forces (Q_{LV}, Q_{LH}), and longitudinal force (Q_{LX}) acting at the section X is defined by the type of the element and load, as follows:

- For force load F_i (pressures on 2d elements, weights of 2d and 1d elements, forces on 1d elements and nodes):

$$M_{iT} = F_{iz}(y_i - Y_r) - F_{iy}(z_i - Z_r)$$
$$M_{iV} = F'_{ix}(z_i - Z_{NA}) - F_{iz}(x_i - X)$$
$$M_{iH} = F_{iy}(x_i - X) - F'_{ix}(y_i - Y_{NA})$$
$$Q_{iX} = F_{ix}$$
$$Q_{iV} = F_{iz}$$
$$Q_{iH} = F_{iy}$$

- For moment load M_i (on 1d elements or nodes):

$$M_{iT} = M_{ix}$$
$$M_{iV} = M_{iy}$$
$$M_{iH} = M_{iz}$$
$$Q_{iX} = Q_{iV} = Q_{iH} = 0$$

Here subscripts V and H denote vertical and horizontal components of the hull girder bending moment and shear force, respectively; M_T denotes torsion moment, and Q_X denotes longitudinal force; Y_{NA} and Z_{NA} are co-ordinates of the centre of gravity (CG) of the ship cross-section at the considered X co-ordinate.

For 2d elements x_i, y_i, z_i are taken equal to co-ordinates of the centre of gravity of the element (or its part being accounted). For pressures, force F is computed as applied pressure load integrated by the area of the element.

For 1d elements x_i, y_i, z_i are taken equal to co-ordinates of the point where concentrated load is applied. Distributed loads on 1d elements are accounted as equivalent concentrated loads, acting at the centre of the interval on which distributed load is applied.

The contribution of longitudinal local forces to bending moments can be disregarded (F'_{ix}=0), in order to comply with definition of hull girder bending moment used in marine design.

4.4.4 Adjustment procedure to obtain the target hull girder loads at the middle of the central tank

The procedure described in Table 6 is used to set-up vertical shear forces and vertical bending moment to the target values given in Table 4 at the middle of the central tank.

Figure 9: Maximal bending moments condition at the middle of the central tank

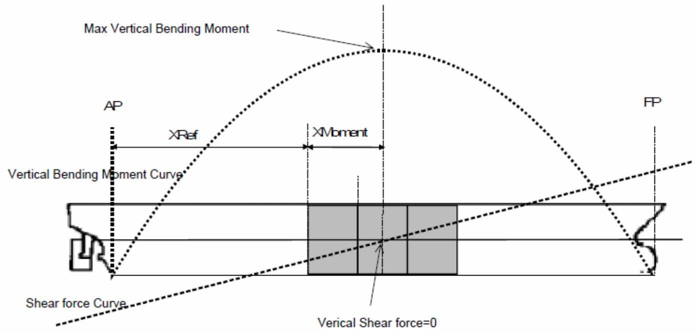
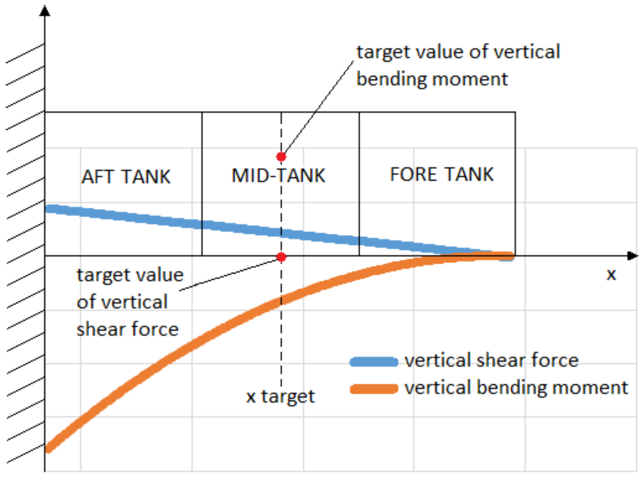


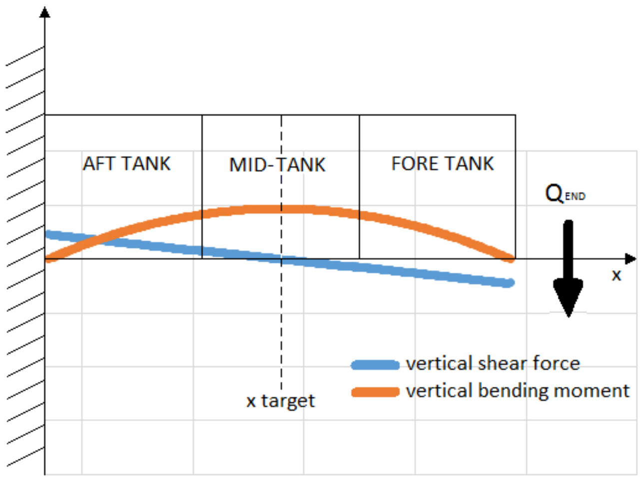
Table 6: Maximal bending moments condition: vertical shear force and bending moment adjustment by application of input vertical force and bending moment at the fore end of the model

<table>
<tr><td>Since the model is clamped at aft end, the hull girder shear force and bending moment distributions due to local loads are given as shown in the figure beside.</td><td>
</td></tr>
<tr><td>A vertical force adjustment Q_{END} is to be applied to the fore end of the model in order to shift the vertical shear force diagram to zero at the x target location (at the middle of the central tank).

$Q_{END} = Q_T – Q_L$

Where:

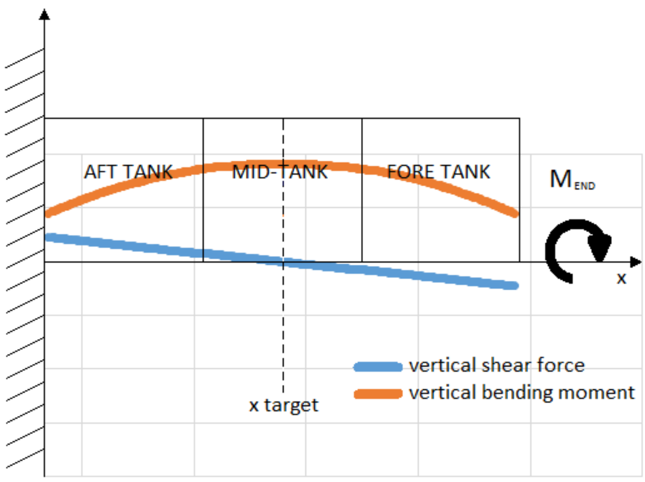
Q_T is the shear force target value at target section (equal to zero);

Q_L is the shear force at target section due to local loads.</td><td>
</td></tr>
<tr><td>A vertical bending moment adjustment M_{END} is to be applied to the fore end of the model in order to obtain the correct value of the bending moment according to **Error! Reference source not found.** at the x target location (at the middle of the central tank).

$M_{END} = M_T – M_L + Q_{END}*(X_{END} – X_T)$

Where:

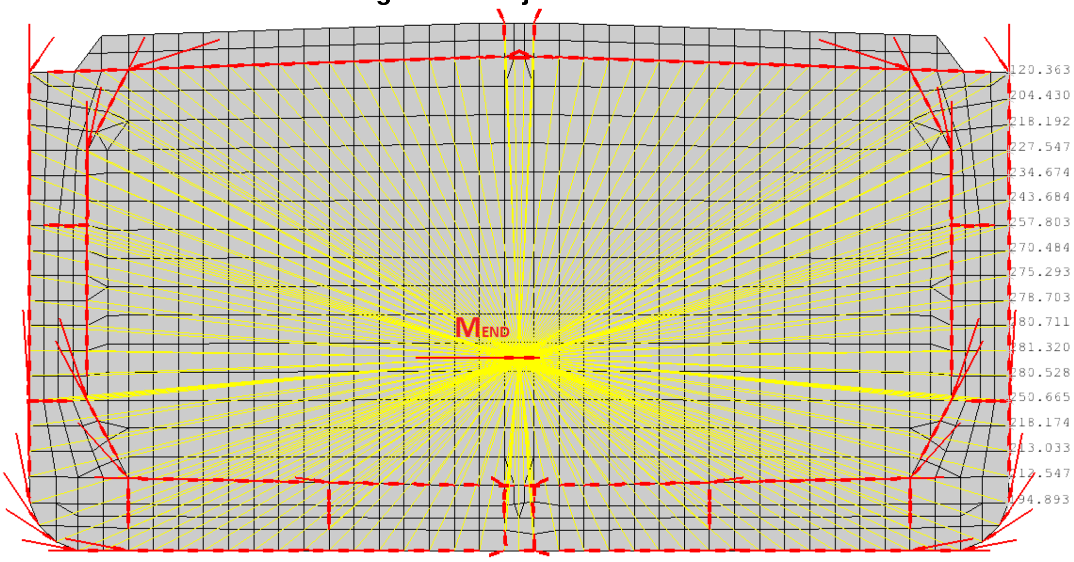
M_T is the target value at target section;

M_L is the bending moment at target section due to local loads;
X_T and X_{END} are x coordinates of end frame and target section.</td><td>
</td></tr>
</table>

The vertical force adjustment applied to the fore end of the model is to be distributed on the plating according to the theory of bidimensional flow of shear stresses. This is because the centre of the shear area is not coincident with the centre of gravity of the section.
The vertical bending moment adjustment load is applied at the centre of gravity of the end section.
In Figure 10 the adjustment loads applied at the fore end section are shown (the rigid links boundary condition is highlighted in yellow):

- The vertical force adjustment is distributed on the longitudinal continuous members as nodal forces highlighted in red and their values are greater in way of the neutral axis of the section, as shown by the number of a practical case on the right of the figure.
- The vertical bending moment adjustment load MEND is applied as concentrated moment at the centre of gravity of the section.

Figure 10: Adjustment loads



The same principle applied for the adjustment of the vertical bending moment is to be used for the adjustment of the horizontal bending moment.

4.4.5 Adjustment procedure to obtain the target hull girder loads in way of the aft transverse bulkhead of the central tank

The procedure described in Table 7 is used to set-up vertical shear force and vertical bending moment to the target values given in Table 5, in way of the aft transverse bulkhead of the central tank.

Figure 11: Maximal shear force condition in way of the aft transverse bulkhead of the central tank

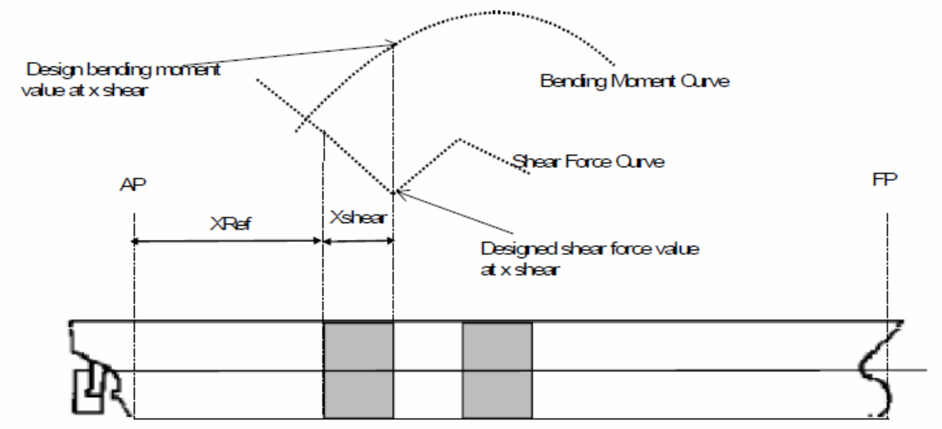
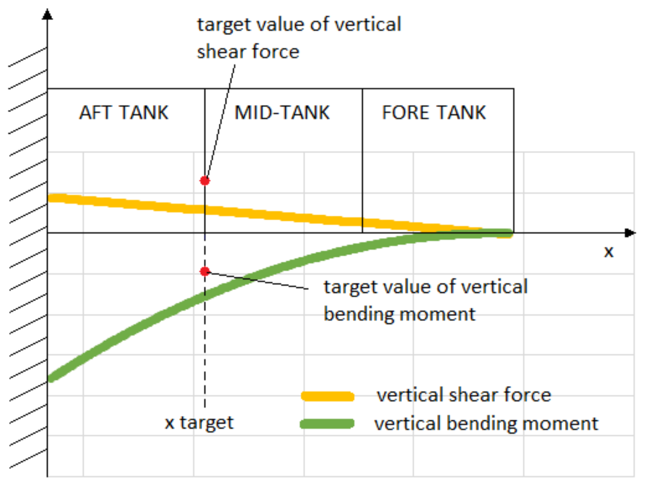
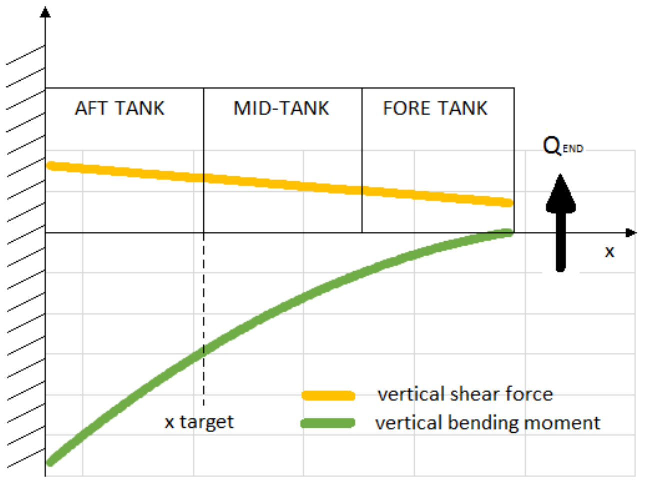


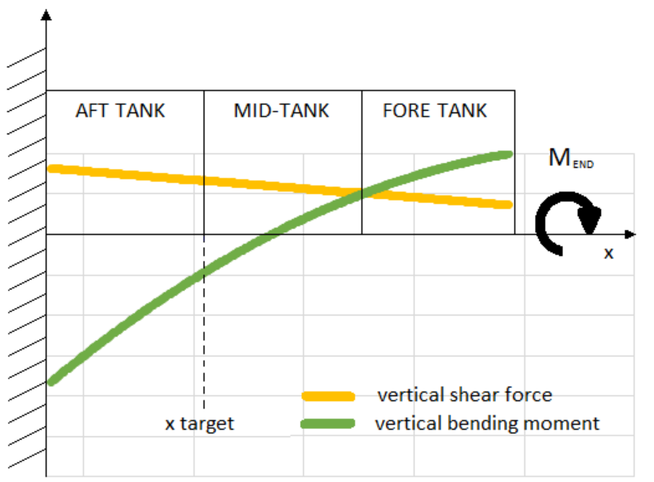
Table 7: Maximal shear force condition: vertical shear force and bending moment adjustment by application of input vertical force and bending moment at the fore end of the model

<table>
<tr><td>Since the model is clamped at aft end, the hull girder shear force and bending moment distributions due to local loads are given as shown in the figure beside.</td><td>
</td></tr>
<tr><td>A vertical force adjustment Q_{END} is to be applied to the fore end of the model in order to shift the vertical shear force diagram to the target value at the x target location (in way of the aft transverse bulkhead of the central tank).

$Q_{END} = Q_T - Q_L$

Where:
Q_T is the shear force target value at target section ;
Q_L is the shear force at target section due to local loads.</td><td>
</td></tr>
<tr><td>A vertical bending moment adjustment M_{END} is to be applied to the fore end of the model in order to obtain the target value of the bending moment according to Table 1 at the x target location (in way of the aft transverse bulkhead of the central tank).

$M_{END} = M_T - M_L + Q_{END}*(X_{END} - X_T)$

Where:
M_T is the target value at target section;
M_L is the bending moment at target section due to local loads;
X_T and X_{END} are x coordinates of end frame and target section.</td><td>
</td></tr>
</table>

The vertical force adjustment applied to the fore end of the model is to be distributed on the plating according to the theory of bidimensional flow of shear stresses (see [4.4.4] for explanation).
The vertical bending moment adjustment load is applied at the centre of gravity of the end section.

The same principle applied for the adjustment of the vertical bending moment is to be used for the adjustment of the horizontal bending moment.

5 Buckling analysis

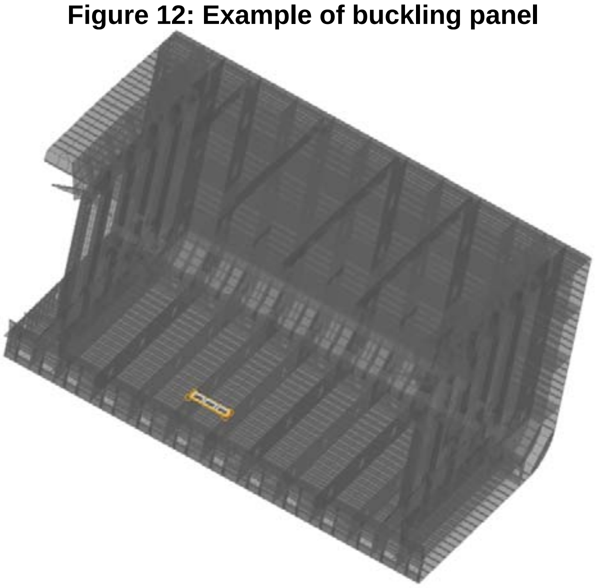
5.1 General

The buckling analysis is to be carried out according to Tasneef Rules Pt B, Ch 7, [5] (the critical stresses are to be calculated according to Pt B, Ch 7, [5.3]) together with the specific provisions for FE calculation given in Pt B, Ch 7, App 1, [6].
For the case of plate that is part of a corrugated bulkhead the uniaxial compression buckling ratio is to be taken as the maximum critical buckling stress calculated by the formulae given in Tasneef Rules Pt B, Ch 7, [5.3.1] and [5.3.5].
An example of buckling panel in the FE three-cargo tank model is shown in Figure 12.

5.1.1 Thickness of buckling panel

Net thickness is to be used in buckling checks of the buckling panel, according to Tasneef Rules Pt B, Ch 4, Sec 2, [1].

Figure 12: Example of buckling panel



6 Local structural strength analysis

6.1 General

The areas that appear from the structural analysis to be highly stressed are to be further investigated by the refined local mesh finite element model.
The details are to be modelled according to the requirements given in [6.3] under the FE load combinations defined in [6.4] and to comply with the criteria given in [8.3.2].
It is advised to evaluate at least one representative manhole and one small opening described in [2.6.7], if any, by means of refined local mesh model.

6.2 Typical structural details

The following structural details, if highly stressed, are to be assessed according to the refined mesh analysis procedure defined in [6.1]:

- Typical transverse web frame ring (see Figure 13)
- Hopper knuckles for ship with double side (see Figure 14)
- Large openings and manholes (see Figure 15)
- Connections of deck and double bottom longitudinal stiffeners to transverse bulkhead (see Figure 16)
- Connections of corrugated bulkhead to adjoining structure (see Figure 17)

6.3 Structural modelling

6.3.1 General

Evaluation of detailed stresses requires the use of refined finite element mesh in way of areas of high stress. This refined mesh analysis can be carried out by fine mesh zones incorporated into the cargo tank model.
Alternatively, separate local FE model with fine mesh zones in conjunction with the boundary conditions obtained from the cargo tank model may be used, as specified in [6.4.2].

6.3.2 Net scantlings

The refined local mesh models used for local structural strength analysis are to be made using gross offered thickness reduced by 0.5 t_c according to Tasneef Rules Pt B, Ch 4, Sec 2, [2.1.5].

6.3.3 Extent of the model

If a separate local fine mesh model is used, its extent is to be such that the calculated stresses at the areas of interest are not significantly affected by the imposed boundary conditions. The boundary of the fine mesh model is to coincide with primary supporting members in the cargo tank model, such as web frame, girders, stringers and floors.

6.3.4 Mesh size

- The size of elements in the area of interest is not to be greater than 50 mm x 50 mm.
- The extent of the refined area is to be at least of 10 elements in any direction around its centre; a smooth transition of mesh density from fine mesh zone to the boundary of the fine mesh model is to be maintained.
- The element mesh size used in the way of rounded edges (openings corners, rounded brackets, etc.) should be such that to ensure at least 12 elements in a 90 degree arc of the edge of the plate.
- The use of membrane elements is only allowed when significant bending effects are not present; in

the other cases, elements with general behaviour are to be used

- The use of linear triangular elements is to be avoided as much as possible in high stress area; quadrilateral elements are to have 90° angles as much as possible, or angles between 60° and 120°; the aspect ratio is to be close to 1; when the use of a linear triangular element cannot be avoided, its edges are to have the same length
- Stiffeners inside the fine mesh zone are to be modelled using shell elements. Stiffeners outside the fine mesh zones may be modelled using beam elements.
- Where refined local mesh analysis is required for an opening, the first two layers of elements around the opening are to be modelled with mesh size not greater than 50 x 50 mm. A smooth transition from the fine mesh to the coarser mesh is to be maintained. Example of fine mesh zone around an opening is shown in Figure 15.

Figure 13: Refined local mesh model of the typical transverse web frame ring

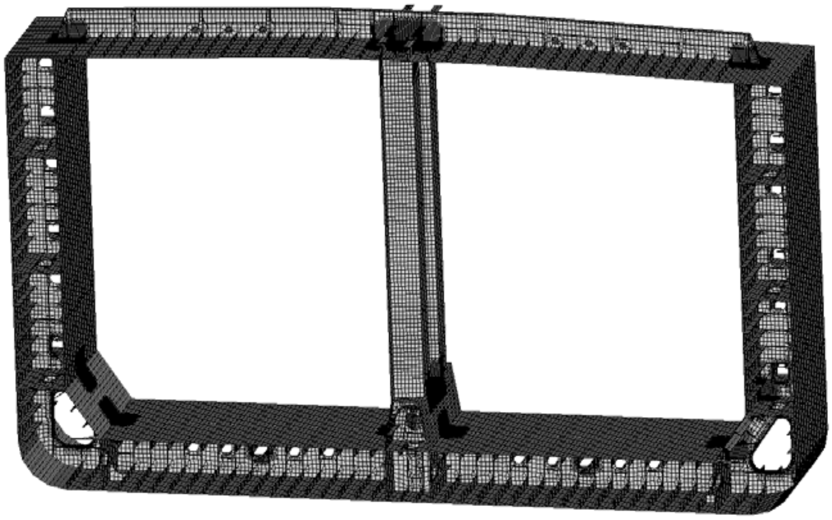


Figure 14: Refined local mesh model of hopper knuckle

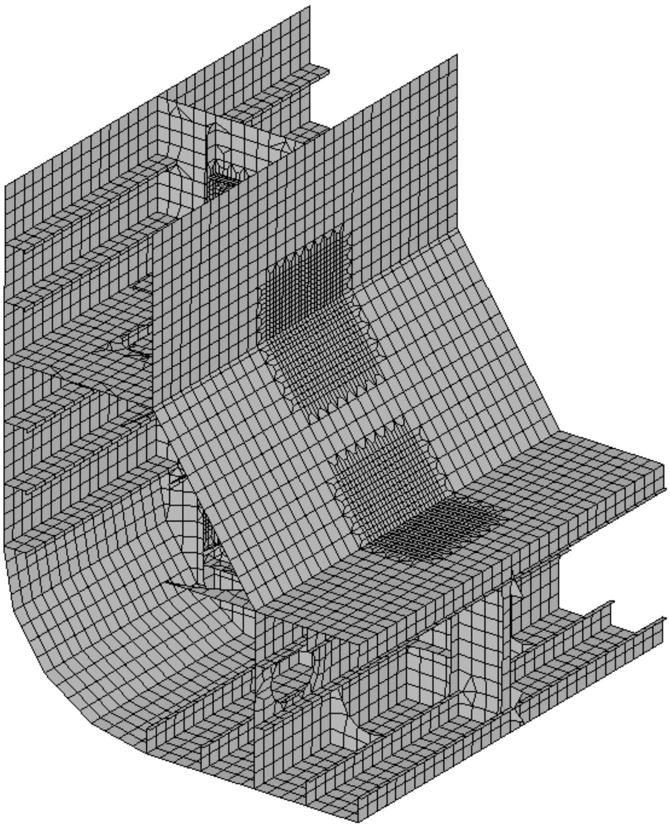


Figure 15: Refined local mesh model around large openings and manholes

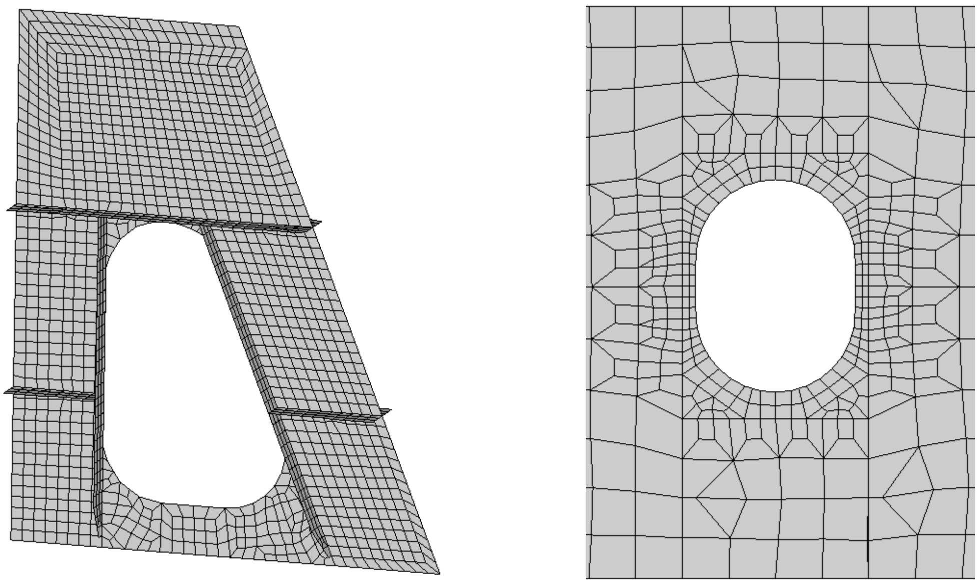


Figure 16: Refined local mesh model of connections of double bottom longitudinal stiffeners to transverse bulkhead

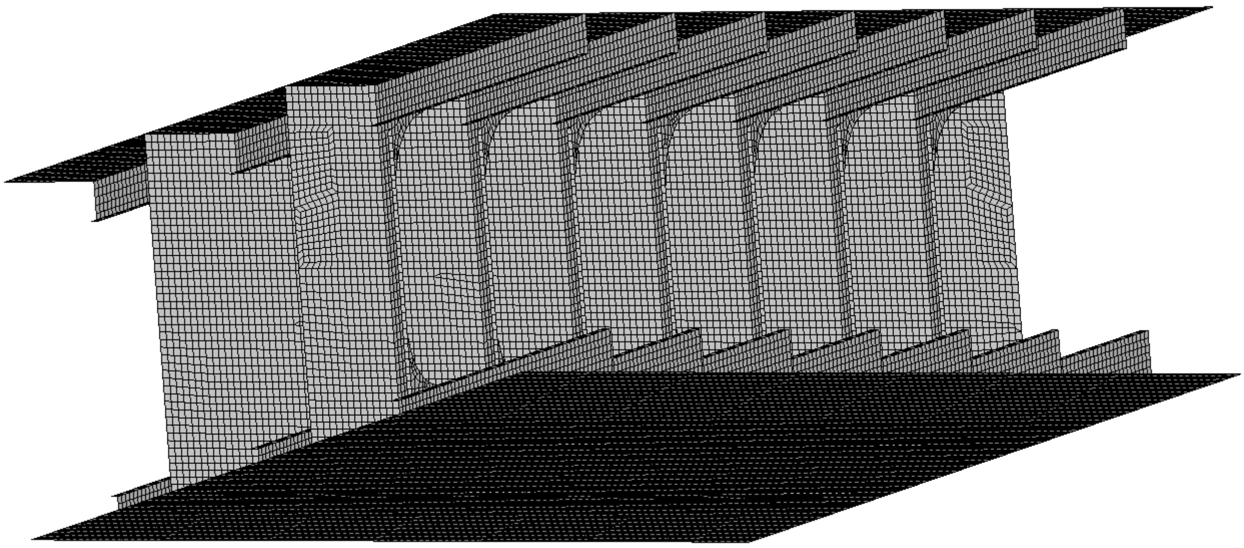
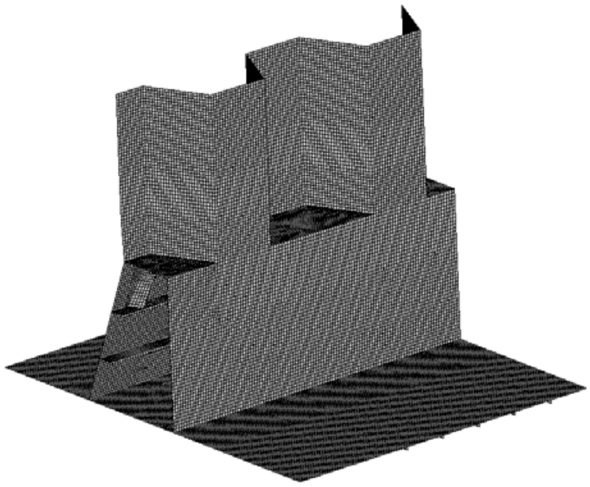
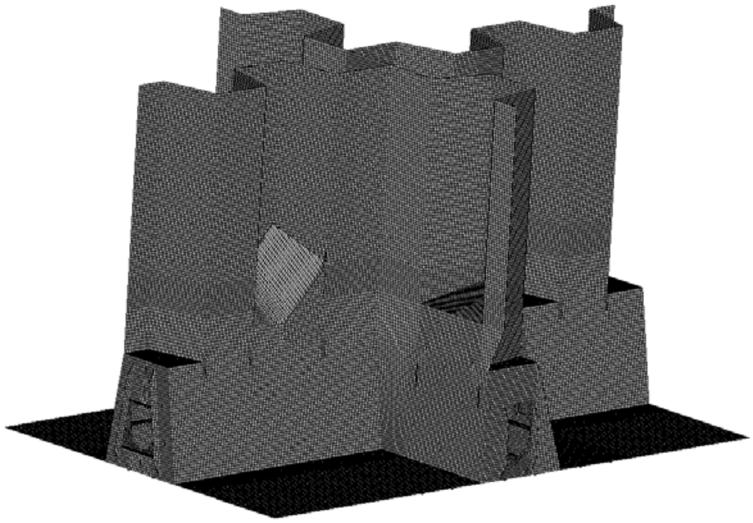


Figure 17: Refined local mesh model of connections of corrugated bulkhead to adjoining structure





6.4 FE load combinations

6.4.1 General

The fine mesh detailed stress analysis is to be carried out for all FE load combinations applied to the corresponding cargo tank analysis.

6.4.2 Application of loads and boundary conditions

Where a separate local model is used for the fine mesh detailed stress analysis, the nodal displacements from the cargo tank model are to be applied to the corresponding boundary nodes on the local model as prescribed displacements. Alternatively, equivalent nodal forces from the cargo tank model may be applied to the boundary nodes.

Where there are nodes on the local model boundaries which are not coincident with the nodal points on the cargo tank model, it is acceptable to impose prescribed displacements on these nodes using multi-point constraints. The use of linear multi-point constraint equations connecting two neighbouring coincident nodes is considered sufficient.

All local loads, including any loads applied for hull girder bending moment and/or shear force adjustments, in way of the structure represented by the separate local finite element model are to be applied to the model.

7 Fatigue analysis

7.1 General

In cases where the fatigue analysis is required by Tasneef Rules for ships having length L less than 150 m (e.g. additional class notation FATIGUELIFE(Y)), the requirements given in Tasneef Rules Pt B, Ch 7, Sec 4 and Pt B, Ch 7, App 1, [7.1], [7.2] apply.

The checking criteria are reported in [8.5].

7.2 Special structural details

With reference to Tasneef Rules Pt B, Ch 12, Sec 2 and Pt B, Ch 12, App 1, the special structural details to be analysed by means of a very fine mesh are reported in the following:

a) Connection of inner bottom with transverse bulkhead or lower stool (see Figure 18)
b) Connection of inner bottom with hopper tank sloping plate (see Figure 19)
c) Connection of lower stool with plane bulkhead
d) Connection of lower stool with corrugated bulkhead
e) Connection of hopper tank sloping plate with inner side (see Figure 20).

7.3 Structural modelling

7.3.1 General

Evaluation of hot spot stresses for fatigue assessment requires the use of very fine finite element meshes in way of areas of high stress concentration. These very fine mesh zones may be incorporated into the global model.

Alternatively, this very fine mesh analysis can be carried out by means of separate local finite element models with very fine mesh zones in conjunction with the boundary conditions obtained from a global model of the cargo tanks.

Extent of the model and mesh size requirements are to be taken as reported in Tasneef Rules Pt B, Ch7, App 1, [7.2.1] and [7.2.2].

It is advisable to extend the very fine mesh zone over at least 10 elements in all directions from the fatigue hot spot position (see Figure 19).

7.3.2 Net scantlings

The very fine mesh models used for fatigue assessment are to be made using the gross offered thickness reduced by 0.5 t_c according to Tasneef Rules Pt B, Ch 4, Sec 2, [2.1.5].

Figure 18: Very fine mesh model of inner bottom with lower stool

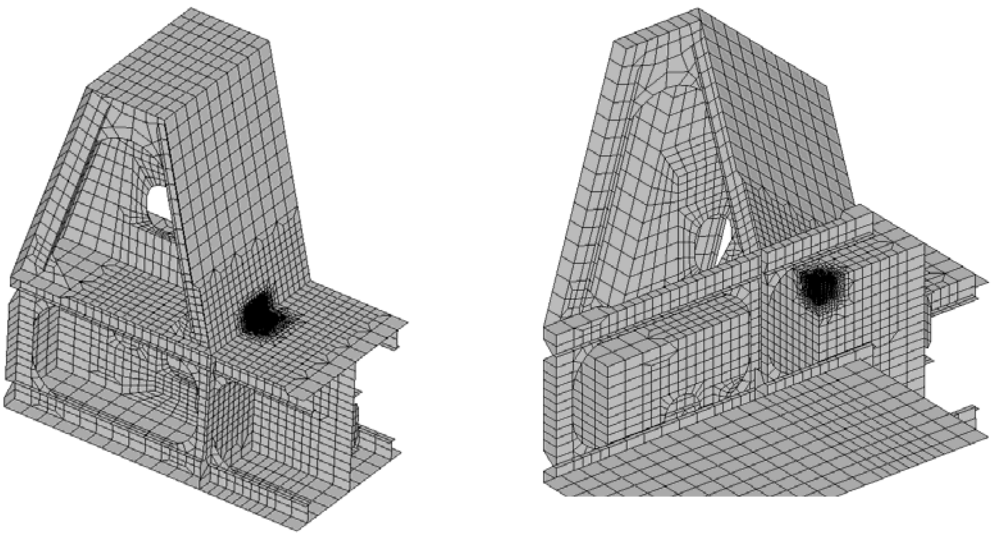
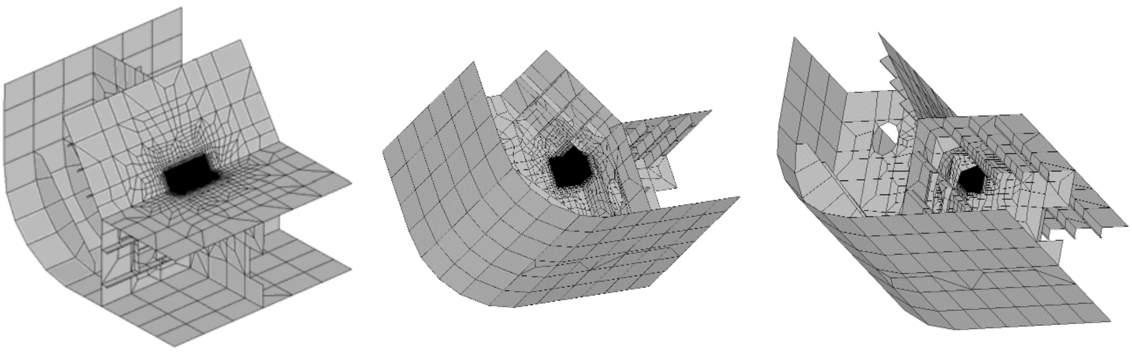


Figure 19: Very fine mesh model of inner bottom with hopper tank sloping plate



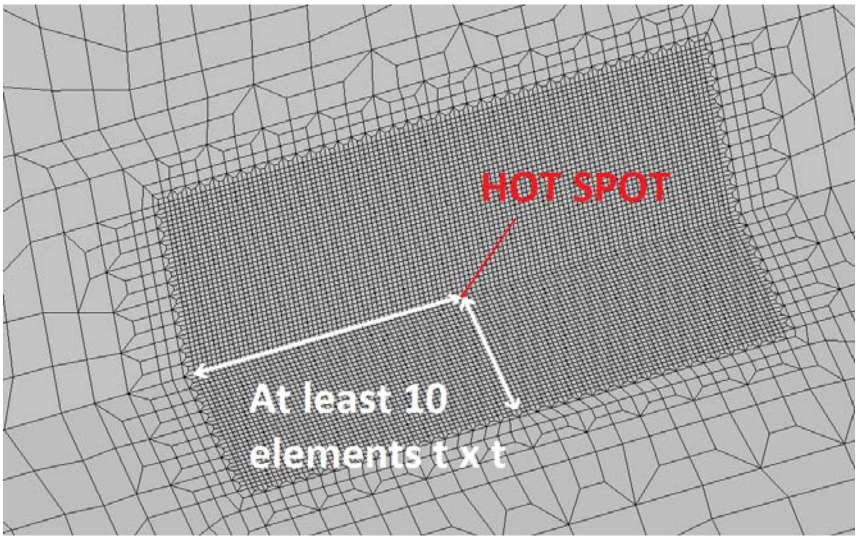
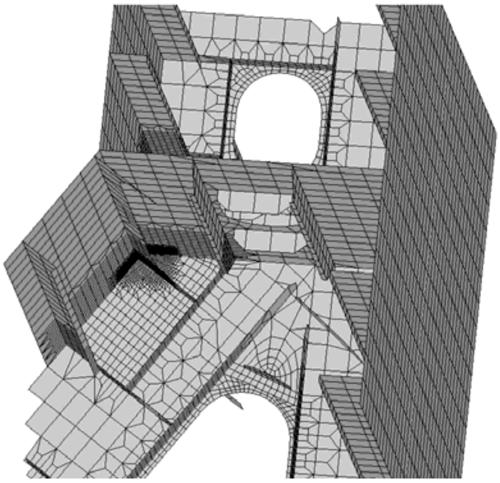
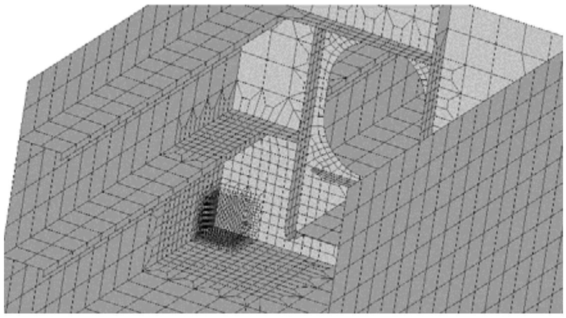


Figure 20: Very fine mesh model of connection of hopper tank sloping plate with inner side





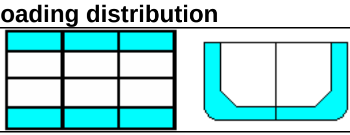
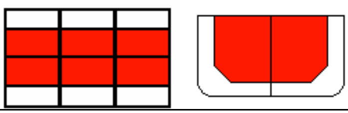
7.4 FE load combinations

7.4.1 Loading conditions

Fatigue analyses are to be carried out for representative loading conditions according to the intended ship operations as given in Tasneef Rules Pt B, Ch 7, Sec 4, Tab 8.

With reference to Tasneef Rules Pt B, Ch 7, Sec 4, [2.1.3], in general the standard loading conditions defined in Table 8 are to be applied to the model in combination with each load case “a”, “b”, “c” and “d”. In cases where the loading condition No. 2F is not the most representative for full load (i.e. it is not the most common full load loading condition of the ship voyages), different condition agreed with the Society is to be considered in the fatigue assessment.

Table 8: Standard design FE loading conditions for fatigue assessment

No.	Loading distribution	Draught	Load case
1F		Light ballast draught	All
2F		Scantling draught	All

7.4.2 Lateral pressure and hull girder normal stress

Lateral pressure and hull girder normal stress are to be considered as described in Tasneef Rules Pt B, Ch 7, Sec 4, [2.2] and [2.3].
Since a stress range is to be calculated, only the wave loads are applied.

The differential hull girder loads at target section are to be taken as difference between 'maximal' and 'minimal' target hull girder loads in corresponding load cases (maximising bending moments and neglecting the still water moments), as shown in Table 9.
Only the maximal bending moments condition, according to [4.3.2] is to be applied.

Table 9: Standard design FE loading conditions for fatigue assessment

FATIGUE LOAD CASE	LOAD CASE 'MAX'	LOAD CASE 'MIN'	TARGET BENDING MOMENTS
Differential a	a crest	a trough	$M_{TV} = \gamma_{W1} * 0,625\ (M_{WV,H} - M_{WV,S})$ $M_{TH} = 0$
Differential b	b crest	b trough	$M_{TV} = \gamma_{W1} * 0,625\ (M_{WV,S} - M_{WV,H})$ $M_{TH} = 0$
Differential c	c negative	c positive	$M_{TV} = \gamma_{W1} * 0,25\ (M_{WV,H} - M_{WV,S})$ $M_{TH} = + 2 * \gamma_{W1} * 0,625 * M_{WH}$
Differential d	d negative	d positive	$M_{TV} = - \gamma_{W1} * 0,25\ (M_{WV,H} - M_{WV,S})$ $M_{TH} = - 2 * \gamma_{W1} * 0,625 * M_{WH}$

7.5 Stress range

7.5.1 Hot spot stress range

The elementary hot spot stress range is to be obtained according to Tasneef Rules Pt B, Ch 7, App 1, [7.2.3] and [7.2.4].

7.5.2 Notch stress range

Elementary notch stress range and equivalent notch stress range are to be calculated according to Tasneef Rules Pt B, Ch 7, Sec 4, [3.3].

8 Analysis criteria

8.1 General

8.1.1 Evaluation area

a) For the maximal bending moments condition described in [4.3.2], verification of results against the acceptance criteria is to be carried out within the elements of the transverse web frame closer to the middle of the central tank and the adjacent longitudinal elements until the next web frames (fore and aft), as shown in Figure 21 and Figure 22.
b) For the maximal shear force condition described in [4.3.3], verification of results against the acceptance criteria is to be carried out within the elements in way of the aft transverse bulkhead of the central tank, as shown in Figure 21 and Figure 23.

If the scantlings change significantly along the tank it may be necessary to repeat the procedure to obtain the target value of vertical bending moment (maximal bending moments condition) at different target locations.

Figure 21: Evaluation area

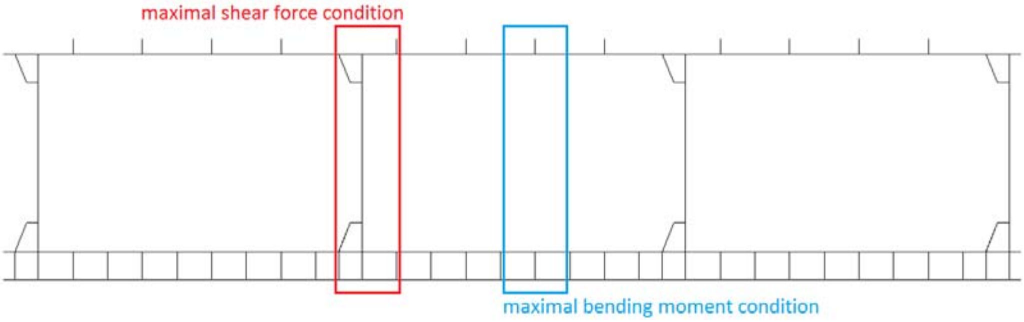


Figure 22: Evaluation area – maximal bending moment condition

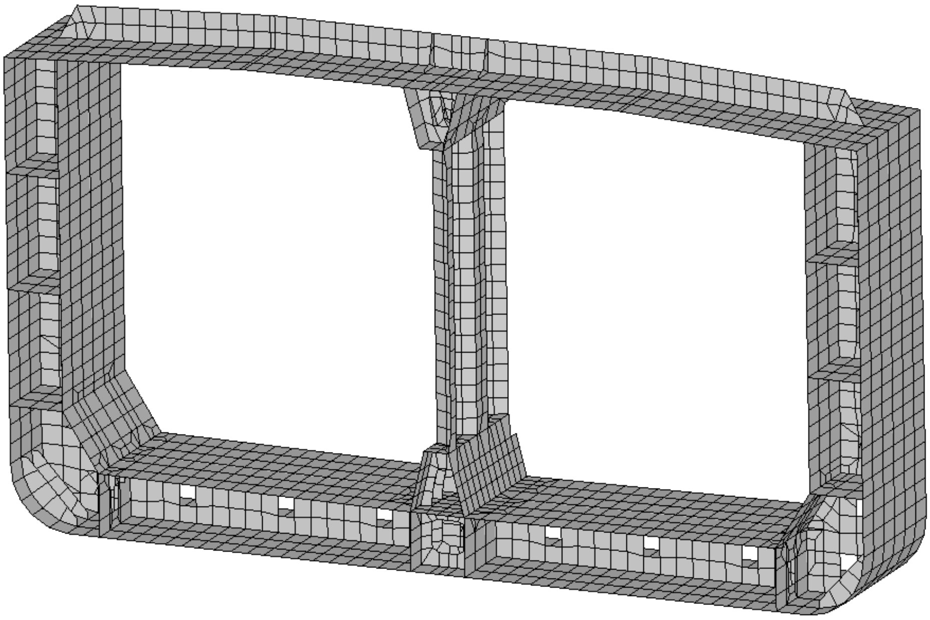
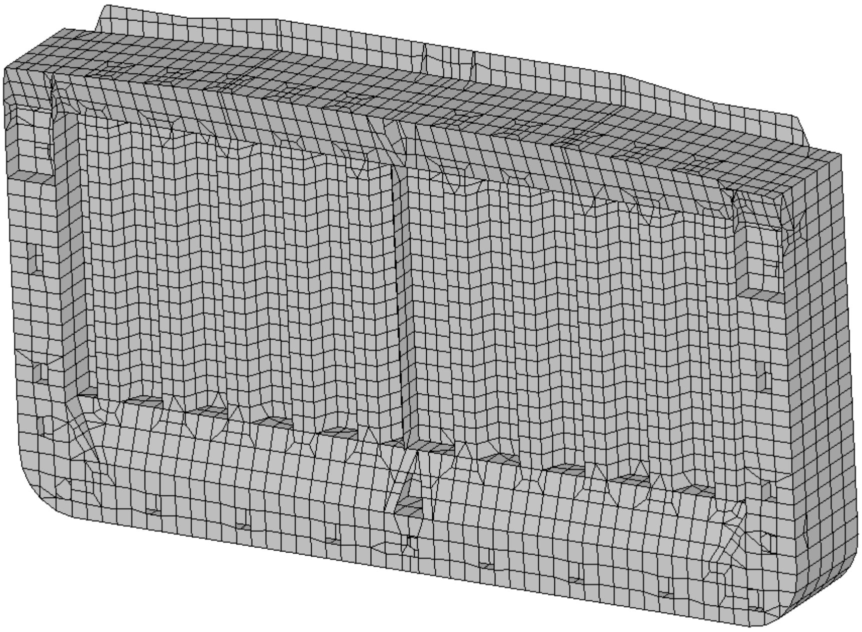


Figure 23: Evaluation area – maximal shear force condition



8.1.2 Structural members

The following structural elements within the evaluation area are to be verified with the criteria given in [8.3.1] and [8.4]:

- Hull girder longitudinal structural members,
- Primary supporting structural members and aft transverse bulkheads of the central tank
- Structural members being part of the transverse bulkhead, such as stringer, buttress structure, stool tanks, partial girder together with attached transverse structures.

8.2 Stress calculation

8.2.1 Stress components

The following stress components are to be calculated at the centroid of each element:

- The normal stresses σ_1 and σ_2 in the directions of the element co-ordinate system axes
- The shear τ_{12} with respect to the element co-ordinate system axes
- The Von Mises equivalent stress, obtained from the following formula:

$$\sigma_{vm} = \sqrt{\sigma_1 + \sigma_2 - \sigma_1\sigma_2 + 3\tau_{12}}$$

8.2.2 Axial stress in beam and rod

For beams and rod elements, the axial stress σ_{axial}, in N/mm^2, is to be calculated on axial force alone. The axial stress is to be evaluated at the middle of element length.

8.2.3 Corrugation of corrugated bulkhead

The stress in corrugation of corrugated bulkheads is to be evaluated based on:

a) The von Mises stress, σ_{vm}, in shell elements on the flange and web of the corrugation
b) The axial stress, σ_{axial}, in dummy rod elements, modelled with unit cross sectional properties at the intersection between the flange and web of corrugation.

8.2.4 Shear stress correction for cut-outs

The element shear stress in way of cut-outs in webs (manholes and small openings as described in [2.6.7]) is to be corrected for loss in shear area in accordance with the following formula. The corrected element shear stress is to be used to calculate the von Mises stress of the element for verification against the yield criteria.

$$\tau_{cor} = \frac{h \cdot t_{mod-n50}}{A_{shr-n50}} \tau_{elem}$$

Where:

τ_{cor} : Corrected element shear stress, in N/mm^2
H : Height of web of girder, in mm, in way of opening. Where the geometry of the opening is modelled, h is to be taken as the height of web of the girder deducting the height of the modelled opening.
$t_{mod-n50}$: Modelled web thickness, in mm, in way of opening
$A_{shr-n50}$: Effective net shear area of web, in mm^2, taken as the web area deducting the height of the modelled opening
τ_{elem} : Element shear stress, in N/mm^2, before correction

8.3 Yielding criteria

8.3.1 FE mesh model checking criteria

The structural elements given in [8.1.2] are to comply with the criteria given in Tasneef Rules Pt B, Ch 7, Sec 3, [4.3.1] and [4.3.2].
All beams or rod elements are to comply with the criteria given in Tasneef Rules Pt B, Ch 7, Sec 3, [4.3.1], where the von Mises stress is to be replaced with the axial stress calculated as specified in [8.2.2].

8.3.2 Refined mesh model checking criteria

The structural details analysed by means of refined mesh models are to comply with the criteria given in Tasneef Rules Pt B, Ch 7, Sec 3, [4.3.4].

8.4 Buckling checking criteria

Buckling checks of the buckling panels are to be performed according to Tasneef Rules Pt B, Ch 7, Sec 1, [5.4].
Buckling check of the stiffeners within the FE analysis is not required by the rules.

8.5 Fatigue checking criteria

Fatigue checks are to be performed according to Tasneef Rules Pt B, Ch 7, Sec 4, [4] and [5].

CHAPTER 2 – BULK CARRIERS

1 GENERAL

1.1 The purpose of Part 2 of this guide is to detail the procedure for the finite element analysis based on three-dimensional models extended over three cargo holds, for ships with the service notation Bulk Carrier having rule length L between 90 m and 150 m.

1.2 Ships with service notation Bulk Carrier having rule length L between 90 m and 150 m are to comply with CSR BC&OT.

It is worth noting that according to CSR BC&OT Pt 2, Ch 1, Sec 4, [4.1], a three dimensional model is not required for the analysis of primary supporting members of ships having length L less than 150 m. Therefore, depending on the extension of the area intended to be investigated by means of direct strength assessment, one or more FE three cargo hold models can be necessary.

1.3 Direct strength analysis is to be carried out according to CSR BC&OT, Pt 1, Ch 7; buckling analysis is to be carried out according to Pt 1, Ch 8, Sec 4; fatigue analysis is to be carried out according to Pt 1, Ch 9, Sec 5.

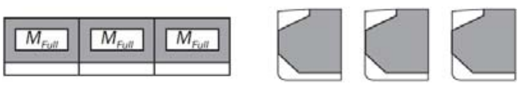
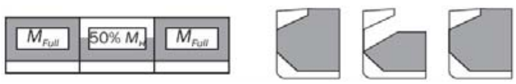
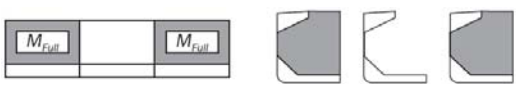
1.4 The load combinations to be applied are reported in [2].

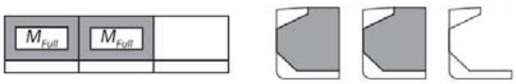
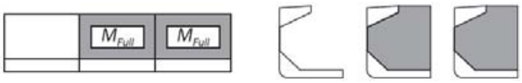
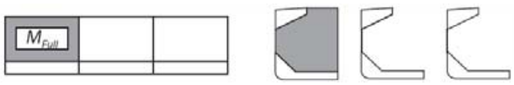
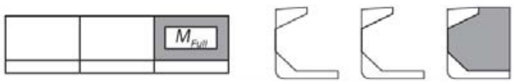
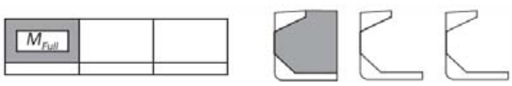
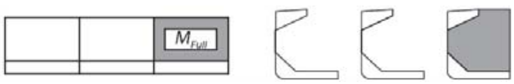
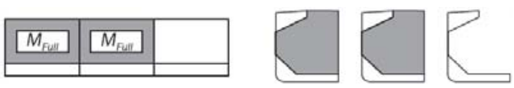
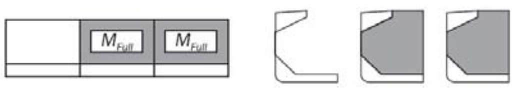
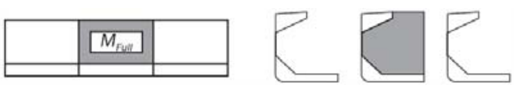
2 FE LOAD COMBINATION

2.1 Design Load combinations

The design load combinations to be considered are reported in Table 10.

Table 10: Bulk carrier loading combinations

No.	Loading pattern Aft Mid Fore	Draught	C_{BM-LC}: % of perm. SWBM	C_{BM-LC}: % of perm. SWBM	Dynamic load case
1 (1) (3)		T_{SC}	50% (sag.)	100%	BSP-1P/S OST-1P/S
2 (2)		T_{SC}	50% (sag.)	100%	BSP-1P/S OST-1P/S
3		T_{SC}	0%	100%	BSP-1P/S
4		0.83 T_{SC}	100% (hog.)	100 % (4) Max SFLC	FSM-2 HSM-2
				100 % (5) Max SFLC	FSM-2 HSM-2
				100 %	OST-2P/S
			100% (sag.)	100 % (6) Max SFLC	HSM-1
				100 %	BSP-1P/S OST-1P/S
No.	Loading pattern Aft Mid Fore	Draught	C_{BM-LC}: % of perm. SWBM	C_{BM-LC}: % of perm. SWBM	Dynamic load case

5		0.67 T_{SC}	100% (sag.)	100%	BSP-1P/S OST-1P/S
6		0.67 T_{SC}	100% (sag.)	100%	BSP-1P/S OST-1P/S
7		0.75 T_{SC}	100% (hog.)	100%	FSM-2 HSM-2 BSR-1P/S OST-2P/S
			100% (sag.)	100%	BSP-1P/S BSR-1P/S OST-1P/S
8		0.75 T_{SC}	100% (hog.)	100%	FSM-2 HSM-2 BSR-1P/S OST-2P/S
			100% (sag.)	100%	BSP-1P/S BSR-1P/S OST-1P/S
Harbour conditions					
9		0.67 T_{SC}	100% (hog.)	100%	N/A
			100% (sag.)	100%	N/A
10		0.67 T_{SC}	100% (hog.)	100%	N/A
			100% (sag.)	100%	N/A
11		T_{H1}	100% (hog.)	100%	N/A
			100% (sag.)	100%	N/A
12		T_{H1}	100% (hog.)	100%	N/A
			100% (sag.)	100%	N/A
13		T_{H2}	100% (hog.)	100 % (7) Max SFLC	N/A
				100 % (8)	N/A

				Max SFLC	
			100% (sag.)	100 % (7) Max SFLC	N/A
				100 % (8) Max SFLC	N/A

(1) Applicable only to bulk carrier designed to carry dry bulk cargoes of cargo density above 1.0 t/m^3 with all cargo holds loaded.
(2) For bulk carrier designed to carry dry bulk cargoes of cargo density above 1.0 t/m^3 with all cargo holds loaded, the loading pattern no. 1 with the cargo mass M_{Full} and the maximum cargo density as defined in CSR Pt 1, Ch 4, Sec 8, [4.1.3] can be analysed in lieu of this loading pattern.
(3) Maximum cargo density as defined in CSR Pt 1, Ch 4, Sec 8, [4.1.3] is to be used for calculation of dry cargo pressure.
(4) For the mid-hold where $x_{b-aft}<0.5L$ and $x_{b-fwd}>0.5L$, the shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(5) For the mid-hold where $x_{b-aft}<0.5L$ and $x_{b-fwd}>0.5L$, the shear force is to be adjusted to target value at forward bulkhead of the mid-hold.
(6) This load combination is to be considered only for the mid-hold where $x_{b-aft}>0.5L$ or $x_{b-fwd}<0.5L$.
(7) The shear force is to be adjusted to target value at aft bulkhead of the mid-hold.
(8) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.