Rules for the Classification of Naval Ships

Effective from 1 July 2017

Part B

Hull and Stability

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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 righ t 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 cl ass, 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 c lients 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 propert y 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, certificat es, 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 t o 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.

EXPLANATORY NOTE TO PART B

1. Reference edition

The reference edition for Part B is this edition effective from 1st January 2015.

2. Effective date of the requirements

2.1 All requirements in which new or amended provisions with respect to those contained in the reference edition have been introduced are followed by a date shown in brackets.

The date shown in brackets is the effective date of entry into force of the requirements as amended by last updating. The effective date of all those requirements not followed by any date shown in brackets is that of the reference edition.

2.2 Item 5 below provides a summary of the technical changes from the preceding edition.

3. Rule Variations and Corrigenda

Until the next edition of the Rules is published, Rule Variations and/or corrigenda, as necessary, will be pub-lished on the Tasneef web site (www.tasneef.ae). Except in particular cases, paper copies of Rule Variations or corrigenda are not issued.

4. Rule subdivision and cross-references

4.1 Rule subdivision

The Rules are subdivided into five parts, from A to E.

Part A: Classification and Surveys

Part B: Hull and Stability

Part C: Machinery, Systems and Fire Protection

Part D: Service Notations

Part E: Additional Class Notations

Each Part consists of:

- Chapters
- Sections and possible Appendices
- Articles
- Sub-articles
- Requirements

Figures (abbr. Fig) and Tables (abbr. Tab) are numbered in ascending order within each Section or Appendix.

4.2 Cross-references

Examples: Pt A, Ch 1, Sec 1, [3.2.1]or Pt A, Ch 1, App 1, [3.2.1]

- Pt A means Part A

The part is indicated when it is different from the part in which the cross-reference appears. Otherwise, it is not indicated.

- Ch 1 means Chapter 1

The Chapter is indicated when it is different from the chapter in which the cross-reference appears. Otherwise, it is not indicated.

- Sec 1 means Section 1 (or App 1 means Appendix 1)

The Section (or Appendix) is indicated when it is different from the Section (or Appendix) in which the cross-reference appears. Otherwise, it is not indicated.

- [3.2.1] refers to requirement 1, within sub-article 2 of article 3.

Cross-references to an entire Part or Chapter are not abbreviated as indicated in the following examples:

- Part A for a cross-reference to Part A
- Part A, Chapter 1 for a cross-reference to Chapter 1 of Part A.

5. Summary of amendments introduced in the edition effective from 1st January 2017

This edition of the Rules for the Classification of Naval Ships contains amendments whose effective date is **1 January2017**.

The date of entry into force of each new or amended item is shown in brackets after the number of the item concerned

This edition of the Rules for the classification of Naval Ships is considered as a reference edition for future amendments.

Description of the amendments
The amendments involve both the framework of the Rules and the technical requirements.

RULES FOR THE CLASSIFICATION OF NAVAL SHIPS

Part B

Hull and Stability

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Part B

Hull and Stability

Chapter 5

DESIGN LOADS

Symbols used in chapter 5

n, n_1 : Navigation coefficients, defined in Pt B, Ch 5, Sec 1, [2.6],

F : Froude's number:

$$F = 0,164 \frac{V}{\sqrt{L}}$$

V : Maximum ahead service speed, in knots,

T_1 : Draught, in m, defined in Pt B, Ch 5, Sec 1, [2.4.3] or Pt B, Ch 5, Sec 1, [2.5.3], as the case may be,

g : Gravity acceleration, in m/s^2:

$g = 9,81$ m/s^2,

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system defined in Pt B, Ch 1, Sec 2, [6].

SECTION 1 GENERAL

1 Definitions

1.1 Cargo

1.1.1 Cargo are liquids and dry units (e.g. containers, vehicles, etc.) carried inside compartments and on decks.

1.2 Still water loads

1.2.1 Still water loads are those acting on the ship at rest in calm water.

1.3 Wave loads

1.3.1 Wave loads are those due to wave pressures and ship motions, which can be assumed to have the same wave encounter period.

1.4 Dynamic loads

1.4.1 Dynamic loads are those that have a duration much shorter than the period of the wave loads.

1.5 Local loads

1.5.1 Local loads are pressures and forces which are directly applied to the individual structural members: plating panels, ordinary stiffeners and primary supporting members.

- Still water local loads are constituted by the hydrostatic external sea pressures and the static pressures and forces induced by the weights carried in the ship spaces.
- Wave local loads are constituted by the external sea pressures due to waves and the inertial pressures and forces induced by the ship accelerations applied to the weights carried in the ship spaces.
- Dynamic local loads are constituted by the impact and sloshing pressures.

1.5.2 For the structures which constitute the boundary of spaces not intended to carry liquids and which do not belong to the outer shell, the still water and wave pressures in flooding conditions are also to be considered.

1.6 Hull girder loads

1.6.1 Hull girder loads are (still water, wave and dynamic) forces and moments which result as effects of local loads acting on the ship as a whole and considered as a beam.

1.7 Loading condition

1.7.1 A loading condition is a distribution of weights carried in the ship spaces arranged for their storage.

1.8 Load case

1.8.1 A load case is a state of the ship structures subjected to a combination of hull girder and local loads.

2 Application criteria

2.1 Fields of application

2.1.1 General

The wave induced and dynamic loads defined in this Chapter corresponds to an operating life of the ship equal to 30 years.

Loads for an operating life different from 30 years are considered by the Society on a case by case basis.

2.1.2 Requirements applicable to all types of ships

The still water, wave induced and dynamic loads defined in this Chapter are to be used for the determination of the hull girder strength and structural scantlings in the central part (see Ch 1, Sec 1) of ships, according to the requirements in Chapter 6 and Chapter 7.

2.1.3 Requirements applicable to specific ship types

The design loads applicable to specific ship types are to be defined in accordance with the requirements in Part D.

2.1.4 Load direct calculation

As an alternative to the formulae in Sec 2 and Sec 3, the Society may accept the values of wave induced loads and dynamic loads derived from direct calculations, when justified on the basis of the ship's characteristics and intended service. The calculations are to be submitted to the Society for approval.

2.2 Hull girder loads

2.2.1 The still water, wave and dynamic hull girder loads to be used for the determination of:

- the hull girder strength, according to the requirements of Chapter 6, and
- the structural scantling of plating, ordinary stiffeners and primary supporting members contributing to the hull girder strength, in combination with the local loads given in Sec 5 and Sec 6

are specified in Chapter 7.

2.3 Local loads

2.3.1 Load cases

The local loads defined in [1.5] are to be calculated in each of the mutually exclusive load cases described in Sec 4.

Dynamic loads are to be taken into account and calculated according to the criteria specified in Sec 5 and Sec 6.

2.3.2 Ship motions and accelerations

The wave local loads are to be calculated on the basis of the reference values of ship motions and accelerations specified in Sec 3.

2.3.3 Calculation and application of local loads

The criteria for calculating:

- still water local loads
- wave local loads on the basis of the reference values of ship motions and accelerations

are specified in Sec 5 for sea pressures and in Sec 6 for internal pressures and forces.

2.3.4 Flooding conditions

The still water and wave pressures in flooding conditions are specified in Sec 6, [7]. The pressures in flooding conditions applicable to specific ship types are to be defined in accordance with the requirements in Part D.

2.4 Load definition criteria to be adopted in structural analyses based on plate or isolated beam structural models

2.4.1 Application

The requirements of this sub-article apply for the definition of local loads to be used in the scantling checks of:

- plating, according to Ch 7, Sec 1
- ordinary stiffeners, according to Ch 7, Sec 2
- primary supporting members for which a three dimensional structural model is not required, according to Ch 7, Sec 3, [3].

2.4.2 Full load and operational load distributions

When calculating the local loads for the structural scantling of an element which separates two adjacent compartments, the latter may not be considered simultaneously loaded. The local loads to be used are those obtained considering the two compartments individually loaded.

For elements of the outer shell, the local loads are to be calculated considering separately:

- the still water and wave external sea pressures, considered as acting alone without any counteraction from the ship interior
- the still water and wave differential pressures (internal pressure minus external sea pressure) considering the compartment adjacent to the outer shell as being loaded.

2.4.3 Draught associated with full load and operational load

Local loads are to be calculated on the basis of the ship's draught T_1 corresponding to the full load or operational load distribution considered according to the criteria in [2.4.2]. The ship draught is to be taken as the distance measured vertically on the hull transverse section at the middle of the length L, from the moulded base line to the waterline in:

- full load condition, when:
  - one or more cargo compartments (e.g. oil tank, dry cargo hold, vehicle space, passenger space) are considered as being loaded and the ballast tanks are considered as being empty
  - the still water and wave external pressures are considered as acting alone without any counteraction from the ship's interior
- operational load condition, when one or more ballast tanks are considered as being loaded and the other compartments are considered as being empty. In the absence of more precise information, the ship's draught in light ballast condition may be obtained, in m, from the following formulae:

$$T_B = 0{,}03L \le 7{,}5 \text{ m}$$

2.5 Load definition criteria to be adopted in structural analyses based on three dimensional structural models

2.5.1 Application

The requirements of this sub-article apply for the definition of local loads to be used in the scantling checks of primary supporting members for which a three dimensional structural model is required, according to Ch 7, Sec 3, [4].

2.5.2 Loading conditions

For all ship types for which analyses based on three dimensional models are required according to Ch 7, Sec 3, [4], the most severe loading conditions for the structural elements under investigation are to be considered. These loading conditions are to be selected among those envisaged in the ship loading manual.

Further criteria applicable to specific ship types are specified in Part D.

2.5.3 Draught associated with each loading condition

Local loads are to be calculated on the basis of the ship's draught T_1 corresponding to the loading condition considered according to the criteria in [2.5.2].

2.6 Navigation coefficients

2.6.1 The navigation coefficents, which appear in the formulae of this Chapter for the definition of wave hull girder and local loads, in Tab 1 depending on the assigned navigation notation.

Table 1 : Navigation coefficients *(1/1/2017)*

Navigation notation	Navigation coefficient n	Navigation coeffient n_1
Unrestricted navigation	1,00	1,00
Summer Zone	0,90	0,95
Tropical Zone	0,80	0,90
Offshore navigation	0,90	0,95
Coastal area	0,80	0,90
Sheltered areas	0,65	0,80

SECTION 2 HULL GIRDER LOADS

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

C : Wave parameter:

$$C = (118 - 0,36L)\frac{L}{1000} \text{ for } 65 \le L < 90$$

$$C = 10,75 - \left(\frac{300 - L}{100}\right)^{1,5} \text{ for } 90\text{m} \le L < 300\text{m}$$

$$C = 10,75 \text{ for } 300\text{m} \le L \le 350\text{m}$$

$$C = 10,75 - \left(\frac{L - 350}{150}\right)^{1,5} \text{ for } L > 350\text{m}$$

H_A : Wave parameter :

$$H_A = \frac{CL}{200}$$

without being taken greater than 0,8 C

B_{MAX} : Maximum moulded breadth amidships, in m, not including sponsons.

F_{CH} : Characteristic Froude number :

$$F_{CH} = 0,164 \cdot \frac{V_{CH}}{\sqrt{L}}$$

V_{CH} : Charatcteristic ship speed; to be taken as the greatest between V_{cruise} and 0,75 V_{max}

V_{cruise} : Cruise speed, in knots,

V_{max} : Max speed, in knots.

1 General

1.1 Application

1.1.1 The requirements of this Section apply to ships having the following characteristics:

- L / B > 5
- B / D < 2,5
- $C_B \ge 0,4$

Ships not having one or more of these characteristics and ships of unusual type o design are considered by the Society on a case by case basis.

1.2 Sign conventions of vertical bending moments and shear forces

1.2.1 The sign conventions of bending moments and shear forces at any ship transverse section are as shown in Fig 1, namely:

- the vertical bending moment M is positive when it induces tensile stresses in the strength deck (hogging bending moment); it is negative in the opposite case (sagging bending moment)
- the vertical shear force Q is positive in the case of downward resulting forces preceding and upward resulting forces following the ship transverse section under consideration; it is negative in the opposite case.

2 Still water loads

2.1 General

2.1.1 Still water load calculation

For all ships, the longitudinal distributions of still water bending moment and shear force are to be calculated, for each of the loading conditions in [2.1.2], on the basis of realistic data related to the amount of cargo, ballast, fuel, lubricating oil and fresh water.

The actual hull lines and lightweight distribution are to be taken into account in the calculations. The lightweight distribution may be replaced, if the actual values are not available, by a statistical distribution of weights accepted by the Society.

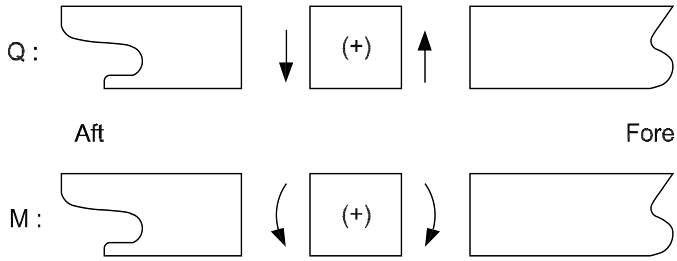
The designer is to supply the data necessary to verify the calculations of still water loads.

Ships with large openings are specially considered by the Society on a case by case basis.

2.1.2 Loading conditions

Still water loads are to be calculated for all the design loading conditions corresponding to full load and operational load conditions on which the approval of hull structural scantlings is based (see Sec 1, [1.2]).

Figure 1 : Sign conventions for shear forces Q and bending moments M



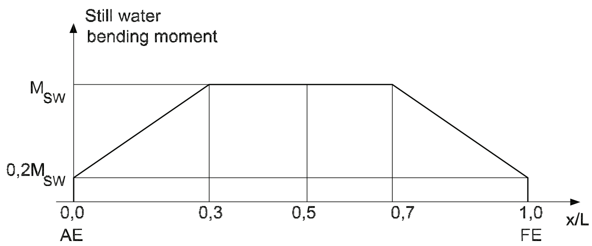
For all ships, the following loading conditions are to be considered:

- homogeneous loading conditions at maximum draught
- operational load conditions
- special loadings (e.g. light load conditions at less than the maximum draught, deck cargo conditions, etc., where applicable)
- short voyage or harbour conditions, where applicable
- loading and unloading transitory conditions, where applicable
- docking condition afloat
- ballast exchange at sea, if applicable.

Part D specifies other loading conditions which are to be considered depending on the ship type.

The final structural checks are, in any case, to be carried out on the basis of the design still water bending moments as specified [2.2.1]

Figure 2 : Preliminary still water bending moment distribution *(1/1/2017)*



2.2 Still water bending moments

2.2.1 *(1/1/2017)*

The design still water bending moments $M_{SW,H}$ and $M_{SW,S}$ at any hull transverse section are the maximum still water bending moments calculated, in hogging and sagging conditions, respectively, at that hull transverse section for the loading conditions specified in [2.1.2].

Where no sagging bending moments act in the hull section considered, the value of $M_{SW,S}$ is to be taken as specified in Chapter 6 and Chapter 7.

When the ship in still water is always in hogging condition, $M_{SW,S}$ is to be taken equal to 0.

2.2.2

If the design still water bending moments are not defined, at a preliminary design stage, at any hull transverse section, the longitudinal distributions shown in Fig 2 may be considered.

In Fig 2 M_{SW} is the design still water bending moment amidships, in hogging or sagging conditions, whose absolute values are to be taken not less than those obtained, in kN.m, from the following formulae:

- hogging conditions:

$$M_{SWM,H} = 175 n_1 C L^2 B (C_B + 0,7) 10^{-3} - M_{WV,H}$$

- sagging conditions:

$$M_{SWM,S} = 175 n_1 C L^2 B (C_B + 0,7) 10^{-3} + M_{WV,S}$$

where $M_{WV,H}$, $M_{WV,S}$ are the vertical wave bending moments, in kN.m, defined in [3.1].

2.3 Still water shear force

2.3.1 The design still water shear force Q_{SW} at any hull transverse section is the maximum positive or negative shear force calculated, at that hull transverse section, for the loading conditions specified in [2.1.2].

3 Wave loads

3.1 Vertical wave bending moments

3.1.1

a) For ships with C_B lower than 0,6 the vertical wave bending moments at any hull transverse section are obtained, in kN.m, from the following formulae:

- hogging conditions:

$$M_{WV,H} = 150 F_M n C L^2 B_{MAX} C_B (1 + C_A) 10^{-3}$$

- sagging conditions:

$$M_{WV,S} = -85 F_M n C L^2 B_{MAX} (C_B + 0,7)(1 + C_A) 10^{-3}$$

where:

F_M : Distribution factor defined in Tab 1 (see also Fig 3).

C_A : Coefficient equal to :

$$C_A = \frac{7,1 H_A (1 + 1,26 F_{CH})^2}{L}$$

b) For ships with C_B equal or greater than 0,6 the vertical wave bending moments at any hull transverse section are obtained, in kN.m, from the following formulae:
- hogging conditions:

$$M_{WV,H} = 190 F_M n C L^2 B C_B 10^{-3}$$

- sagging conditions:

$$M_{WV,S} = -110 F_M n C L^2 B (C_B + 0,7) 10^{-3}$$

where:

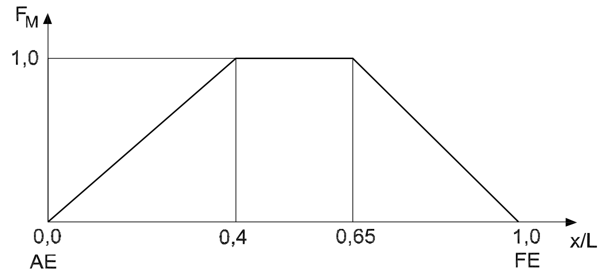
F_M : Distribution factor defined in Tab 1 (see also Fig 3).

3.1.2 The effects of bow flare impact are to be taken into account, for the cases specified in [4.1.1], according to [4.2.1].

Table 1 : Distribution factor F_M

Hull transverse section location	Distribution factor F_M
$0 \le x < 0,4L$	$2,5\frac{x}{L}$
$0,4L \le x \le 0,65L$	1
$0,65L < x \le L$	$2,86\left(1 - \frac{x}{L}\right)$

Figure 3 : Distribution factor F_M



3.2 Horizontal wave bending moment

3.2.1 The horizontal wave bending moment at any hull transverse section is obtained, in kN.m, from the following formula:

$$M_{WH} = 0,42 F_M H_A L^2 T C_B$$

where F_M is the distribution factor defined in [3.1.1].

Figure 4 : Distribution factor F_Q

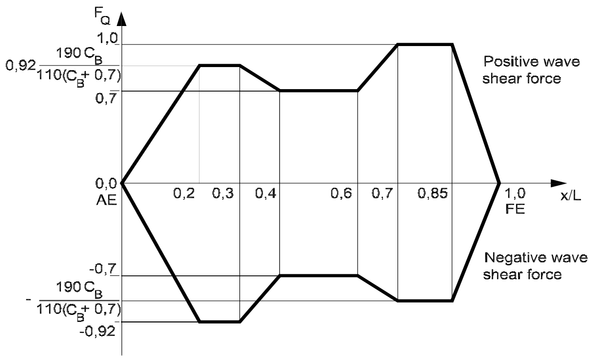


Table 2 : Distribution factor F_Q

Hull transverse section location	Distribution factor F_Q	
	Positive wave shear force	Negative wave shear force
$0 \le x < 0,2L$	$4,6A\frac{x}{L}$	$-4,6\frac{x}{L}$
$0,2L \le x \le 0,3L$	0,92A	- 0,92
$0,3L < x < 0,4L$	$(9,2A - 7)\left(0,4 - \frac{x}{L}\right) + 0,7$	$-2,2\left(0,4 - \frac{x}{L}\right) - 0,7$
$0,4L \le x \le 0,6L$	0,7	- 0,7
Note 1: $A = \frac{190 C_B}{110(C_B + 0,7)}$		

Hull transverse section location	Distribution factor F_Q	
	Positive wave shear force	Negative wave shear force
$0,6L < x < 0,7L$	$3\left(\frac{x}{L} - 0,6\right) + 0,7$	$-(10A - 7)\left(\frac{x}{L} - 0,6\right) - 0,7$
$0,7L \le x \le 0,85L$	1	- A
$0,85L < x \le L$	$6,67\left(1 - \frac{x}{L}\right)$	$-6,67A\left(1 - \frac{x}{L}\right)$
Note 1: $A = \frac{190C_B}{110(C_B + 0,7)}$		

3.3 Wave torque

3.3.1 The wave torque at any hull transverse section is to be calculated considering the ship in two different conditions:

- condition 1: ship direction forming an angle of 60° with the prevailing sea direction
- condition 2: ship direction forming an angle of 120° with the prevailing sea direction.

The values of the wave torques in these conditions, calculated with respect to the section centre of torsion, are obtained, in kN.m, from the following formula:

$$M_{WT} = \frac{HL}{4}n(F_{TM}C_M + F_{TQ}C_Qd)$$

where:

H : Wave parameter:

$$H = 8,13 - \left(\frac{250 - 0,7L}{125}\right)^3$$

without being taken greater than 8,13

F_{TM}, F_{TQ} : Distribution factors defined in Tab 3 for ship conditions 1 and 2 (see also Fig 5 and Fig 6)

C_M : Wave torque coefficient:

$$C_M = 0,38B^2C_W^2$$

C_Q : Horizontal wave shear coefficient:

$$C_Q = 2,8TC_B$$

C_W : Waterplane coefficient, to be taken not greater than the value obtained from the following formula:

$$C_W = 0,165 + 0,95C_B$$

where C_B is to be assumed not less than 0,6. In the absence of more precise determination, C_W may be taken equal to the value provided by the above formula.

d : Vertical distance, in m, from the centre of torsion to a point located 0,6T above the baseline.

Table 3 : Distribution factors F_{TM} and F_{TQ}

Ship condition	Distribution factor F_{TM}	Distribution factor F_{TQ}
1	$1 - \cos\frac{2\pi x}{L}$	$\sin\frac{2\pi x}{L}$
2	$1 - \cos\frac{2\pi(L - x)}{L}$	$\sin\frac{2\pi(L - x)}{L}$

Figure 5 : Ship condition 1 - Distribution factors F_{TM} and F_{TQ}

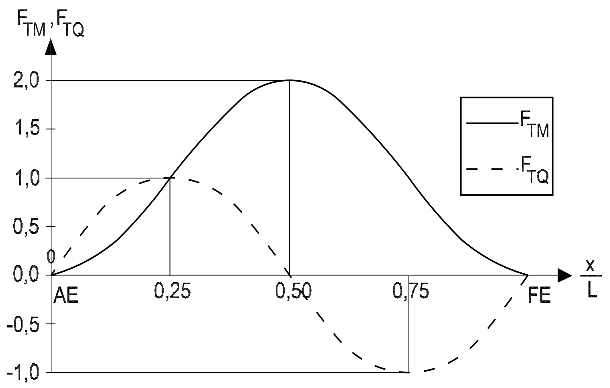
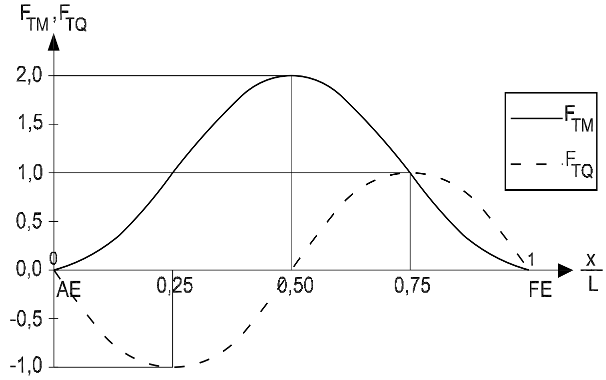


Figure 6 : Ship condition 2 - Distribution factors F_{TM} and F_{TQ}



3.4 Vertical wave shear force

3.4.1

The vertical wave shear force at any hull transverse section is obtained, in kN, from the following formula:

$$Q_{WV} = 30F_QnCLB(C_{BW} + 0,7)10^{-2}$$

where:

F_Q : Distribution factor defined in Tab 2 for positive and negative shear forces (see also Fig 4).

4 Dynamic loads due to bow flare impact

4.1 Application

4.1.1 The effects of bow flare impact are to be considered where all the following conditions occur:

- $V \geq 17,5$ knots
- $\frac{100FA_S}{LB} > 1$

where:

A_S : Twice the shaded area shown in Fig 7, which is to be obtained, in m², from the following formula:

$$A_S = ba_0 + 0,1L(a_0 + 2a_1 + a_2)$$

b, a_0, a_1, a_2:Distances, in m, shown in Fig 7.

For multideck ships, the upper deck shown in Fig 7 is to be taken as the deck (including superstructures) which extends up to the extreme forward end of the ship and has the largest breadth forward of 0,2L from the fore end.

4.1.2 When the effects of bow flare impact are to be considered, according to [4.1.1], the sagging wave bending moment is to be increased as specified in [4.2.1] and [4.2.2].

4.1.3 The Society may require the effects of bow flare impact to be considered also when one of the conditions in [4.1.1] does not occur, if deemed necessary on the basis of the ship's characteristics.

In such cases, the increase in sagging wave bending moment is defined on a case by case basis.

4.2 Increase in sagging wave bending moment

4.2.1 General

The sagging wave bending moment at any hull transverse section, defined in [3.1], is to be multiplied by the coefficient F_D obtained from the formulae in Tab 4, which takes into account the dynamic effects of bow flare impact.

Where at least one of the conditions in [4.1.1] does not occur, the coefficient F_D may be taken equal to 1.

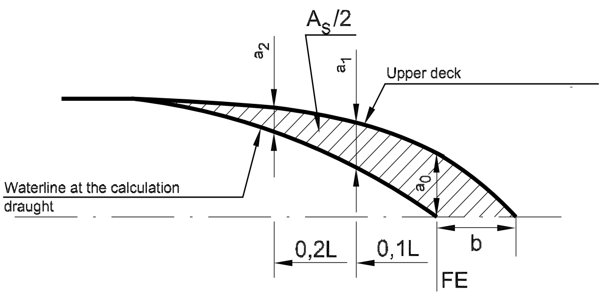
4.2.2 Direct calculations

As an alternative to the formulae in [4.2.1], the Society may accept the evaluation of the effects of bow flare impact from direct calculations, when justified on the basis of the ship's characteristics. The calculations are to be submitted to the Society for approval.

Table 4 : Coefficient F_D

Hull transverse section location	Coefficient F_D
$0 \leq x < 0,4L$	1
$0,4L \leq x < 0,5L$	$1 + 10(C_D - 1)\left(\frac{x}{L} - 0,4\right)$
$0,5L \leq x \leq L$	C_D
Note 1: $C_D = 262,5\frac{A_S}{CLB(C_B + 0,7)} - 0,6$ without being taken greater than 1,2. A_S : Area, in m², defined in [4.1.1].	

Figure 7 : Area A_S



SECTION 3 SHIP MOTIONS AND ACCELERATIONS

Symbols

For the symbols not defined in this Section, refer to the list at the beginning of this Chapter.

a_B : Motion and acceleration parameter:

$$a_B = n\left(0,76F + 1,875\frac{h_W}{L}\right)$$

h_W : Wave parameter, in m:

$$h_W = 11,44 - \left|\frac{L-250}{110}\right|^3 \quad \text{for} \quad L < 350\ \text{m}$$

$$h_W = \frac{200}{\sqrt{L}} \quad \text{for} \quad L \geq 350\ \text{m}$$

a_{SU} : Surge acceleration, in m/s², defined in [2.1]

a_{SW} : Sway acceleration, in m/s², defined in [2.2]

a_H : Heave acceleration, in m/s², defined in [2.3]

α_R : Roll acceleration, in rad/s², defined in [2.4]

α_P : Pitch acceleration, in rad/s², defined in [2.5]

α_Y : Yaw acceleration, in rad/s², defined in [2.6]

T_{SW} : Sway period, in s, defined in [2.2]

T_R : Roll period, in s, defined in [2.4]

T_P : Pitch period, in s, defined in [2.5]

A_R : Roll amplitude, in rad, defined in [2.4]

A_P : Pitch amplitude, in rad, defined in [2.5].

1 General

1.1

1.1.1 Ship motions and accelerations are defined, with their signs, according to the reference co-ordinate system in Ch 1, Sec 2, [10].

1.1.2 Ship motions and accelerations are assumed to be periodic. The motion amplitudes, defined by the formulae in this Section, are half of the crest to through amplitudes.

1.1.3 As an alternative to the formulae in this Section, the Society may accept the values of ship motions and accelerations derived from direct calculations or obtained from model tests, when justified on the basis of the ship's characteristics. In general, the values of ship motions and accelerations to be calculated are those which can be reached with a probability of 10^{-5} . In any case, the model tests or the calculations, including the assumed sea scatter diagrams and spectra, are to be submitted to the Society for approval.

2 Ship absolute motions and accelerations

2.1 Surge

2.1.1 The surge acceleration a_{SU} is to be taken equal to 0,5 m/s².

2.2 Sway

2.2.1 The sway period and acceleration are obtained from the formulae in Tab 1.

Table 1 : Sway period and acceleration

Period T_{SW}, in s	Acceleration a_{SW}, in m/s²
$\dfrac{0,8\sqrt{L}}{1,22F+1}$	$0,775\ a_B\ g$

2.3 Heave

2.3.1 The heave acceleration is obtained, in m/s², from the following formula:

$$a_H = a_B g$$

2.4 Roll

2.4.1 The roll amplitude, period and acceleration are obtained from the formulae in Tab 2.

Table 2 : Roll amplitude, period and acceleration

Amplitude A_R, in rad	Period T_R, in s	Acceleration α_R, in rad/s²
$a_B\sqrt{E}$ without being taken greater than 0,35	$2,2\dfrac{\delta}{\sqrt{GM}}$	$A_R\left(\dfrac{2\pi}{T_R}\right)^2$

The meaning of symbols in Tab 2 is as follows:

$$E = 1,39\frac{GM}{\delta^2}B \quad \text{to be taken not less than 1,0}$$

GM : Distance, in m, from the ship's centre of gravity to the transverse metacentre, for the loading considered; when GM is not known, the following values may be assumed:

GM = 0,07 B

δ : roll radius of gyration, in m, for the loading considered; when δ is not known, it may be taken equal to :

$$\delta = 0,35B$$

2.5 Pitch

2.5.1 The pitch amplitude, period and acceleration are obtained from the formulae in Tab 3.

Table 3 : Pitch amplitude, period and acceleration

Amplitude A_P, in rad	Period T_P, in s	Acceleration α_P, in rad/s²
$0,328a_B\left(1,32-\frac{h_W}{L}\right)\left(\frac{0,6}{C_B}\right)^{0,75}$	$0,575\sqrt{L}$	$A_P\left(\frac{2\pi}{T_P}\right)^2$

2.6 Yaw

2.6.1 The yaw acceleration is obtained, in rad/s², from the following formula:

$$\alpha_Y = 1,581\frac{a_B g}{L}$$

3 Ship relative motions and accelerations

3.1 Definitions

3.1.1 Ship relative motions

The ship relative motions are the vertical oscillating translations of the sea waterline on the ship side. They are measured, with their sign, from the waterline at draught T_1.

3.1.2 Accelerations

At any point, the accelerations in X, Y and Z direction are the acceleration components which result from the ship motions defined in [2.1] to [2.6].

3.2 Ship conditions

3.2.1 General

Ship relative motions and accelerations are to be calculated considering the ship in the following conditions:

- upright ship condition
- inclined ship condition.

3.2.2 Upright ship condition

In this condition, the ship encounters waves which produce ship motions in the X-Z plane, i.e. surge, heave and pitch.

3.2.3 Inclined ship condition

In this condition, the ship encounters waves which produce ship motions in the X-Y and Y-Z planes, i.e. sway, roll and yaw.

3.3 Ship relative motions

3.3.1 The reference value of the relative motion in the upright ship condition is obtained, at any hull transverse section, from the formulae in Tab 4.

Table 4 : Reference value of the relative motion h_1 in the upright ship condition *(1/1/2017)*

Location	Reference value of the relative motion h_1 in the upright ship condition, in m
$x = 0$	$0,7\left(\frac{4,35}{\sqrt{C_B}}-3,25\right)h_{1,M}$
$0 < x < 0,3L$	$h_{1,AE}-\frac{h_{1,AE}-h_{1,M}}{0,3}\frac{x}{L}$
$0,3L \le x \le 0,7L$	$0,42nC(C_B+0,7)$ without being taken greater than the minimun of T_1 and D-0,9T
$0,7L < x < L$	$h_{1,M}+\frac{h_{1,FE}-h_{1,M}}{0,3}\left(\frac{x}{L}-0,7\right)$
$x = L$	$\left(\frac{4,35}{\sqrt{C_B}}-3,25\right)h_{1,M}$

Note 1:
C : Wave parameter defined in Sec 2
$h_{1,AE}$: Reference value h_1 calculated for x = 0
$h_{1,M}$: Reference value h_1 calculated for x = 0,5L
$h_{1,FE}$: Reference value h_1 calculated for x = L

3.3.2 The reference value, in m, of the relative motion in the inclined ship condition is obtained, at any hull transverse section, from the following formula:

$$h_2 = 0,5h_1 + A_R\frac{B_W}{2}$$

where:

h_1 : Reference value, in m, of the relative motion in the upright ship, calculated according to [3.3.1]

B_W : Moulded breadth, in m, measured at the waterline at draught T_1 at the hull transverse section considered.

3.4 Accelerations

3.4.1 The reference values of the longitudinal, transverse and vertical accelerations at any point are obtained from the formulae in Tab 5 for upright and inclined ship conditions.

Table 5 : Reference values of the accelerations a_X, a_Y and a_Z

Direction	Upright ship condition	Inclined ship condition
X - Longitudinal a_{X1} and a_{X2} in m/s^2	$a_{X1} = \sqrt{a_{SU}^2 + [A_P g + \alpha_p (z - T_1)]^2}$	$a_{x2} = 0$
Y - Transverse a_{Y1} and a_{Y2} in m/s^2	$a_{Y1} = 0$	$a_{Y2} = \sqrt{a_{SW}^2 + [A_R g + \alpha_R (z - T_1)]^2 + \alpha_Y^2 K_X L^2}$
Z - Vertical a_{Z1} and a_{Z2} in m/s^2	$a_{Z1} = \sqrt{a_H^2 + \alpha_p^2 K_X L^2}$	$a_{Z2} = \alpha_R y$
Note 1: $K_X = 1{,}2\left(\frac{x}{L}\right)^2 - 1{,}1\frac{x}{L} + 0{,}2$ without being taken less than 0,018		

SECTION 4 LOAD CASES

Symbols

h_1 : Reference value of the ship relative motion in the upright ship condition, defined in Sec 3, [3.3]

h_2 : Reference value of the ship relative motion in the inclined ship condition, defined in Sec 3, [3.3]

a_{X1},a_{Y1},a_{Z1}: Reference values of the accelerations in the upright ship condition, defined in Sec 3, [3.4]

a_{X2},a_{Y2},a_{Z2}: Reference values of the accelerations in the inclined ship condition, defined in Sec 3, [3.4]

M_{WV} : Reference value of the vertical wave bending moment, defined in Sec 2, [3.1]

M_{WH} : Reference value of the horizontal wave bending moment, defined in Sec 2, [3.2]

M_{WT} : Reference value of the wave torque, defined in Sec 2, [3.3]

Q_{WV} : Reference value of the vertical wave shear force, defined in Sec 2, [3.4].

1 General

1.1 Load cases for structural analyses based on partial ship models

1.1.1 The load cases described in this section are those to be used for structural element analyses which do not require complete ship modelling. They are:

- the analyses of plating (see Ch 7, Sec 1)
- the analyses of ordinary stiffeners (see Ch 7, Sec 2)
- the analyses of primary supporting members analysed through isolated beam structural models or three dimensional structural models (see Ch 7, Sec 3)
- the fatigue analysis of the structural details of the above elements (see Ch 7, Sec 4).

1.1.2 These load cases are the mutually exclusive load cases “a”, “b”, “c” and “d” described in [2].

Load cases “a” and “b” refer to the ship in upright conditions (see Sec 3, [3.2]), i.e. at rest or having surge, heave and pitch motions.

Load cases “c” and “d” refer to the ship in inclined conditions (see Sec 3, [3.2]), i.e. having sway, roll and yaw motions.

1.2 Load cases for structural analyses based on complete ship models

1.2.1 When primary supporting members are to be analysed through complete ship models, according to Ch 7, Sec 3, [1.1.2], specific load cases are to be considered.

These load cases are to be defined considering the ship as sailing in regular waves with different length, height and heading angle, each wave being selected in order to maximise a design load parameter. The procedure for the determination of these load cases is specified in Ch 7, App 3.

2 Load cases

2.1 Upright ship conditions (Load cases “a” and “b”)

2.1.1 Ship condition

The ship is considered to encounter a wave which produces (see Fig 1 for load case “a” and Fig 2 for load case “b”) a relative motion of the sea waterline (both positive and negative) symmetric on the ship sides and induces wave vertical bending moment and shear force in the hull girder. In load case “b”, the wave is also considered to induce heave and pitch motions.

2.1.2 Local loads

The external pressure is obtained by adding to or subtracting from the still water head a wave head corresponding to the relative motion.

The internal loads are the still water loads induced by the weights carried, including those carried on decks. For load case “b”, those induced by the accelerations are also to be taken into account.

2.1.3 Hull girder loads

The hull girder loads are:

- the vertical still water bending moment and shear force
- the vertical wave bending moment and the shear force.

Figure 1 : Wave loads in load case "a"

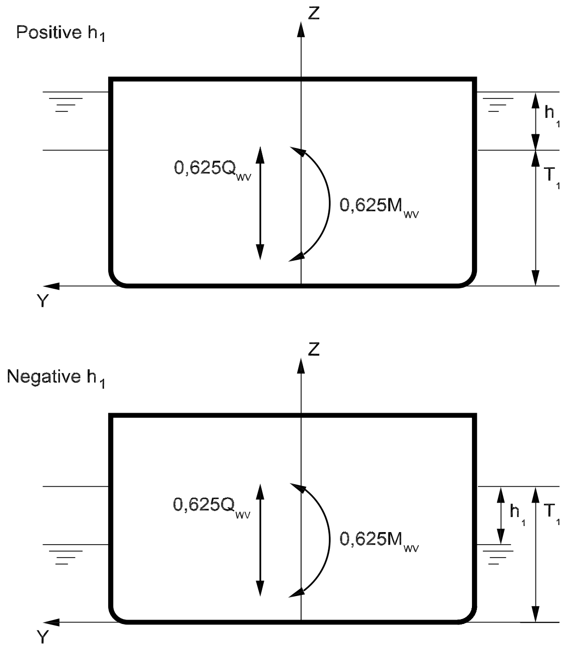
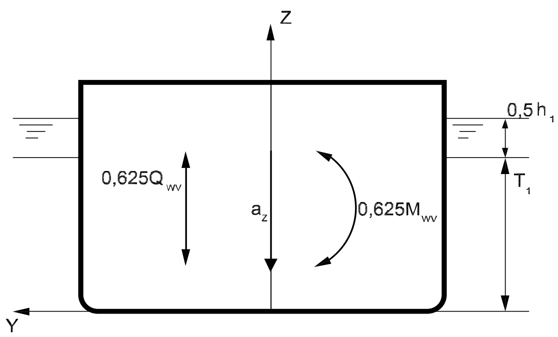


Figure 2 : Wave loads in load case "b"



2.2 Inclined ship conditions (Load cases "c" and "d")

2.2.1 Ship condition

The ship is considered to encounter a wave which produces (see Fig 3 for load case "c" and Fig 4 for load case "d"):

- sway, roll and yaw motions
- a relative motion of the sea waterline anti-symmetric on the ship sides

and induces:

- vertical wave bending moment and shear force in the hull girder
- horizontal wave bending moment in the hull girder
- in load case "c", torque in the hull girder.

Figure 3 : Wave loads in load case "c"

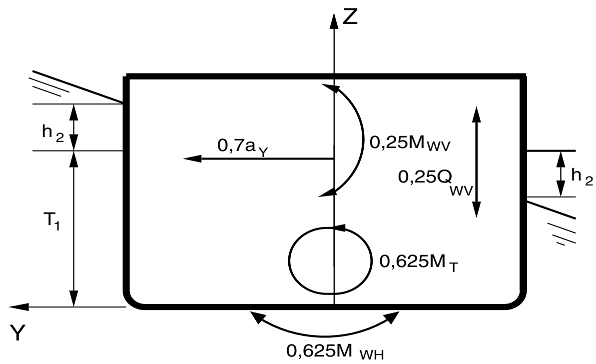
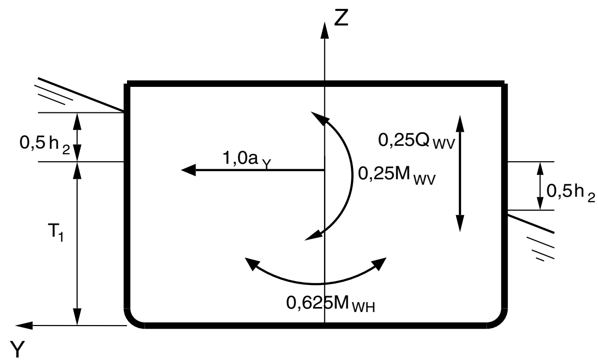


Figure 4 : Wave loads in load case "d"



2.2.2 Local loads

The external pressure is obtained by adding or subtracting from the still water head a wave head linearly variable from positive values on one side of the ship to negative values on the other.

The internal loads are the still water loads induced by the weights carried, including those carried on decks, and the wave loads induced by the accelerations.

2.2.3 Hull girder loads

The hull girder loads are:

- the still water bending moment and shear force
- the vertical wave bending moment and shear force
- the horizontal wave bending moment
- the wave torque (for load case "c").

2.3 Summary of load cases

2.3.1 The wave local and hull girder loads to be considered in each load case are summarised in Tab 1 and Tab 2, respectively.

These loads are obtained by multiplying, for each load case, the reference value of each wave load by the relevant combination factor.

Table 1 : Wave local loads in each load case

Ship condition	Load case	Relative motions		Accelerations a_X, a_Y, a_Z	
		Reference value	Combination factor	Reference value	Combination factor
Upright	"a"	h_1	1,0	a_{X1}; 0; a_{Z1}	0,0
	"b" **(1)**	h_1	0,5	a_{X1}; 0; a_{Z1}	1,0
Inclined	"c" **(2)**	h_2	1,0	0; a_{Y2}; a_{Z2}	0,7
	"d" **(2)**	h_2	0,5	0; a_{Y2}; a_{Z2}	1,0

(1) For a ship moving with a positive heave motion:
- h_1 is positive
- the acceleration a_{X1} is directed towards the positive part of the X axis
- the acceleration a_{Z1} is directed towards the negative part of the Z axis

(2) For a ship rolling with a negative roll angle:
- h_2 is positive for the points located in the positive part of the Y axis and, vice-versa, it is negative for the points located in the negative part of the Y axis
- the acceleration a_{Y2} is directed towards the positive part of the Y axis
- the acceleration a_{Z2} is directed towards the negative part of the Z axis for the points located in the positive part of the Y axis and, vice-versa, it is directed towards the positive part of the Z axis for the points located in the negative part of the Y axis.

Table 2 : Wave hull girder loads in each load case

Ship condition	Load case	Vertical bending moment		Vertical shear force		Horizontal bending moment		Torque	
		Reference value	Comb. factor	Reference value	Comb. factor	Reference value	Comb. factor	Reference value	Comb. factor
Upright	"a"	0,625 M_{WV}	1,0	0,625Q_{WV}	1,0	0,625 M_{WH}	0,0	0,625M_T	0,0
	"b"	0,625 M_{WV}	1,0	0,625Q_{WV}	1,0	0,625 M_{WH}	0,0	0,625M_T	0,0
Inclined	"c"	0,625 M_{WV}	0,4	0,625Q_{WV}	0,4	0,625 M_{WH}	1,0	0,625M_T	1,0
	"d"	0,625 M_{WV}	0,4	0,625Q_{WV}	0,4	0,625 M_{WH}	1,0	0,625M_T	0,0

Note 1: The sign of the hull girder loads, to be considered in association with the wave local loads for the scantling of plating, ordinary stiffeners and primary supporting members contributing to the hull girder longitudinal strength, is defined in Chapter 7.

SECTION 5 SEA PRESSURES

Symbols

For the symbols not defined in this Section, refer to the list at the beginning of this Chapter.

- ρ : Sea water density, taken equal to 1,025 t/m^3
- h_1 : Reference values of the ship relative motions in the upright ship condition, defined in Sec 3, [3.3]
- h_2 : Reference values of the ship relative motions in the inclined ship conditions, defined in Sec 3, [3.3].

1 Still water pressure

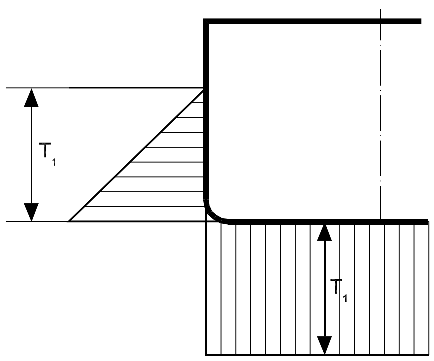
1.1 Pressure on sides and bottom

1.1.1 The still water pressure at any point of the hull is obtained from the formulae in Tab 1 (see also Fig 1).

Table 1 : Still water pressure

Location	Still water pressure p_S, in kN/m^2
Points at and below the waterline ($z \leq T_1$)	$\rho g (T_1 - z)$
Points above the waterline ($z > T_1$)	0

Figure 1 : Still water pressure



1.2 Pressure on exposed decks

1.2.1 On exposed decks, the pressure due to the load carried is to be considered. This pressure is to be defined by the Designer and, in general, it may not be taken less than 10φ kN/m^2, where φ is defined in Tab 2.

The Society may accept pressure values lower than 10φ kN/m^2, when considered appropriate on the basis of the intended use of the deck.

Table 2 : Coefficient for pressure on exposed decks *(1/1/2017)*

Exposed deck location	φ
Bulkhead deck	1,00
Superstructure deck	0,75
1st tier of deckhouse	0,56
2nd tier of deckhouse	0,42
3rd tier of deckhouse	0,32
4th tier of deckhouse	0,25
5th tier of deckhouse	0,20
6th tier of deckhouse	0,15
7th tier of deckhouse and above	0,10

2 Wave pressure

2.1 Upright ship conditions (Load cases "a" and "b")

2.1.1 Pressure on sides and bottom

The wave pressure at any point of the hull is obtained from the formulae in Tab 3 (see also Fig 2 for load case "a" and Fig 3 for load case "b").

Figure 2 : Wave pressure in load case “a”

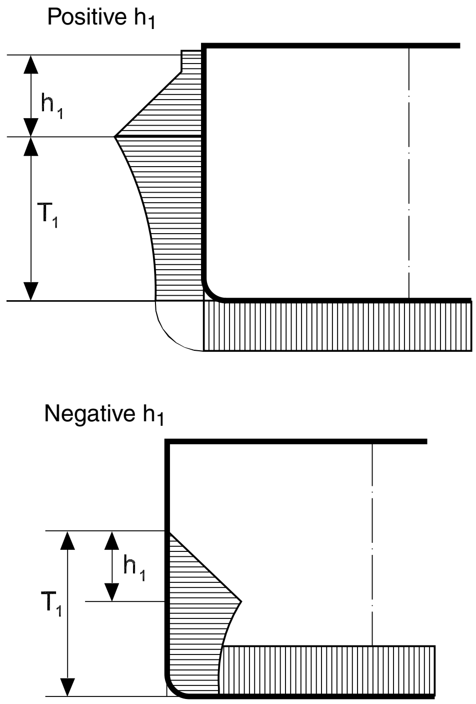
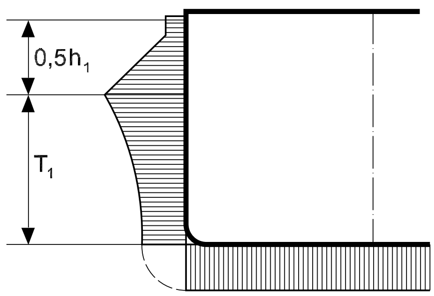


Figure 3 : Wave pressure in load case “b”



2.1.2 Pressure on exposed decks

The wave pressure on exposed decks is to be considered for load cases “a, crest” and “b” only. This pressure is obtained from the formulae in Tab 4.

2.2 Inclined ship conditions (Load cases “c” and “d”)

2.2.1 The wave pressure at any point of the hull is obtained from the formulae in Tab 5 (see also Fig 4 for load case “c” and Fig 5 for load case “d”).

Figure 4 : Wave pressure in load case “c”

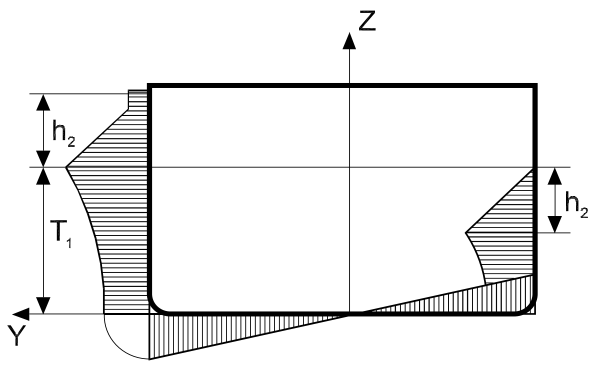


Figure 5 : Wave pressure in load case “d”

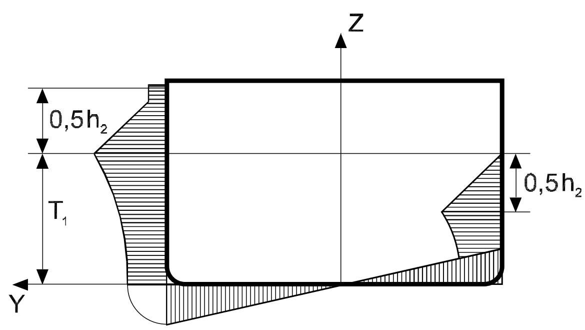


Table 3 : Wave pressure on sides and bottom in upright ship conditions (load cases "a" and "b")

Location	Wave pressure p_W, in kN/m²	C_1	
		crest	trough **(1)**
Bottom and sides below the waterline with: $z \le T_1 - h$	$C_1 \rho g h e^{\frac{-2\pi(T_1 - z)}{L}}$	1,0	-1,0
Sides below the waterline with: $T_1 - h < z \le T_1$	$C_1 \rho g h e^{\frac{-2\pi(T_1 - z)}{L}}$	1,0	$\frac{z - T_1}{h}$
Sides above the waterline: $z > T_1$	$C_1 \rho g(T_1 + h - z)$ without being taken less than 0,15 C_1 L for load case "a" only	1,0	0,0

(1) The wave pressure for load case "b, trough" is to be used only for the fatigue check of structural details according to Ch 7, Sec 4.

Note 1:

$h = C_{F1} h_1$

C_{F1} : Combination factor, to be taken equal to:
- $C_{F1} = 1,0$ for load case "a"
- $C_{F1} = 0,5$ for load case "b".

Table 4 : Wave pressure on exposed decks in upright ship conditions (load cases "a" and "b") *(1/1/2017)*

Location	Wave pressure p_W, in kN/m²
$0 \le x \le 0,5\ L$	$17,5 n \varphi$
$0,5\ L < x < 0,75\ L$	$\left\{17,5 + \left[\frac{19,6\sqrt{H_F} - 17,5}{0,25}\right]\left(\frac{x}{L} - 0,5\right)\right\} n\ \varphi$
$0,75\ L \le x \le L$	$19,6 n \varphi \sqrt{H}$

Note 1:

$$H = C_{F1}\left[2,66\left(\frac{x}{L} - 0,7\right)^2 + 0,14\right]\sqrt{\frac{VL}{C_B}} - (z - T_1)$$ without being taken less than 0,8

φ : Coefficient defined in Tab 2

H_F : Value of H calculated at x = 0,75L

C_{F1} : Combination factor, to be taken equal to:
- $C_{F1} = 1,0$ for load case "a, crest"
- $C_{F1} = 0,5$ for load case "b"

V : Maximum ahead service speed, in knots, to be taken not less than 13 knots.

Table 5 : Wave pressure in inclined ship conditions (load cases “c” and “d”)

Location	Wave pressure p_W, in kN/m²	C_2 (negative roll angle)	
		$y \geq 0$	$y < 0$
Bottom and sides below the waterline with: $z \leq T_1 - h$	$C_2 C_{F2} \rho g \left[\frac{y}{B_W} h_1 e^{\frac{-2\pi(T_1 - z)}{L}} + A_R y e^{\frac{-\pi(T_1 - z)}{L}}\right]$	1,0	1,0
Sides below the waterline with: $T_1 - h < z \leq T_1$	$C_2 C_{F2} \rho g \left[\frac{y}{B_W} h_1 e^{\frac{-2\pi(T_1 - z)}{L}} + A_R y e^{\frac{-\pi(T_1 - z)}{L}}\right]$	1,0	$\frac{T_1 - z}{h}$
Sides above the waterline: $z > T_1$	$C_2 \rho g \left[T_1 + C_{F2}\left(\frac{y}{B_W} h_1 + A_R y\right) - z\right]$ without being taken less than 0,15 C_2 L for load case "c" only	1,0	0,0
Exposed decks	$C_2 \rho g \left[T_1 + C_{F2}\left(\frac{y}{B_W} h_1 + A_R y\right) - z\right]$ without being taken less than 0,15φ C_2 L for load case "c" only	0,4	0,0

Note 1:
$h = C_{F2} h_2$
C_{F2} : Combination factor, to be taken equal to:
- C_{F2} = 1,0 for load case “c”
- C_{F2} = 0,5 for load case “d”.

B_W : Moulded breadth, in m, measured at the waterline at draught T_1, at the hull transverse section considered
A_R : Roll amplitude, defined in Sec 3, [2.4.1].

SECTION 6 INTERNAL PRESSURES AND FORCES

Symbols

For the symbols not defined in this Section, refer to the list at the beginning of this Chapter.

ρ_L : Density, in t/m^3, of the liquid carried

z_{TOP} : Z co-ordinate, in m, of the highest point of the tank in the z direction

z_L : Z co-ordinate, in m, of the highest point of the liquid:

$$z_L = z_{TOP} + 0,5(z_{AP} - z_{TOP})$$

z_{AP} : Z co-ordinate, in m, of the moulded deck line of the deck to which the air pipes extend, to be taken not less than z_{TOP}

p_{PV} : Setting pressure, in bar, of safety valves

M : Mass, in t, of a dry unit cargo carried

a_{X1}, a_{Y1}, a_{Z1}: Reference values of the accelerations in the upright ship condition, defined in Sec 3, [3.4], calculated in way of:

- the centre of gravity of the compartment, in general
- the centre of gravity of any dry unit cargo, in the case of this type of cargo

a_{X2}, a_{Y2}, a_{Z2}: Reference values of the accelerations in the inclined ship condition, defined in Sec 3, [3.4], calculated in way of:

- the centre of gravity of the compartment, in general
- the centre of gravity of any dry unit cargo, in the case of this type of cargo

C_{FA} : Combination factor, to be taken equal to:

- $C_{FA} = 0,7$ for load case "c"
- $C_{FA} = 1,0$ for load case "d"

H : Height, in m, of a tank, to be taken as the vertical distance from the bottom to the top of the tank, excluding any small hatchways

d_{AP} : Distance from the top of air pipe to the top of compartment, in m.

1 Liquids

1.1 Still water pressure

1.1.1 Still water pressure

The still water pressure to be used in combination with the inertial pressure in [1.2] is the greater of the values obtained, in kN/m^2, from the following formulae:

$$p_S = \rho_L g(z_L - z)$$

$$p_S = \rho_L g(z_{TOP} - z) + 100 p_{PV}$$

1.2 Inertial pressure

1.2.1 Inertial pressure

The inertial pressure is obtained from the formulae in Tab 1, or from App 1 for typical tank arrangements.

Moreover, the inertial pressure is to be taken such that:

$$p_S + p_W \geq 0$$

where p_S is defined in [1.1].

Table 1 : Liquids - Inertial pressure

Ship condition	Load case	Inertial pressure p_W, in kN/m^2
Upright	"a"	No inertial pressure
	"b"	$\rho_L[0,5 a_{X1} \ell_B + a_{Z1}(z_{TOP} - z)]$
Inclined (negative roll angle)	"c"	$\rho_L[a_{TY}(y - y_H) + a_{TZ}(z - z_H) + g(z - z_{TOP})]$
	"d"	

Note 1:
ℓ_B : Longitudinal distance, in m, between the transverse tank boundaries, without taking into account small recesses in the lower part of the tank (see Fig 1)
a_{TY}, a_{TZ} : Y and Z components, in m/s^2, of the total acceleration vector defined in [1.2.2] for load case "c" and load case "d"
y_H, z_H : Y and Z co-ordinates, in m, of the highest point of the tank in the direction of the total acceleration vector, defined in [1.2.3] for load case "c" and load case "d".

Figure 1 : Upright ship conditions - Distance ℓ_B

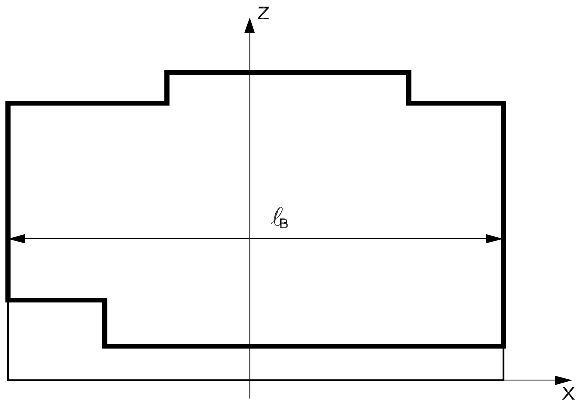
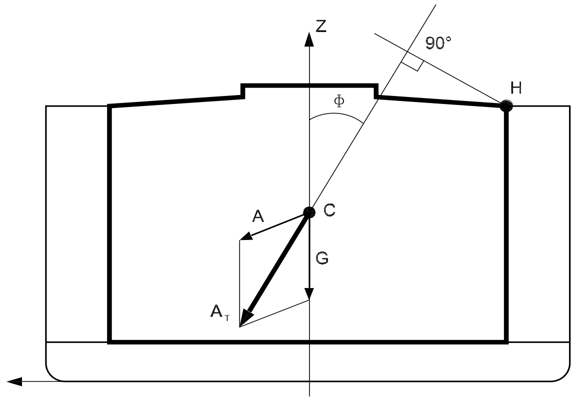


Figure 2 : Inclined ship conditions Highest point H of the tank in the direction of the total acceleration vector



1.2.2 Total acceleration vector

The total acceleration vector is the vector obtained from the following formula:

$$\vec{A}_T = \vec{A} + \vec{G}$$

where:

A : Acceleration vector whose absolute values of X, Y and Z components are the longitudinal, transverse and vertical accelerations defined in Sec 3, [3.4]

G : Gravity acceleration vector.

The Y and Z components of the total acceleration vector and the angle it forms with the z direction are defined in Tab 2.

Table 2 : Inclined ship conditions Y and Z components of the total acceleration vector and angle Φ it forms with the z direction

Components (negative roll angle)		Angle Φ, in rad
a_{TY} , in m/s²	a_{TZ} , in m/s²	
$0,7C_{FA}a_{Y2}$	$-0,7C_{FA}a_{Z2} - g$	$\operatorname{atan}\frac{a_{TY}}{a_{TZ}}$

1.2.3 Highest point of the tank in the direction of the total acceleration vector

The highest point of the tank in the direction of the total acceleration vector A_T, defined in [1.2.2], is the point of the tank boundary whose projection on the direction forming the angle Φ with the vertical direction is located at the greatest distance from the tank's centre of gravity. It is to be determined for the inclined ship condition, as indicated in Fig 2, where A and G are the vectors defined in [1.2.2] and C is the tank's centre of gravity.

2 Dry uniform loads

2.1 Still water and inertial pressures

2.1.1 General

The still water and inertial pressures are obtained, in kN/m², as specified in Tab 3.

Table 3 : Dry uniform loads Still water and inertial pressure

Ship condition	Load case	Still water pressure p_S and inertial pressure p_W, in kN/m²
Still water		The value of p_S is generally specified by the Designer; in any case, it may not be taken less than 10 kN/m². When the value of p_S is not specified by the Designer, it may be taken, in kN/m², equal to 6,9 h_{TD} , where h_{TD} is the compartment 'tweendeck height at side, in m.
Upright (positive heave motion)	"a"	No inertial pressure
	"b"	$p_{W,Z} = -p_S\frac{a_{Z1}}{g}$ in z direction
Inclined (negative roll angle)	"c"	$p_{W,Y} = p_S\frac{C_{FA}a_{Y2}}{g}$ in y direction
	"d"	$p_{W,Z} = p_S\frac{C_{FA}a_{Z2}}{g}$ in z direction

3 Dry unit cargoes

3.1 Still water and inertial forces

3.1.1 The still water and inertial forces transmitted to the hull structures are to be determined on the basis of the forces obtained, in kN, as specified in Tab 4 taking into account the elastic characteristics of the lashing arrangement and/or the structure which contains the unit..

Table 4 : Dry unit Still water and inertial forces

Ship condition	Load case	Still water force F_S and inertial force F_W, in kN
Still water		$F_S = Mg$
Upright (positive heave motion)	"a"	No inertial force
	"b"	$F_{W,X} = Ma_{X1}$ in x direction $F_{W,Z} = -Ma_{Z1}$ in z direction
Inclined (negative roll angle)	"c"	$F_{W,Y} = MC_{FA}a_{Y2}$ in y direction $F_{W,Z} = MC_{FA}a_{Z2}$ in z direction
	"d"	

4 Vehicles and helicopters

4.1 Still water and inertial forces

4.1.1 General

Caterpillar trucks and unusual vehicles are considered by the Society on a case by case basis.

The load supported by the crutches of semi-trailers, handling machines and platforms is considered by the Society on a case by case basis.

4.1.2 Tyred vehicles and helicopters

The forces transmitted through the tyres are comparable to pressure uniformly distribuited on the tyre print, whose dimensions are to be indicated by the Designer together with information concerning the arrangement of wheels on axles, the load per axles and the tyre pressure.

With the exception of dimensioning of plating, such forces may be considered as concentrated in the tyre print centre.

The still water and inertial forces transmitted to the hull structures are to be determined on the basis of the forces obtained, in kN, as specified in Tab 5.

4.1.3 Non-tyred rolling vehicles

The requirements of [4.1.2] also apply to tracked vehicles; in this case the print to be considered is that below each wheel or wheelwork.

4.1.4 Other vehicles

For other vehicles on fixed supports, all the forces transmitted are to be considered as concentrated at the contact area centre.

5 Accomodation

5.1 Still water and inertial pressures

5.1.1 *(1/1/2017)*

In absence of specific data the designer may use the still water and inertial pressures transmitted to the deck structures are obtained, in kN/m², as specified in Tab 6.

5.1.2 In addition to the pressures defined in [5.1.1] , the effect of significant concentrated loads must be taken into account, when deemed necessary by the Society.

5.1.3 Manoeuvring areas are always to be considered as exposed areas, and as such, subject to the relevant loads in Sec 5.

6 Machinery

6.1 Still water and inertial pressures

6.1.1 The still water and inertial pressures transmitted to the deck structures are obtained, in kN/m², as specified in Tab 8.

Table 5 : Vehicles and helicopters-Still water and inertial forces

Ship condition	Load case	Still water force F_S and inertial force F_W, in kN
Still water **(1) (2)**		$F_S = Mg$
Upright (positive heave motion)	"a"	No inertial force
	"b" **(3)**	$F_{W,Z} = -Ma_{Z1}$ in Z direction
Inclined (negative roll angle)	"c"	$F_{W,Y} = MC_{FA}a_{Y2}$ in y direction $F_{W,Z} = MC_{FA}a_{Z2}$ in z direction
	"d"	

(1) This conditions defines the force, applied by one wheel, to be considered for the determination of scantlings of plating ,ordinary stiffners and primary supporting members, as defined in Chapter 7 , with M obtained , in t, from the following formula :

$$M = \frac{Q_A}{n_W}$$

Where :

Q_A : Axle load, in t. For fork-lift trucks, the value of Q_A is to be taken equal to the total mass of the vehicle, including that of the cargo handled, applied to one axle only.

n_W : Number of wheels for the axle considered.

(2) This condition is to be considered for the racking analysis, as defined in Ch 7, App 1, with the M taken equal to the mass, in t, of the wheeled loads located on the structural member under condsideration.

(3) For fork-lift trucks operating in harbour conditions, the inertial force may be reduced by 50 %.

Table 6 : Accomodations Still water and inertial pressures *(1/1/2017)*

Ship condition	Load case	Still water pressure p_S and inertial pressure p_W, in kN/m²
Still water		In absence of specific data the designer may use the value of p_S defined in Tab 7 depending on the type of the accomodation compartment
Upright (positive heave motion)	"a"	No inertial force
	"b"	$p_W = (-p_S)\frac{a_{Z1}}{g}$
IInclined	"c"	The inertial pressure tranmitted to the deck structures in inclined condition may generally be disregarded. Specific cases in which this simplification is not deemed permissible by the Society are considered individually.
	"d"	

Table 7 : Still water deck pressure in operational and accomodation compartments *(1/1/2017)*

Type of operational and accomodation compartment	p_S, in kN/m²
Operational rooms (COC, COP, TLC, ECG, ADT, GE, RADAR room, EMPAR, METEO, workhops and galleys	5,0
Cabins, baggage rooms, lounges , restaurant , meeting rooms , briefing rooms, hospitals, corridors	3,0
Storages intended for mineral water , wine, oil , paintings	15,0
Other storages	10,0
Ammunition storages	**(1)**
(1) The value of p_S is to be specified by the Designer; in any case, it may not be less than 15,0 kN/m² . This value may also be assumed for the scantling checks where, at a preliminary design stage, the value of p_S is not yet defined by the Designer.	

Table 8 : Machinery Still water and inertial pressures

Ship condition	Load case	Still water pressure p_S and inertial pressure p_W, in kN/m²
Still water		$p_S = 10$
Upright (positive heave motion)	"a"	No inertial pressure
	"b"	$p_W = (-p_S)\frac{a_{Z1}}{g}$
Inclined	"c"	The inertial pressure transmitted to the deck structures in inclined condition may generally be disregarded. Specific cases in which this simplification is not deemed permissible by the Society are considered individually.
	"d"	

7 Flooding

7.1 Still water and inertial pressures

7.1.1 Unless otherwise specified, the still water and inertial pressures to be considered as acting on bulkheads or inner sides which constitute boundaries of compartments not intended to carry liquids are obtained, in kN/m², from the formulae in Tab 9.

Table 9 : Flooding Still water and inertial pressures

Still water pressure p_{SF}, in kN/m²	Inertial pressure p_{WF}, in kN/m²
$\rho g(Z_F - Z)$ without being taken less than 0,4 g d_0	$0,6\rho a_{Z1}(Z_F - Z)$ without being taken less than 0,4 g d_0
Note 1: Z_F : Z co-ordinate , in m , at the deepest equilibrium waterline at side in way of the tranverse section considered, obtained from the damage stability calculations, for which the transient conditions are to be taken into account d_0 : Distance , in m, to be taken equal to : d_0 = 0,02L for 65 m ≤ L ≤ 120 m d_0 = 2,4 for L > 120 m	

8 Weapons firing dynamic loads

8.1 Dynamic loads

8.1.1 General

The following weapons firing dynamic loads are to be specified by the Designer:

- Missile blast dynamic pressure
- Accidental missile ignition dynamic pressure
- Gun blast dynamic pressure
- Gun recoil dynamic force, for all the possible combinations of elevation and slewing angle of the weapon system.

As guidance, they may be obtained from the formulae specified in [8.2].

8.1.2 Other loads

Weapon firing dynamic loads other than those specified in [8.1.1], such as loads on vertical missile launching systems (VLS) and loads on rocket or missile launching systems with elevation and slewing capabilities, are generally to be specified by the weapon manufacturer. In any event, they are to be considered by the Society on a case-by-case basis.

8.1.3 Additional loads

At the request of the interested parties, additional weapon firing dynamic loads other than those specified in [8.1.1] and [8.1.2], such as collision or hitting against fixed devices fitted in way of the weapon system rail limits, may be considered by the Society on a case-by-case basis, together with the relevant weapon manufacturer specification.

8.2 Guidance values

8.2.1 Missile blast dynamic pressure

As guidance, the missile blast dynamic pressure may be obtained, in kN/m², from the following formula:

$$p_W = \frac{T\left(\sin\alpha + \left(\frac{0,0225}{\sin\alpha}\right)\right)}{A}$$

where:

T : total thrust, in kN, of the missile,

α : angle, in degrees, of incidence for missile blast with respect to the considered surface,

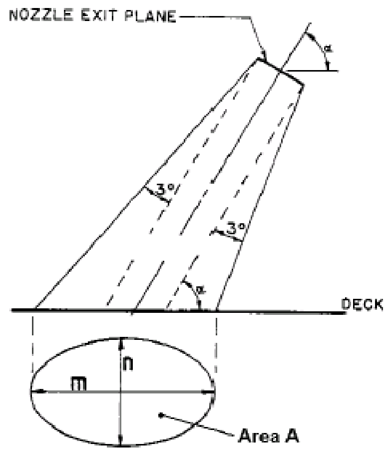
A : impingement area, in m², of the considered surface bounded by the blast cone, i.e. the cone generated by rotating about the missile axis a line with a 3° divergence from the axis and passing through the circumference of the exit nozzle (see Fig 3). The impingement area is to be obtained, in m², from the following formula:

$$A = \alpha m \frac{n}{4}$$

m : major axis, in m, of the impingement area (see Fig 3),

n : minor axis, in m, of the impingement area (see Fig 3)

Figure 3 : Missile blast impingement area



8.2.2 Accidental missile dynamic pressure

As guidance, the accidental missile ignition dynamic pressure may be obtained, in kN/m², from the following formula:

$$p_W = \frac{67,4R}{A_B}$$

where:

R : burning rate, in kg / s, of the missile booster,

A_B : total area, in m², of blow-out opening.

8.2.3 Gun blast dynamic pressure

As guidance, the blast dynamic pressure for one gun may be obtained, in kN/m², from the following formula:

$$p_W = \frac{1380(1+\cos\beta)}{\left(\frac{r}{d}\right)^{1,5}}$$

β : angle, in degrees, between the gun barrel axis and the straight line passing through the gun muzzle and the calculation point (see Fig 4),

r : distance, in mm, from the gun muzzle to the calculation point (see Fig 4),

d : gun diameter (calibre), in mm.

When two or more guns firing simultaneously are considered, the blast dynamic pressure is the greater of the values obtained by applying the above formula for each gun, considered as being firing independently from the others.

8.2.4 Gun recoil dynamic forcr

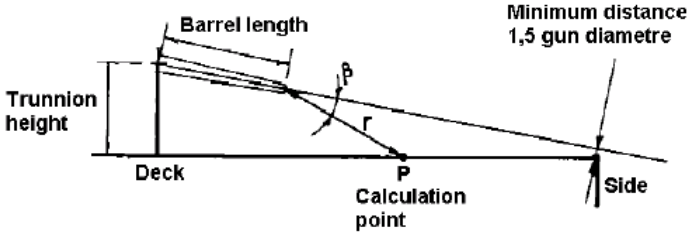
As guidance, the gun recoil dynamic force may be obtained, in kN, from the following formula:

$$F_W = 1,3F_B$$

where:

F_B : rated brake load, in kN, of the recoil mechanism.

Figure 4 : Angle β and distance r for gun blast dynamic pressure calculation



9 Testing

9.1 Still water pressures

9.1.1 *(1/1/2017)*

The still water pressure is to be considered as acting on plates and stiffeners subject to tank testing is obtained, in kN/m², from the formulae in Tab 10.

No inertial pressure is to be considered as acting on plates and stiffeners subject to tank testing.

Table 10 : Testing - Still water pressures *(1/1/2017)*

Compartment or structure to be tested	Still water pressure p_{ST}, in kN/m²
Double bottom tanks	The greater of the following: $p_{ST} = 10\ [(z_{TOP} - z) + d_{AP}]$ $p_{ST} = 10\ (z_{ml} - z)$ where: Z_{ml}: Z co-ordinate, in m, of the margin line
Double side tanks, fore and after peaks used as tank, cofferdams	The greater of the following: $p_{ST} = 10\ [(z_{TOP} - z) + d_{AP}]$ $p_{ST} = 10\ [(z_{TOP} - z) + 2,4]$
Tank bulkheads, deep tanks, fuel oil bunkers	The greater of the following: $p_{ST} = 10\ [(z_{TOP} - z) + d_{AP}]$ $p_{ST} = 10\ [(z_{TOP} - z) + 2,4]$ $p_{ST} = 10\ [(z_{TOP} - z) + 10\ p_{PV}]$
Fore peak not used as tank	The greater of the following: $p_{ST} = 10\ (z_F - z)$ $p_{ST} = 10\ (z_{ml} - z)$ where: z_F : As defined in Tab 9 z_{ml} : Z co-ordinate, in m, of the margin line
Watertight doors below bulkhead deck	$p_{ST} = 10\ (z_{bd} - z)$ where: z_{bd} : Z co-ordinate, in m,of the bulkhead deck
Chain locker (if aft of collision bulkhead)	$p_{ST} = 10\ (z_{CP} - z)$ where: z_{CP} : Z co-ordinate, in m, of the top of chain pipe
Independent tanks	The greater of the following: $p_{ST} = 10\ [(z_{TOP} - z) + d_{AP}]$ $p_{ST} = 10\ [(z_{TOP} - z) + 0,9]$
Ballast ducts	Ballast pump maximum pressure

10 Flooding

10.1 Still water and inertial pressures

10.1.1 *(1/1/2017)*

Unless otherwise specified, the still water and inertial pressures to be considered as acting on bulkheads, or inner sides or internal decks, which constitute boundaries of compartments not intended to carry liquids are obtained, in kN/m2, from the formulae in Tab 12.

APPENDIX 1 INERTIAL PRESSURE FOR TYPICAL TANK ARRANGEMENT

1 Liquid cargoes and ballast - Inertial pressure

1.1 Introduction

1.1.1 Sec 6, [1] defines the criteria to calculate the inertial pressure p_W induced by liquid cargoes and ballast in any type of tank. The relevant formulae are specified in Sec 6, Tab 1 and entail the definition of the highest point of the tank in the direction of the total acceleration vector. As specified in Sec 6, [1.2], this point depends on the geometry of the tank and the values of the acceleration. For typical tank arrangements, the highest point of the tank in the direction of the total acceleration vector can easily be identified and the relevant formulae written using the tank geometric characteristics.

1.1.2 This Appendix provides the formulae for calculating the inertial pressure p_W in the case of typical tank arrangements.

1.2 Formulae for the inertial pressure calculation

1.2.1 For typical tank arrangements, the inertial pressure transmitted to the hull structures at the calculation point P in inclined ship condition may be obtained from the formulae in Tab 1, obtained by applying to those tanks the general formula in Sec 6, Tab 1.

Table 1 : Liquid cargoes and ballast - Inertial pressure for typical tank arrangements

Ship condition	Load case	Inertial pressure p_W , in kN/m²
Inclined (negative roll angle)	"c"	$0,7 C_{FA} \rho_L (a_{Y2} b_L + a_{Z2} d_H)$
	"d"	

Note 1:

- C_{FA} : Combination factor, to be taken equal to:
  - C_{FA} = 0,7 for load case "c"
  - C_{FA} = 1,0 for load case "d"
- ρ_L : Density, in t/m³, of the liquid cargo carried
- a_{Y2}, a_{Z2} : Reference values of the acceleration in the inclined ship condition, defined in Sec 3, [3.4], calculated in way of the centre of gravity of the tank
- b_L, d_H : Transverse and vertical distances, in m, to be taken as indicated in Fig 1 to Fig 4 for various types of tanks; for the cases in Fig 1 , where the central cargo area is divided into two or more tanks by longitudinal bulkheads, b_L and d_H for calculation points inside each tank are to be taken as indicated in Fig 3 for the double side.

Figure 1 : Distances b_L and d_H

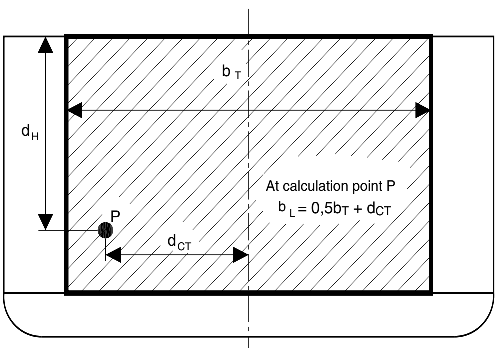


Figure 2 : Distances b_L and d_H

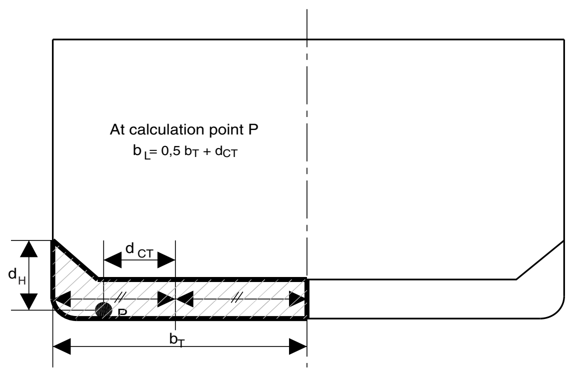


Figure 3 : Distances b_L and d_H

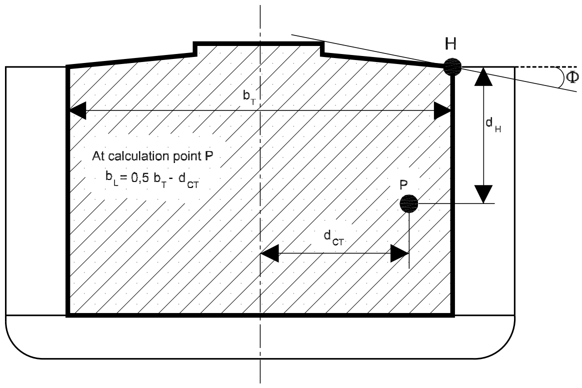
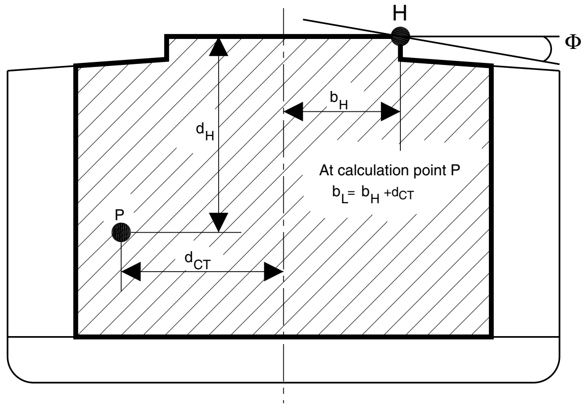


Figure 4 : Distances b_L and d_H



Part B
Hull and Stability

Chapter 6
HULL GIRDER STRENGTH

Symbols used in chapter 6

E : Young's modulus, in N/mm^2, to be taken equal to:

- for steels in general:
  $E = 2{,}06.10^5 \ N/mm^2$
- for stainless steels:
  $E = 1{,}95.10^5 \ N/mm^2$
- for aluminium alloys:
  $E = 7{,}0.10^4 \ N/mm^2$

M_{SW} : Still water bending moment, in kN.m:

- in hogging conditions:
  $M_{SW} = M_{SW,H}$
- in sagging conditions:
  $M_{SW} = M_{SW,S}$

$M_{SW,H}$: Design still water bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [2.2],

$M_{SW,S}$: Design still water bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [2.2], when the ship in still water is always in hogging condition, $M_{SW,S}$ is to be taken equal to 0,

M_{WV} : Vertical wave bending moment, in kN.m:

- in hogging conditions:
  $M_{WV} = M_{WV,H}$
- in sagging conditions:
  $M_{WV} = M_{WV,S}$

$M_{WV,H}$: Vertical wave bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [3.1],

$M_{WV,S}$: Vertical wave bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [3.1],

g : Gravity acceleration, in m/s^2:
$g = 9{,}81 \ m/s^2$.

SECTION 1 STRENGTH CHARACTERISTICS OF THE HULL GIRDER TRANSVERSE SECTIONS

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

1 Application

1.1 General

1.1.1 This Section specifies the criteria for calculating the hull girder strength characteristics to be used for the checks in Sec 2 and Sec 3, in association with the hull girder loads specified in Ch 5, Sec 2.

1.2 Dynamic analysis

1.2.1 General

The dynamic analysis of the hull girder is to be based on direct calculations performed through a complete three-dimensional model of the hull and superstructures.

The criteria adopted for structural modelling are to comply with the requirements specified in Ch 7, App 1.

In any case, the mesh accuracy is to be such that the hull girder stiffness and the mass distributions are properly reproduced.

1.2.2 Normal mode analysis

It is to be checked that each normal mode frequency F_{Ni}, in Hz, of the hull girder is in compliance with one of the following formulae:

$$F_{Ni} < 0,7 f_{E,MIN}$$

$$F_{Ni} > 1,3 f_{E,MAX}$$

where:

$f_{E,MIN}$, $f_{E,MAX}$: the lesser and the greater values, in Hz, respectively, among the possible excitations frequencies due to the ship's motions or the propulsion system, to be calculated for the ship at the following speeds:

- cruise speed
- maximum continuous rate speed
- patrol speed.

The normal mode calculation method and the number of normal modes to be taken into account are considered by the Society on a case by case basis.

When at least one of the hull girder normal mode frequencies does not comply with the above formulae, a dynamic analysis is to be carried out according to the requirements in [1.2.3].

1.2.3 Dynamic analysis

It is to be checked that the dynamic effects induced in the hull girder by the ship's motions or propulsion system excitations are within the allowable limits, when this is required according to [1.2.2].

The dynamic effects are to be calculated by means of a dynamic analysis aiming at evaluating the response of the hull girder in the frequency domain.

When the dynamic analysis is based on normal models, their number is, in general, to be such that the modal effective mass is not less than 95% of the hull girder mass.

The modal effective mass is defined as:

$$\sum_{i=1}^{N} \gamma_i^2$$

where γ_i is the i^{th} modal participation factor and N is the number of the considered normal modes.

The dynamic analysis criteria and the relevant allowable limits are considered by the Society on a case by case basis.

2 Calculation of the strength characteristics of hull girder transverse sections

2.1 Hull girder transverse sections

2.1.1 General

Hull girder transverse sections are to be considered as being constituted by the members contributing to the hull girder longitudinal strength, i.e. all continuous longitudinal members below the strength deck defined in [2.2], taking into account the requirements in [2.1.2] to [2.1.9].

These members are to be considered as having gross scantlings (see also Ch 4, Sec 2):

- gross scantlings, when the hull girder strength characteristics to be calculated are used for the yielding checks in Sec 2
- net scantlings, when the hull girder strength characteristics to be calculated are used for the ultimate strength checks in Sec 3 and for calculating the hull girder stresses for the strength checks of plating, ordinary stiffeners and primary supporting members in Chapter 7.

2.1.2 Continuous trunks and continuous lngitudinal hatch coamings

Continuous trunks and continuous longitudinal hatch coamings may be included in the hull girder transverse sections, provided they are effectively supported by longitudinal bulkheads or primary supporting members.

2.1.3 Longitudinal ordinary stiffeners or girders welded above the decks

Longitudinal ordinary stiffeners or girders welded above the decks (including the deck of any trunk fitted as specified in [2.1.2]) may be included in the hull girder transverse sections.

2.1.4 Longitudinal girders between hatchways

Where longitudinal girders are fitted between hatchways, the sectional area that can be included in the hull girder transverse sections is obtained, in m², from the following formula:

$$A_{EFF} = A_{LG} a$$

where:

A_{LG} : Sectional area, in m², of longitudinal girders,

a : Coefficient:

- for longitudinal girders effectively supported by longitudinal bulkheads or primary supporting members:

  a = 1

- for longitudinal girders not effectively supported by longitudinal bulkheads or primary supporting members and having dimensions and scantlings such that $\ell_0 / r \le 60$:

  $$a = 0{,}6\left(\frac{s}{b_1} + 0{,}15\right)^{0{,}5}$$

- for longitudinal girders not effectively supported by longitudinal bulkheads or primary supporting members and having dimensions and scantlings such that $\ell_0 / r > 60$:

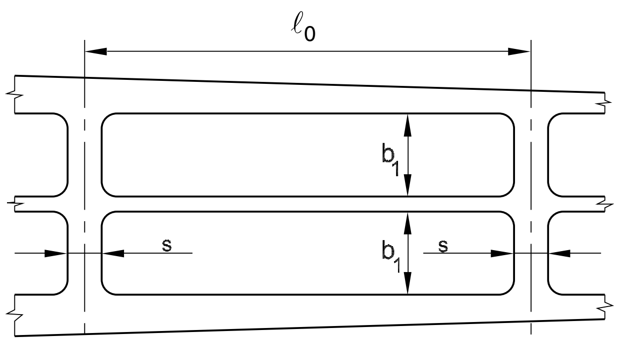
  a = 0

ℓ_0 : Span, in m, of longitudinal girders, to be taken as shown in Fig 1

r : Minimum radius of gyration, in m, of the longitudinal girder transverse section

s, b_1 : Dimensions, in m, defined in Fig 1.

Figure 1 : Longitudinal girders between hatchways



2.1.5 Longitudinal bulkheads with vertical corrugations

Longitudinal bulkheads with vertical corrugations may not be included in the hull girder transverse sections.

2.1.6 Members in materials other than steel

Where a member contributing to the longitudinal strength is made in material other than steel with a Young's modulus E equal to 2,06 10^5 N/mm², the steel equivalent sectional area that may be included in the hull girder transverse sections is obtained, in m², from the following formula:

$$A_{SE} = \frac{E}{2{,}06{,}10^5} A_M$$

where:

A_M : Sectional area, in m², of the member under consideration.

2.1.7 Large openings

Large openings are:

- elliptical openings exceeding 2,5 m in length or 1,2 m in breadth
- circular openings exceeding 0,9 m in diameter.

Large openings and scallops, where scallop welding is applied, are always to be deducted from the sectional areas included in the hull girder transverse sections.

2.1.8 Small openings

Smaller openings than those in [2.1.7] in one transverse section in the strength deck or bottom area need not be deducted from the sectional areas included in the hull girder transverse sections, provided that:

$$\Sigma b_S \le 0{,}06(B - \Sigma b)$$

where:

Σb_S : Total breadth of small openings, in m, in the strength deck or bottom area at the transverse section considered, determined as indicated in Fig 2

Σb : Total breadth of large openings, in m, at the transverse section considered, determined as indicated in Fig 2

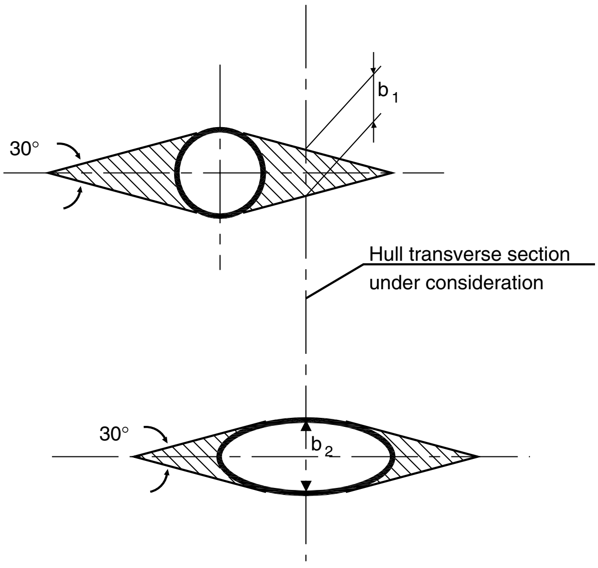
Where the total breadth of small openings Σb_S does not fulfil the above criteria, only the excess of breadth is to be deducted from the sectional areas included in the hull girder transverse sections.

2.1.9 Lightening holes, draining holes and single scallops

Lightening holes, draining holes and single scallops in longitudinals need not be deducted if their height is less than 0,25 h_W 10^{-3}, without being greater than 75 mm, where h_W is the web height, in mm, defined in Ch 4, Sec 3.

Otherwise, the excess is to be deducted from the sectional area or compensated.

Figure 2 : Calculation of Σb and Σb_S



b_1 and b_2 included in Σ b and Σ bs

2.2 Strength deck

2.2.1 The strength deck is, in general, the uppermost continuous deck.

In the case of a superstructure or deckhouses contributing to the longitudinal strength, the strength deck is the deck of the superstructure or the deck of the uppermost deckhouse.

2.2.2 A superstructure extending at least 0,15 L within 0,4 L amidships may generally be considered as contributing to the longitudinal strength. For other superstructures and for deckhouses, their contribution to the longitudinal strength is to be assessed on a case by case basis, through a finite element analysis of the whole ship, which takes into account the general arrangement of the longitudinal elements (side, decks, bulkheads).

The presence of openings in the side shell and longitudinal bulkheads is to be taken into account in the analysis. This may be done in two ways:

- by including these openings in the finite element model
- by assigning to the plate panel between the side frames beside each opening an equivalent thickness, in mm, obtained from the following formula:

$$t_{EQ} = 10^3\left[\ell_P\left(\frac{Gh^2}{12EI_J} + \frac{1}{A_J}\right)\right]^{-1}$$

where (see Fig 3):

ℓ_P : Longitudinal distance, in m, between the frames beside the opening

h : Height, in m, of openings

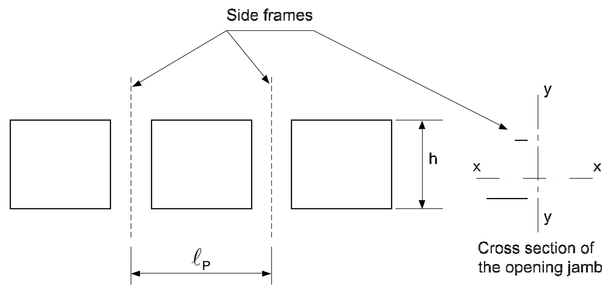
I_J : Moment of inertia, in m^4, of the opening jamb about the transverse axis y-y

A_J : Shear area, in m^2, of the opening jamb in the direction of the longitudinal axis x-x

G : Coulomb's modulus, in N/mm^2, of the material used for the opening jamb, to be taken equal to:

- for steels:
  $G = 8{,}0.10^4$ N/mm^2
- for aluminium alloys:
  $G = 2{,}7.10^4$ N/mm^2.

Figure 3 : Side openings



2.3 Section modulus

2.3.1 The section modulus at any point of a hull transverse section is obtained, in m^3, from the following formula:

$$Z_A = \frac{I_Y}{|z - N|}$$

where:

I_Y : Moment of inertia, in m^4, of the hull transverse section defined in [2.1], about its horizontal neutral axis

z : Z co-ordinate, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6]

N : Z co-ordinate, in m, of the centre of gravity of the hull transverse section defined in [2.1], with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6].

2.3.2 The section moduli at bottom and at deck are obtained, in m^3, from the following formulae:

- at bottom:

$$Z_{AB} = \frac{I_Y}{N}$$

- at deck:

$$Z_{AD} = \frac{I_Y}{V_D}$$

where:

I_Y, N : Defined in [2.3.1]

V_D : Vertical distance, in m:

- in general:
  $V_D = z_D - N$
  where:
  z_D : Z co-ordinate, in m, of strength deck, defined in [2.2], with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6]

- if continuous trunks or hatch coamings are taken into account in the calculation of I_Y, as specified in [2.1.2]:

$$V_D = (z_T - N)\left(0,9 + 0,2\frac{y_T}{B}\right) \geq z_D - N$$

where:

y_T, z_T : Y and Z co-ordinates, in m, of the top of continuous trunk or hatch coaming with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6]; y_T and z_T are to be measured for the point which maximises the value of V

- if longitudinal ordinary stiffeners or girders welded above the strength deck are taken into account in the calculation of I_Y, as specified in [2.1.3], V_D is to be obtained from the formula given above for continuous trunks and hatch coamings. In this case, y_T and z_T are the Y and Z co-ordinates, in m, of the top of the longitudinal stiffeners or girders with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6].

2.4 Moments of inertia

2.4.1 The moments of inertia I_Y and I_Z, in m^4, are those, calculated about the horizontal and vertical neutral axes, respectively, of the hull transverse sections defined in [2.1].

2.5 First moment

2.5.1 The first moment S, in m^3, at a level z above the baseline is that, calculated with respect to the horizontal neutral axis, of the portion of the hull transverse sections defined in [2.1] located above the z level.

2.6 Structural models for the calculation of normal warping stresses and shear stresses

2.6.1 The structural models that can be used for the calculation of normal warping stresses, induced by torque, and shear stresses, induced by shear forces or torque, are:

- three dimensional finite element models
- thin walled beam models

representing the members which constitute the hull girder transverse sections according to [2.1].

SECTION 2 YIELDING CHECKS

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

M_{WH} : Horizontal wave bending moment, in kN.m, defined in Ch 5, Sec 2, [3.2]

M_{WT} : Wave torque, in kN.m, defined in Ch 5, Sec 2, [3.3]

Q_{SW} : Design still water shear force, in kN, defined in Ch 5, Sec 2, [2.3]

Q_{WV} : Vertical wave shear force, to be calculated according to Ch 5, Sec 2, [3.4]:

- if $Q_{SW} \geq 0$, Q_{WV} is the positive wave shear force
- if $Q_{SW} < 0$, Q_{WV} is the negative wave shear force

k : Material factor, as defined in Ch 4, Sec 1, [2.3]

x : X co-ordinate, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6]

I_Y : Moment of inertia, in m^4, of the hull transverse section about its horizontal neutral axis, to be calculated according to Sec 1, [2.4]

I_Z : Moment of inertia, in m^4, of the hull transverse section about its vertical neutral axis, to be calculated according to Sec 1, [2.4]

S : First moment, in m^3, of the hull transverse section, to be calculated according to Sec 1, [2.5]

Z_A : Section modulus, in cm^3, at any point of the hull transverse section, to be calculated according to Sec 1, [2.3.1]

Z_{AB},Z_{AD} : Section moduli, in cm^3, at bottom and deck, respectively, to be calculated according to Sec 1, [2.3.2]

n_1 : Navigation coefficient defined in Ch 5, Sec 1, Tab 1

C : Wave parameter defined in Ch 5, Sec 2.

1 Application

1.1

1.1.1 The requirements of this Section apply to ships having the following characteristics:

- L < 500 m
- L / B > 5
- B / D < 2,5
- $C_B \geq 0,4$

Ships not having one or more of these characteristics and ships of unusual type or design are considered by the Society on a case by case basis.

2 Hull girder stresses

2.1 Normal stresses induced by vertical bending moments

2.1.1 The normal stresses induced by vertical bending moments are obtained, in N/mm^2, from the following formulae:

- at any point of the hull transverse section:

$$\sigma_1 = \frac{M_{SW} + M_{WV}}{Z_A} 10^{-3}$$

- at bottom:

$$\sigma_1 = \frac{M_{SW} + M_{WV}}{Z_{AB}} 10^{-3}$$

- at deck:

$$\sigma_1 = \frac{M_{SW} + M_{WV}}{Z_{AD}} 10^{-3}$$

2.1.2 The normal stresses in a member made in material other than steel with a Young's modulus E equal to 2,06 10^5 N/mm^2, included in the hull girder transverse sections as specified in Sec 1, [2.1.6], are obtained from the following formula:

$$\sigma_1 = \frac{E}{2,06 \cdot 10^5} \sigma_{1S}$$

where:

σ_{1S} : Normal stress, in N/mm^2, in the member under consideration, calculated according to [2.1.1] considering this member as having the steel equivalent sectional area A_{SE} defined in Sec 1, [2.1.6].

2.2 Normal stresses induced by vertical and horizontal bending moments

2.2.1 The normal stresses induced by vertical and horizontal bending moments are to be calculated for the load case constituted by the hull girder loads specified in Tab 1 together with their combination factors. They are to be obtained, in N/mm^2, from the following formula:

$$\sigma_1 = \frac{M_{SW}}{Z_A} + \frac{0,4 M_{WV}}{Z_A} + \frac{M_{WH}}{I_Z}|y|$$

where:

y : Y co-ordinate, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6].

2.3 Shear stresses

2.3.1 The shear stresses induced by shear forces and torque are obtained through direct calculation analyses based on a structural model in accordance with Sec 1, [2.6].

2.3.2 The hull girder loads to be considered in these analyses are the vertical shear forces Q_{SW} and Q_{WV}.

When deemed necessary by the Society on the basis of the ship's characteristics and intended service, the horizontal shear force and torqua are also to be calculated and taken into account in the calculation of shear stresses.

2.3.3 As an alternative to the above procedure, the shear stresses induced by the vertical shear forces Q_{SW} and Q_{WV} may be obtained through the simplified procedure in [2.4].

2.4 Simplified calculation of shear stresses induced by vertical shear forces

2.4.1 Ships without effective longitudinal bulkheads or with one effective longitudinal bulkhead

In this context, effective longitudinal bulkhead means a bulkhead extending from the bottom to the strength deck.

The shear stresses induced by the vertical shear forces in the calculation point are obtained, in N/mm², from the following formula:

$$\tau_1 = 0,5(Q_{SW} + Q_{WV})\frac{S}{I_Y t_s}$$

where:

t_s : Minimum thickness, in mm, of side plating (see Fig 1), Tab 2

Figure 1 : Single side ship without effective longitudinal bulkheads

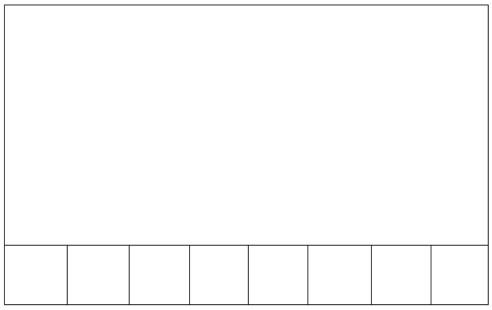
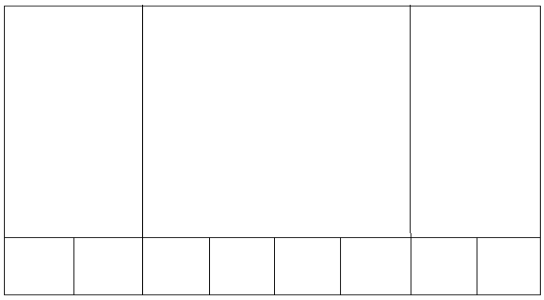


Figure 2 : Single side ship with two effective longitudinal bulkheads



2.4.2 Single side ships with two effective longitudinal bulkheads

In this context, effective longitudinal bulkhead means a bulkhead extending from the bottom to the strength deck.

The shear stresses induced by the vertical shear force in the calculation point are obtained, in N/mm², from the following formula:

$$\tau_1 = [(Q_{SW} + Q_{WV})\delta]\frac{S}{I_Y t}$$

where:

δ : Shear distribution coefficient defined in Tab 2

t : Minimum thickness, in mm, of side, inner side and longitudinal bulkhead plating, as applicable according to Tab 2.

Table 1 : Torque and bending moments

Still water loads		Wave loads					
Vertical bending moment		Torque (1)		Vertical bending moment		Horizontal bending moment	
Reference value	Comb.factor	Reference value	Comb.factor	Reference value	Comb.factor	Reference value	Comb.factor
M_{SW}	1,0	M_{WT}	1,0	M_{WV}	0,4	M_{WH}	1,0
(1) To be considered only when deemed necessary by the Society							

Table 2 : Shear stresses induced by vertical shear forces

Location (see Fig 2)	t, in mm	δ
Sides	t_S	$(1-\Phi)/2$
Longitudinal bulkheads	t_S	$\Phi/2$

Note 1:

$$\Phi = 0,3 + 0,21 t_{BM}/t_{SM}$$

t_S, t_B : Minimum net thicknesses, in mm, of side and longitudinal bulkhead plating, respectively

t_{SM}, t_{BM} : Mean thicknesses, in mm, over all the strakes of side and longitudinal bulkhead plating, respectively. They are calculated as $\Sigma(\ell_i t_i)/\Sigma\ell_i$, where ℓ_i and t_i are the length, in m, and the thickness, in mm, of the i^{th} strake of side and longitudinal bulkheads.

3 Checking criteria

3.1 Normal stresses induced by vertical bending moments

3.1.1 It is to be checked that the normal stresses σ_1 calculated according to [2.1] and, when applicable, [2.2] are in compliance with the following formula:

$\sigma_1 \leq \sigma_{1,ALL}$

where:

$\sigma_{1,ALL}$: Allowable normal stress, in N/mm²:

$\sigma_{1,ALL} = 175/k$ N/mm²

3.2 Shear stresses

3.2.1 It is to be checked that the shear stresses τ_1 calculated according to [2.3] are in compliance with the following formula:

$\tau_1 \leq \tau_{1,ALL}$

where:

$\tau_{1,ALL}$: Allowable shear stress, in N/mm²:

$\tau_{1,ALL} = 110/k$ N/mm².

4 Section modulus and moment of inertia

4.1 General

4.1.1 The requirements in [4.2] to [4.5] provide for the minimum hull girder section modulus, complying with the checking criteria indicated in [3], and the midship section moment of inertia required to ensure sufficient hull girder rigidity.

4.1.2 The k material factors are to be defined with respect to the materials used for the bottom and deck members contributing to the longitudinal strength according to Sec 1, [2]. When material factors for higher strength steels are used, the requirements in [4.5] apply.

4.2 Section modulus within 0,4L amidships

4.2.1

a) For ships with C_B lower than 0,6 the gross section moduli Z_{AB} and Z_{AD} within 0,4L a midships are to be not less than the value obtained, in m³, from the following formula:

$$Z_R = \frac{M_{SW} + M_{WV}}{\sigma_{1,ALL}} 10^{-3}$$

In addition, the gross section moduli Z_{AB} and Z_{AD} at the midship section are to be not less than the value obtained, in m³, from the following formula:

$$Z_{R\Delta} = \frac{M_{WV,H} - M_{WV,S}}{2\sigma_{\Delta,ALL}} 10^{-3}$$

where:

$\sigma_{\Delta,ALL}$: Allowable normal stress, in N/mm² to be taken as:

$\sigma_{\Delta,ALL}$: 110 N/mm² for steel with R_{eH} = 235 N/mm²

$\sigma_{\Delta,ALL}$: 140 N/mm² for steel with R_{eH} = 315 N/mm²

$\sigma_{\Delta,ALL}$: 150 N/mm² for steel with R_{eH} = 355 N/mm² or 390 N/mm²

b) For ships with C_B between 0,6 and 0,8 the gross section moduli Z_{AB} and Z_{AD} at the midship section are to be not less than the value obtained, in m³, from the following formula:

$$Z_{R,MIN} = n_1 C L^2 B (C_B + 0,7) k 10^{-6}$$

In addition, the gross section moduli Z_{AB} and Z_{AD} within 0,4L amidships are to be not less than the value obtained, in m³, from the following formula:

$$Z_R = \frac{M_{WV} + M_{WV}}{175/k} 10^{-3}$$

c) For ships with C_B greater than 0,8 the gross section moduli Z_{AB} and Z_{AD} within 0,4L amidships are to be not less than the greater value obtained, in m³, from the following formulae:

$$Z_{R,MIN} = n_1 C L^2 B (C_B + 0,7) k 10^{-6}$$

$$Z_R = \frac{M_{SW} + M_{WV}}{175/k} 10^{-3}$$

4.2.2 Where the total breadth Σb_S of small openings, as defined in Sec 1, [2.1.8], is deducted from the sectional areas included in the hull girder transverse sections, the values Z_R and $Z_{R,MIN}$ defined in [4.2.1] may be reduced by 3%.

4.2.3 Scantlings of members contributing to the longitudinal strength (see Sec 1, [2]) are to be maintained within 0,4L amidships.

4.3 Section modulus outside 0,4L amidships

4.3.1 *(1/1/2017)*

Scantlings of members contributing to the hull girder longitudinal strength (see Sec 1, [2]) may be gradually reduced, outside 0,4L amidships, to the minimum required for local strength purposes at fore and aft parts, as specified in Chapter 8.

As a minimum, hull girder bending strength checks are to be carried out at the following locations:

- in way of the forward end of the engine room
- "in way of the forward end of the foremost cargo tank for supply ships
- "at any locations where there are significant changes in hull cross-section
- "at any locations where there are changes in the framing system.

Buckling strength of members contributing to the longitudinal strength and subjected to compressive and shear stresses is to be checked, in particular in regions where changes in the framing system or significant changes in the hull cross-section occur. The buckling evaluation criteria used for this check are determined by the Society.

Continuity of structure is be maintained throughout the length of the ship. Where significant changes in structural arrangement occur, adequate transitional structure is to be provided.

4.4 Midship section moment of inertia

4.4.1

a) For ships with C_B lower than 0,6, the midship section moment of inertia about its horizontal neutral axis is to be not less than the value obtained, in m⁴, from the following formula:

$$I_{YR} = 3 Z'_{R\Delta} L 10^{-2}$$

where Z'_{RD} is the required midship section modulus Z_{RD}, in m³, calculated as specified in [4.2.1], but assuming $s_{D,ALL}$ = 130 N/mm² in all cases.

b) For ships with C_B equal or greater than 0,6 the gross midship section moment of inertia about its horizontal neutral axis is to be not less than the value obtained, in m⁴, from the following formula:

$$I_{YR} = 3 Z'_{R,MIN} L 10^{-2}$$

where $Z'_{R,MIN}$ is the required midship section modulus $Z_{R,MIN}$, in m³, calculated as specified in [4.2.1], item b) or c) as applicable, but assuming k = 1.

4.5 Extent of higher strength steel

4.5.1 When a material factor for higher strength steel is used in calculating the required section modulus at bottom or deck according to [4.2] or [4.3], the relevant higher strength steel is to be adopted for all members contributing to the longitudinal strength (see Sec 1, [2]), at least up to a vertical distance, in m, obtained from the following formulae:

- above the baseline (for section modulus at bottom):

$$V_{HB} = \frac{\sigma_{1B} - k\sigma_{1,ALL}}{\sigma_{1B} + \sigma_{1D}} z_D$$

- below a horizontal line located at a distance V_D (see Sec 1, [2.3.2]) above the neutral axis of the hull transverse section (for section modulus at deck):

$$V_{HD} = \frac{\sigma_{1D} - k\sigma_{1,ALL}}{\sigma_{1B} + \sigma_{1D}} (N + V_D)$$

where:

σ_{1B}, σ_{1D} : Normal stresses, in N/mm², at bottom and deck, respectively, calculated according to [2.1.1]

z_D : Z co-ordinate, in m, of the strength deck, defined in Sec 1, [2.2], with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6]

N : Z co-ordinate, in m, of the centre of gravity of the hull transverse section defined in Sec 1, [2.3.1], with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6]

V_D : Vertical distance, in m, defined in Sec 1, [2.3.2].

4.5.2

When a higher strength steel is adopted at deck, members not contributing to the longitudinal strength and welded on the strength deck (e.g. hatch coamings, strengthening of deck openings) are also generally to be made of the same higher strength steel.

4.5.3 The higher strength steel is to extend in length at least throughout the whole midship area where it is required for strength purposes according to the provisions of Part B.

5 Permissible still water bending moment and shear force during navigation

5.1 Permissible still water bending moment

5.1.1 The permissible still water bending moment at any hull transverse section during navigation, in hogging or sagging conditions, is the value M_{SW} considered in the hull girder section modulus calculation according to [4].

In the case of structural discontinuities in the hull transverse sections, the distribution of permissible still water bending moments is considered on a case by case basis.

5.2 Permissible still water shear force

5.2.1 Direct calculations

Where the shear stresses are obtained through calculation analyses according to [2.3], the permissible positive or negative still water shear force at any hull transverse section is obtained, in kN, from the following formula:

$$Q_P = \varepsilon|Q_T| - Q_{WV}$$

where:

$\varepsilon = \text{sgn}(Q_{SW})$

Q_T : Shear force, in kN, which produces a shear stress $\tau = 110/k$ N/mm² in the most stressed point of the hull transverse section.

5.2.2 Single side ships without effective longitudinal bulkeads

Where the shear stresses are obtained through the simplified procedure in [2.4.1], the permissible positive or negative still water shear force at any hull transverse section is obtained, in kN, from the following formula:

$$Q_P = \varepsilon\left(\frac{110}{0,5k} \cdot \frac{I_Y t_S}{S}\right) - Q_{WV}$$

where:

$\varepsilon = \text{sgn}(Q_{SW})$

t_S : Minimum net thickness, in mm, of side plating see Fig 1

5.2.3 Single side ships with two effective longitudinal bulkeads

Where the shear stresses are obtained through the simplified procedure in [2.4.2], the permissible positive or negative still water shear force at any hull transverse section is obtained, in kN, from the following formula:

$$Q_P = \frac{1}{\delta}\left(\varepsilon\frac{110}{k} \cdot \frac{I_Y t}{S}\right) - Q_{WV}$$

where:

δ : Shear distribution coefficient defined in Tab 2

$\varepsilon = \text{sgn}(Q_{SW})$

t : Minimum thickness, in mm, of side, inner side and longitudinal bulkhead plating, as applicable according to Tab 2

6 Permissible still water bending moment and shear force in harbour conditions

6.1 Permissible still water bending moment

6.1.1 The permissible still water bending moment at any hull transverse section in harbour conditions, in hogging or sagging conditions, is obtained, in kN.m, from the following formula:

$$M_{P,H} = M_P + 0,6 M_W$$

where $M_{p,}$ is the permissible still water bending moment during navigation in KN m, to be calculated according to [5.1.1].

6.2 Permissible shear force

6.2.1 The permissible positive or negative still water shear force at any hull transverse section, in harbour conditions, is obtained, in kN, from the following formula:

$$Q_{P,H} = \varepsilon Q_P + 0,7\ Q_{WV}$$

where:

$\varepsilon = \text{sgn}(Q_{SW})$

Q_P : Permissible still water shear force during navigation, in kN, to be calculated according to [5.2].

SECTION 3 ULTIMATE STRENGTH CHECK

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

1 Application

1.1

1.1.1 The requirements of this Section apply to ships equal to or greater than 90 m in length.

2 General

2.1 Net scantlings

2.1.1 As specified in Ch 4, Sec 2, [1], the ultimate strength of the hull girder is to be checked on the basis of the net strength characteristics of the transverse section which is to be calculated according to Ch 4, Sec 2, [2].

2.2 Partial safety factors

2.2.1 The partial safety factors to be considered for checking the ultimate strength of the hull girder are specified in Tab 1.

Table 1 : Partial safety factors

Partial safety factor covering uncertainties on:	Symbol	Value
Still water hull girder loads	γ_{S1}	1,00
Wave induced hull girder loads	γ_{W1}	1,10
Material	γ_m	1,02
Resistance	γ_R	1,15

3 Hull girder ultimate strength check

3.1 Hull girder loads

3.1.1 Bending moments

The bending moment in sagging and hogging conditions, to be considered in the ultimate strength check of the hull girder, is to be obtained, in kN.m, from the following formula:

$$M = \gamma_{S1} M_{SW} + \gamma_{W1} M_{WV}$$

3.2 Hull girder ultimate bending moment capacities

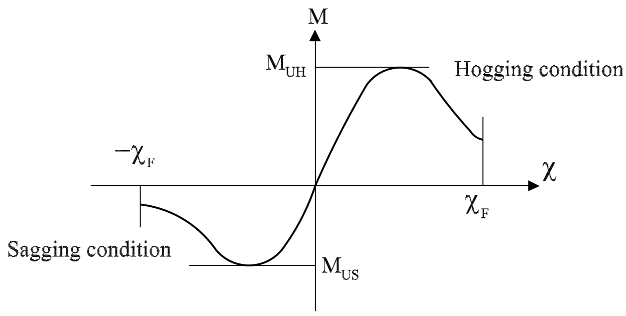
3.2.1 Curve M-χ

The ultimate bending moment capacities of a hull girder transverse section, in hogging and sagging conditions, are defined as the maximum values of the curve of bending moment capacity M versus the curvature χ of the transverse section considered (see Fig 1).

The curvature χ is positive for hogging condition and negative for sagging condition.

The curve M-χ is to be obtained through an incremental-iterative procedure according to the criteria specified in App 1.

Figure 1 : Curve bending moment capacity M versus curvature χ



3.2.2 Hull girder transverse sections

The hull girder transverse sections are constituted by the elements contributing to the hull girder longitudinal strength, considered with their net scantlings, according to Sec 1, [2].

3.3 Checking criteria

3.3.1 It is to be checked that the hull girder ultimate bending capacity at any hull transverse section is in compliance with the following formula:

$$\frac{M_U}{\gamma_R \gamma_m} \geq M$$

where:

M_U : Ultimate bending moment capacity of the hull transverse section considered, in kN.m:

- in hogging conditions:

  $M_U = M_{UH}$

- in sagging conditions:

  $M_U = M_{US}$

M_{UH} : Ultimate bending moment capacity in hogging conditions, defined in [3.2.1]

M_{US} : Ultimate bending moment capacity in sagging conditions, defined in [3.2.1]

M : Bending moment, in kN.m, defined in [3.1.1].

APPENDIX 1 HULL GIRDER ULTIMATE STRENGTH

Symbols

For symbols not defined in this Appendix, refer to the list at the beginning of this Chapter.

R_{eH} : Minimum upper yield stress, in N/mm^2, of the material

I_Y : Moment of inertia, in m^4, of the hull transverse section around its horizontal neutral axis, to be calculated according to Sec 1, [2.4]

Z_{AB} ,Z_{AD} : Section moduli, in cm^3, at bottom and deck, respectively, defined in Sec 1, [2.3.2]

s : Spacing, in m, of ordinary stiffeners

ℓ : Span, in m, of ordinary stiffeners, measured between the supporting members (see Ch 4, Sec 3, Fig 2 to Ch 4, Sec 3, Fig 5)

h_w : Web height, in mm, of an ordinary stiffener

t_w : Web net thickness, in mm, of an ordinary stiffener

b_f : Face plate width, in mm, of an ordinary stiffener

t_f : Face plate net thickness, in mm, of an ordinary stiffener

A_S : Net sectional area, in cm^2, of an ordinary stiffener

t_p : Net thickness, in mm, of the plating attached to an ordinary stiffener.

1 Hull girder ultimate strength check

1.1 Introduction

1.1.1 Sec 3, [2] defines the criteria for calculating the ultimate bending moment capacities in hogging condition M_{UH} and sagging condition M_{US} of a hull girder transverse section.

As specified in Sec 3, [2], the ultimate bending moment capacities are defined as the maximum values of the curve of bending moment capacity M versus the curvature χ of the transverse section considered (see Fig 1).

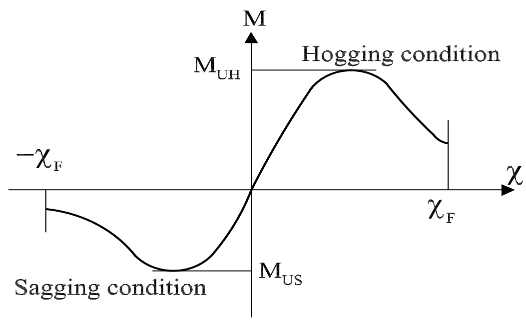
1.1.2 This Appendix provides the criteria for obtaining the curve M-χ.

1.2 Criteria for the calculation of the curve M-χ

1.2.1 Procedure

The curve M-χ is to be obtained by means of an incremental-iterative approach, summarised in the flow chart in Fig 2.

Figure 1 : Curve bending moment capacity M versus curvature χ



Each step of the incremental procedure is represented by the calculation of the bending moment M_i which acts on the hull transverse section as the effect of an imposed curvature χ_i.

For each step, the value χ_i is to be obtained by summing an increment of curvature $\Delta\chi$ to the value relevant to the previous step χ_{i-1}.This increment of curvature corresponds to an increment of the rotation angle of the hull girder transverse section around its horizontal neutral axis.

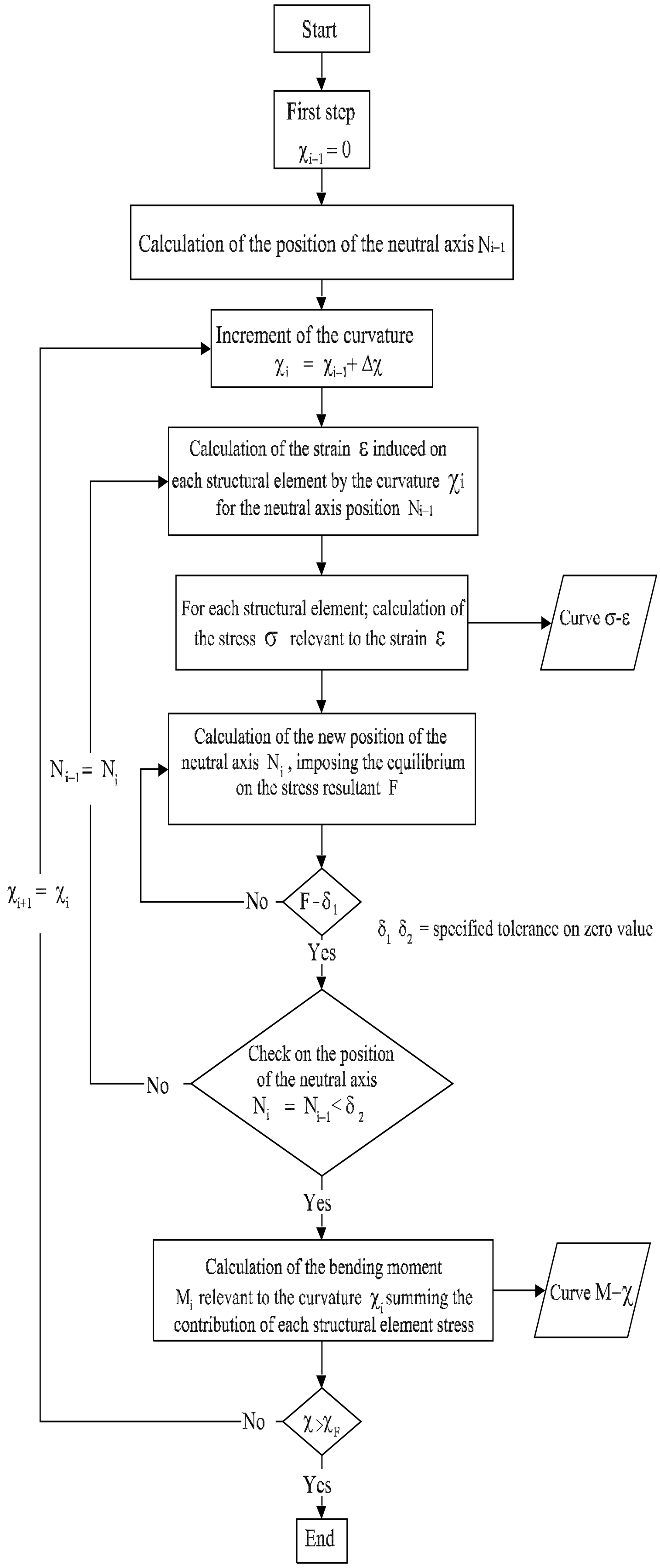
This rotation increment induces axial strains ε in each hull structural element, whose value depends on the position of the element. In hogging condition, the structural elements above the neutral axis are lengthened, while the elements below the neutral axis are shortened. Vice-versa in sagging condition.

The stress σ induced in each structural element by the strain ε is to be obtained from the load-end shortening curve σ-ε of the element, which takes into account the behaviour of the element in the non-linear elasto-plastic domain.

The distribution of the stresses induced in all the elements composing the hull transverse section determines, for each step, a variation of the neutral axis position, since the relationship σ-ε is non-linear. The new position of the neutral axis relevant to the step considered is to be obtained by means of an iterative process, imposing the equilibrium among the stresses acting in all the hull elements.

Once the position of the neutral axis is known and the relevant stress distribution in the section structural elements is obtained, the bending moment of the section M_i around the new position of the neutral axis, which corresponds to the curvature χ_i imposed in the step considered, is to be obtained by summing the contribution given by each element stress.

Figure 2 : Flow chart of the procedure for the evaluation of the curve M-χ



1.2.2 Assumption

In applying the procedure described in [1.2.1], the following assumptions are generally to be made:

- The ultimate strength is calculated at hull transverse sections between two adjacent reinforced rings.
- The hull girder transverse section remains plane during each curvature increment.
- The hull material has an elasto-plastic behaviour.
- The hull girder transverse section is divided into a set of elements, which are considered to act independently. These elements are:
  - transversely framed plating panels and/or ordinary stiffeners with attached plating, whose structural behaviour is described in [1.3.1]
  - hard corners, constituted by plating crossing, whose structural behaviour is described in [1.3.2].
- According to the iterative procedure, the bending moment M_i acting on the transverse section at each curvature value χ_i is obtained by summing the contribution given by the stress σ acting on each element. The stress σ, corresponding to the element strain ε, is to be obtained for each curvature increment from the non-linear load-end shortening curves σ-ε of the element.

  These curves are to be calculated, for the failure mechanisms of the element, from the formulae specified in [1.3]. The stress σ is selected as the lowest among the values obtained from each of the considered load-end shortening curves σ-ε.
- The procedure is to be repeated for each step, until the value of the imposed curvature reaches the value χ_F, in m^{-1}, in hogging and sagging condition, obtained from the following formula:

  $$\chi_F = \pm 0{,}003\frac{M_Y}{EI_Y}$$

  where:

  M_Y : the lesser of the values M_{Y1} and M_{Y2}, in kN.m:

  $M_{Y1} = 10^{-3}\ R_{eH}\ Z_{AB}$

  $M_{Y2} = 10^{-3}\ R_{eH}\ Z_{AD}$

  If the value χ_F is not sufficient to evaluate the peaks of the curve M-χ, the procedure is to be repeated until the value of the imposed curvature permits the calculation of the maximum bending moments of the curve.

1.3 Load-end shortening curves σ-ε

1.3.1 Plating panels and ordinary stiffeners

Plating panels and ordinary stiffeners composing the hull girder transverse sections may collapse following one of the modes of failure specified in Tab 1.

1.3.2 Hard corners

Hard corners are sturdier elements composing the hull girder transverse section, which collapse mainly according to an elasto-plastic mode of failure. The relevant load-end shortening curve σ-ε is to be obtained for lengthened and shortened hard corners according to [1.3.3].

Table 1 : Modes of failure of plating panels and ordinary stiffeners

Element	Mode of failure	Curve σ-ε defined in
Lengthened transversely framed plating panel or ordinary stiffeners	Elasto-plastic collapse	[1.3.3]
Shortened ordinary stiffeners	Beam column buckling	[1.3.4]
	Torsional buckling	[1.3.5]
	Web local buckling of flanged profiles	[1.3.6]
	Web local buckling of flat bars	[1.3.7]
Shortened transversely framed plating panel	Plate buckling	[1.3.8]

1.3.3 Elasto-plastic collapse

The equation describing the load-end shortening curve σ-ε for the elasto-plastic collapse of structural elements composing the hull girder transverse section is to be obtained from the following formula, valid for both positive (shortening) and negative (lengthening) strains (see Fig 3):

$$\sigma = \Phi R_{eH}$$

where:

Φ : Edge function:

$\Phi = -1$ for $\varepsilon < -1$

$\Phi = \varepsilon$ for $-1 < \varepsilon < 1$

$\Phi = 1$ for $\varepsilon > 1$

ε : Relative strain:

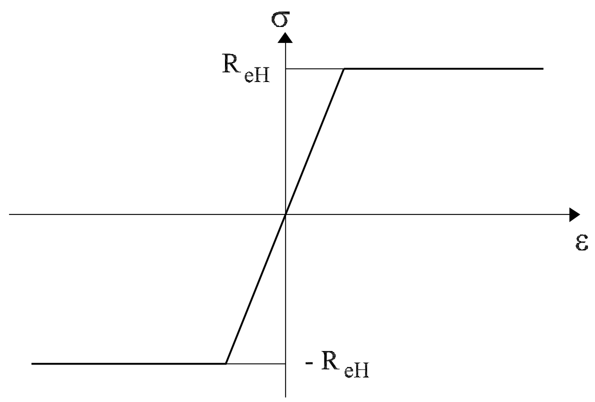
$$\varepsilon = \frac{\varepsilon_E}{\varepsilon_Y}$$

ε_E : Element strain

ε_Y : Strain inducing yield stress in the element:

$$\varepsilon_Y = \frac{R_{eH}}{E}$$

Figure 3 : Load-end shortening curve σ-ε for elasto-plastic collapse



1.3.4 Beam column buckling

The equation describing the load-end shortening curve σ_{CR1}-ε for the beam column buckling of ordinary stiffeners composing the hull girder transverse section is to be obtained from the following formula (see Fig 4):

$$\sigma_{CR1} = \Phi\sigma_{C1}\frac{A_S + 10b_E t_P}{A_S + 10st_P}$$

where:

Φ : Edge function defined in [1.3.3]

σ_{C1} : Critical stress, in N/mm²:

$$\sigma_{C1} = \frac{\sigma_{E1}}{\varepsilon} \quad \text{for} \quad \sigma_{E1} \le \frac{R_{eH}}{2}\varepsilon$$

$$\sigma_{C1} = R_{eH}\left(1 - \frac{\Phi R_{eH}\varepsilon}{4\sigma_{E1}}\right) \quad \text{for} \quad \sigma_{E1} > \frac{R_{eH}}{2}\varepsilon$$

ε : Relative strain defined in [1.3.3]

σ_{E1} : Euler column buckling stress, in N/mm²:

$$\sigma_{E1} = \pi^2 E\frac{I_E}{A_E l^2}10^4$$

I_E : Net moment of inertia of ordinary stiffeners, in cm⁴, with attached shell plating of width b_{E1}

b_{E1} : Width, in m, of the attached shell plating:

$$b_{E1} = \frac{s}{\beta_E} \quad \text{for} \quad \beta_E > 1,0$$

$$b_{E1} = s \quad \text{for} \quad \beta_E \le 1,0$$

$$\beta_E = 10^3\frac{s}{t_p}\sqrt{\frac{\varepsilon R_{eH}}{E}}$$

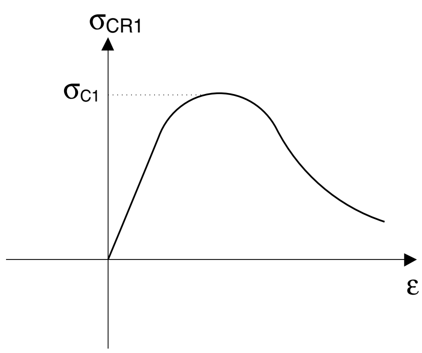
A_E : Net sectional area, in cm², of ordinary stiffeners with attached shell plating of width b_E

b_E : Width, in m, of the attached shell plating:

$$b_E = \left(\frac{2,25}{\beta_E} - \frac{1,25}{\beta_E^2}\right)s \quad \text{for} \quad \beta_E > 1,25$$

$$b_E = s \quad \text{for} \quad \beta_E \le 1,25$$

Figure 4 : Load-end shortening curve σ_{CR1}-ε for beam column buckling



1.3.5 Torsional buckling

The equation describing the load-end shortening curve σ_{CR2}-ε for the lateral-flexural buckling of ordinary stiffeners composing the hull girder transverse section is to be obtained according to the following formula (see Fig 5):

$$\sigma_{CR2} = \Phi\frac{A_S\sigma_{C2} + 10st_P\sigma_{CP}}{A_S + 10st_P}$$

where:

Φ : Edge function defined in [1.3.3]

σ_{C2} : Critical stress, in N/mm²:

$$\sigma_{C2} = \frac{\sigma_{E2}}{\varepsilon} \quad \text{for} \quad \sigma_{E2} \le \frac{R_{eH}}{2}\varepsilon$$

$$\sigma_{C2} = R_{eH}\left(1 - \frac{\Phi R_{eH}\varepsilon}{4\sigma_{E2}}\right) \quad \text{for} \quad \sigma_{E2} > \frac{R_{eH}}{2}\varepsilon$$

σ_{E2} : Euler torsional buckling stress, in N/mm², defined in Ch 7, Sec 2, [4.3.3]

ε : Relative strain defined in [1.3.3]

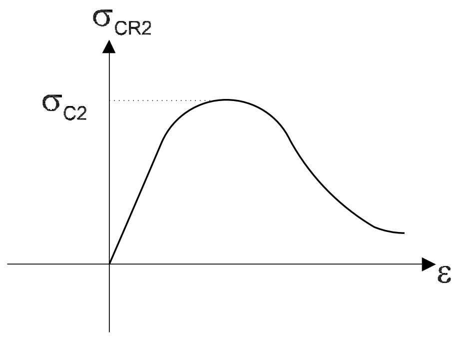
σ_{CP} : Buckling stress of the attached plating, in N/mm²:

$$\sigma_{CP} = \left(\frac{2,25}{\beta_E} - \frac{1,25}{\beta_E^2}\right)R_{eH} \quad \text{for} \quad \beta_E > 1,25$$

$$\sigma_{CP} = R_{eH} \quad \text{for} \quad \beta_E \le 1,25$$

β_E : Coefficient defined in [1.3.4].

Figure 5 : Load-end shortening curve σ_{CR2}-ε for flexural-torsional buckling



1.3.6 Web local buckling of flanged ordinary stiffeners

The equation describing the load-end shortening curve σ_{CR3}-ε for the web local buckling of flanged ordinary stiffeners composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR3} = \Phi R_{eH}\frac{10^3 b_E t_P + h_{WE}t_W + b_F t_F}{10^3 st_P + h_W t_W + b_F t_F}$$

where:

Φ : Edge function defined in [1.3.3]

b_E : Width, in m, of the attached shell plating, defined in [1.3.4]

h_{WE} : Effective height, in mm, of the web:

$$h_{WE} = \left(\frac{2,25}{\beta_E} - \frac{1,25}{\beta_E^2}\right)h_W \quad \text{for} \quad \beta_W > 1,25$$

$$h_{WE} = h_W \quad \text{for} \quad \beta_W \le 1,25$$

β_E : Coefficient defined in [1.3.4]

$$\beta_W = 10^3\frac{h_W}{t_W}\sqrt{\frac{\varepsilon R_{eH}}{E}}$$

ε : Relative strain defined in [1.3.3].

1.3.7 Web local buckling of flat bar ordinary stiffeners

The equation describing the load-end shortening curve σ_{CR4}-ε for the web local buckling of flat bar ordinary stiffeners composing the hull girder transverse section is to be obtained from the following formula (see Fig 6):

$$\sigma_{CR4} = \Phi \frac{10 s t_P \sigma_{CP} + A_S \sigma_{C4}}{A_S + 10 s t_P}$$

where:

Φ : Edge function defined in [1.3.3]

σ_{CP} : Buckling stress of the attached plating, in N/mm², defined in [1.3.5]

σ_{C4} : Critical stress, in N/mm²:

$$\sigma_{C4} = \frac{\sigma_{E4}}{\varepsilon} \qquad \text{for} \qquad \sigma_{E4} \le \frac{R_{eH}}{2}\varepsilon$$

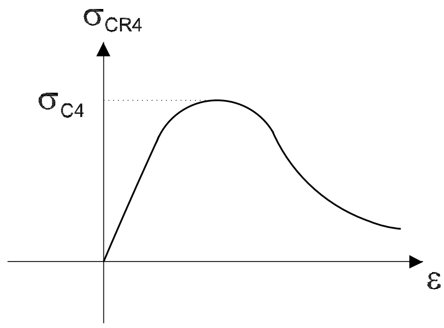
$$\sigma_{C4} = R_{eH}\left(1 - \frac{\Phi R_{eH} \varepsilon}{4\sigma_{E4}}\right) \qquad \text{for} \qquad \sigma_{E4} > \frac{R_{eH}}{2}\varepsilon$$

σ_{E4} : Local Euler buckling stress, in N/mm²:

$$\sigma_{E4} = 160000\left(\frac{t_W}{h_W}\right)^2$$

ε : Relative strain defined in [1.3.3].

Figure 6 : Load-end shortening curve σ_{CR4}-ε for web local buckling of flat bars



1.3.8 Plate buckling

The equation describing the load-end shortening curve σ_{CR5}-ε for the buckling of transversely stiffened panels composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR5} = R_{eH}\left[\frac{s}{l}\left(\frac{2,25}{\beta_E} - \frac{1,25}{\beta_E^2}\right) + 0,1\left(1 - \frac{s}{l}\right)\left(1 + \frac{1}{\beta_E^2}\right)^2\right]$$

where:

β_E : Coefficient defined in [1.3.4].

Part B
Hull and Stability

Chapter 7
HULL SCANTLINGS

Symbols used in chapter 7

L_1, L_2 : Lengths, in m, defined in Pt B, Ch 1, Sec 2, [2.1.1],

E : Young's modulus, in N/mm^2, to be taken equal to:
- for steels in general: $E = 2{,}06.10^5$ N/mm^2
- for stainless steels: $E = 1{,}95.10^5$ N/mm^2
- for aluminium alloys: $E = 7{,}0.10^4$ N/mm^2

ν : Poisson's ratio. Unless otherwise specified, a value of 0,3 is to be taken into account,

k : material factor, defined in:
- Pt B, Ch 4, Sec 1, [2.3], for steel,
- Pt B, Ch 4, Sec 1, [4.4], for aluminium alloys

R_y : Minimum yield stress, in N/mm^2, of the material, to be taken equal to 235/k N/mm^2, unless otherwise specified,

t_c : Corrosion addition, in mm, defined in Pt B, Ch 4, Sec 2, Tab 2,

I_Y : Net moment of inertia, in m^4, of the hull transverse section around its horizontal neutral axis, to be calculated according to Pt B, Ch 6, Sec 1, [2.4] considering the members contributing to the hull girder longitudinal strength as having their net scantlings,

I_Z : Net moment of inertia, in m^4, of the hull transverse section around its vertical neutral axis, to be calculated according to Pt B, Ch 6, Sec 1, [2.4] considering the members contributing to the hull girder longitudinal strength as having their net scantlings,

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system defined in Pt B, Ch 1, Sec 2, [6],

N : Z co-ordinate, in m, with respect to the reference co-ordinate system defined in Pt B, Ch 1, Sec 2, [6], of the centre of gravity of the hull transverse section constituted by members contributing to the hull girder longitudinal strength considered as having their net scantlings (see Pt B, Ch 6, Sec 1, [2]),

$M_{SW,H}$: Design still water bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [2.2],

$M_{SW,S}$: Design still water bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [2.2],

$M_{SW,Hmin}$: Minimum still water bending moment, in kN.m, in hogging condition, at the hull transverse section considered, without being taken greater than $0{,}3M_{WV,S}$,

$M_{WV,H}$: Vertical wave bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [3.1],

$M_{WV,S}$: Vertical wave bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [3.1],

M_{WH} : Horizontal wave bending moment, in kN.m, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [3.2],

M_{WT} : Wave torque, in kN.m, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [3.3].

SECTION 1 PLATING

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

p_S : Still water pressure, in kN/m², see [3.2.2]

p_W : Wave pressure and, if necessary, dynamic pressures, according to the criteria in Ch 5, Sec 5, [2] and Ch 5, Sec 6, [2], in kN/m² (see [3.2.2])

p_{SF}, p_{WF} : Still water and wave pressure, in kN/m², in flooding conditions, defined in Ch 5, Sec 6, [7] (see [3.2.3])

F_S : Still water wheeled force, in kN, see [4.2.2]

$F_{W,Z}$: Inertial wheeled force, in kN, see [4.2.2]

σ_{X1} : In-plane hull girder normal stress, in N/mm², defined in:

- [3.2.6] for the strength check of plating subjected to lateral pressure
- [5.2.2] for the buckling check of plating

τ_1 : In-plane hull girder shear stress, in N/mm², defined in [3.2.7]

R_{eH} : Minimum yield stress, in N/mm², of the plating material, defined in Ch 4, Sec 1, [2]

ℓ : Length, in m, of the longer side of the plate panel

s : Length, in m, of the shorter side of the plate panel

c_a : Aspect ratio of the plate panel, equal to:

$$c_a = 1,21\sqrt{1+0,33\left(\frac{s}{\ell}\right)^2} - 0,69\frac{s}{\ell}$$

to be taken not greater than 1,0

c_r : Coefficient of curvature of the panel, equal to:

$$c_r = 1 - 0,5s/r$$

to be taken not less than 0,75

r : Radius of curvature, in m

t_{net} : Net thickness, in mm, of a plate panel

1 General

1.1 Net thicknesses

1.1.1 As specified in Ch 4, Sec 2, [1], all thicknesses referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross thicknesses are obtained as specified in Ch 4, Sec 2.

1.2 Partial safety factors

1.2.1 The partial safety factors to be considered for the checking of the plating are specified in Tab 1.

Table 1 : Plating - Partial safety factors *(1/1/2017)*

Partial safety factors covering uncertainties regarding:	Symbol	Strength check of plating subjected to lateral pressure			Buckling check (see [5])
		General (see [3.2], [3.3.1], [3.4.1], [3.5.1] and [4])	Flooding pressure **(1)** (see [3.2], [3.3.2], [3.4.2] and [3.5.2])	Testing check (see [3.2], see [3.3.2], [3.4.2] and [3.5.2])	
Still water hull girder loads	γ_{S1}	1,00	1,00	Not applicable	1,00
Wave hull girder loads	γ_{W1}	1,15	1,15	Not applicable	1,15
Still water pressure	γ_{S2}	1,00	1,00	1,00	Not applicable
Wave pressure	γ_{W2}	1,20	1,20	Not applicable	Not applicable
Material	γ_m	1,02	1,02	1,02	1,02
Resistance	γ_R	1,20 **(2)**	1,05	1,05	1,10

(1) Applies only to plating to be checked in flooding conditions
(2) For plating of the collision bulkhead, γ_R =1,25

1.3 Elementary plate panel

1.3.1 The elementary plate panel is the smallest unstiffened part of plating.

1.4 Load point

1.4.1 Unless otherwise specified, lateral pressure and hull girder stresses are to be calculated:

- for longitudinal framing, at the lower edge of the elementary plate panel or, in the case of horizontal plating, at the point of minimum y-value among those of the elementary plate panel considered
- for transverse framing, at the lower edge of the strake.

2 General requirements

2.1 General

2.1.1 The requirements in [2.2] and [2.3] are to be applied to plating in addition of those in [3] to [5].

2.2 Minimum net thicknesses

2.2.1 The net thickness of plating is to be not less than the values given in Tab 2.

The Society may consider lower thicknesses than those in Tab 2, on a case by case basis, when this is deemed appropriate on the basis of the plating location, loads acting and spacing of ordinary stiffeners.

2.3 Bilge plating

2.3.1 The bilge plating net thickness is to be not less than the values obtained from:

- strength check of plating subjected to lateral pressure:
  - criteria in [3.3.1] for longitudinally framed bilges
  - criteria in [3.4.1] for transversely framed bilges
- buckling check:
  - criteria in [5] for longitudinally framed bilge, to be checked as plane plating
  - criteria in [5.3.4] for transversely framed bilge, considering only the case of compression stresses perpendicular to the curved edges.

The net thickness of longitudinally framed bilge plating is to be not less than that required for the adjacent bottom or side plating, whichever is the greater.

The net thickness of transversely framed bilge plating may be taken not greater than that required for the adjacent bottom or side plating, whichever is the greater.

2.4 Sheerstrake

2.4.1 Welded sheerstrake

The net thickness of a welded sheerstrake is to be not less than that of the adjacent side plating, taking into account higher strength steel corrections if needed.

In general, the required net thickness of the adjacent side plating is to be taken as a reference. In specific case, depending on its actual net thickness, this latter may be required to be considered when deemed necessary by the Society.

Table 2 : Minimum net thickness of steel plating *(1/1/2017)*

Plating	Minimum net thickness, in mm
Longitudinal watertight bulkhead Shell	5
Deck	3
Transverse watertight bulkhead	4

2.4.2 Rounded sheerstrake

The net thickness of a rounded sheerstrake is to be not less than the actual net thickness of the adjacent deck plating.

2.4.3 Net thickness of the sheerstrake in way of breaks of long superstructures

The net thickness of the sheerstrake is to be increased in way of breaks of long superstructures occurring within 0,5L amidships, over a length of about one sixth of the ship's breadth on each side of the superstructure end.

This increase in net thickness is to be equal to 40%, but need not exceed 4,5 mm.

Where the breaks of superstructures occur outside 0,5L amidships, the increase in net thickness may be reduced to 30%, but need not exceed 2,5 mm.

2.4.4 Net thickness of the sheerstrake in way of breaks of short superstructures

The net thickness of the sheerstrake is to be increased in way of breaks of short superstructures occurring within 0,6L amidships, over a length of about one sixth of the ship's breadth on each side of the superstructure end.

This increase in net thickness is to be equal to 15%, but need not exceed 4,5 mm.

2.5 Stringer plate

2.5.1 General

The net thickness of the stringer plate is to be not less than the actual net thickness of the adjacent deck plating.

2.5.2 Net thickness of the stringer plate in way of breaks of long superstructures

The net thickness of the stringer plate is to be increased in way of breaks of long superstructures occurring within 0,5L amidships, over a length of about one sixth of the ship's breadth on each side of the superstructure end.

This increase in net thickness is to be equal to 40%, but need not exceed 4,5 mm.

Where the breaks of superstructures occur outside 0,5L amidships, the increase in net thickness may be reduced to 30%, but need not exceed 2,5 mm.

2.5.3 Net thickness of the stringer plate in way of breaks of short superstructures

The net thickness of the stringer plate is to be increased in way of breaks of short superstructures occurring within 0,6L amidships, over a length of about one sixth of the ship breadth on each side of the superstructure end.

This increase in net thickness is to be equal to 15%, but need not exceed 4,5 mm.

3 Strength check of plating subjected to lateral pressure

3.1 General

3.1.1 The requirements of this Article apply for the yielding check of plating subjected to lateral pressure, wheeled loads or weapon firing dynamic loads and, for plating contributing to the longitudinal strength, to in-plane hull girder normal and shear stresses.

3.2 Load model

3.2.1 General

The still water and wave lateral pressures induced by the sea and the various types of cargoes and ballast in intact conditions are to be considered, depending on the location of the plating under consideration and the type of the compartments adjacent to it, in accordance with Ch 5, Sec 1, [2.4].

The plating of bulkheads or inner side which constitute the boundary of compartments not intended to carry liquids is to be subjected to lateral pressure in flooding conditions.

The wave lateral pressures and hull girder loads are to be calculated in the mutually exclusive load cases “a”, “b”, “c” and “d” in Ch 5, Sec 4.

3.2.2 Lateral pressure in intact conditions

The lateral pressure in intact conditions is constituted by still water pressure and wave pressure.

Still water pressure (p_S) includes:

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

Wave pressure (p_W) includes:

- the wave pressure, defined in Ch 5, Sec 5, [2] for each load case “a”, “b”, “c” and “d”
- the inertial pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast, and for each load case “a”, “b”, “c” and “d”
- the dynamic pressures, according to the criteria in Ch 5, Sec 6, [2].

3.2.3 Lateral pressure in flooding conditions

The lateral pressure in flooding conditions is constituted by the still water pressure p_{SF} and wave pressure p_{WF} defined in Ch 5, Sec 6, [7].

3.2.4 Lateral pressure in testing conditions *(1/1/2017)*

The lateral pressure (p_T) in testing conditions is taken equal to:

- p_{ST} -p_S for bottom shell plating and side shell plating
- p_{ST} otherwise

where:

p_{ST} : Still water pressure defined in Ch 5, Sec 6, Tab 10

p_S : Still water sea pressure defined in Ch 5, Sec 5, [1.1.1] for the draught T_1 at which the testing is carried out.

If the draught T1 is not defined by the Designer, it may be taken equal to the light ballast draught T_B defined in Ch 5, Sec 1, [2.4.3].

3.2.5 Pressures induced by weapon firing dynamic loads

The following weapon firing dynamic loads are to be considered, depending on the location of the plating under consideration:

- missile blast dynamic pressure
- accidental missile ignition dynamic pressure
- gun blast dynamic pressure.

The lateral pressure p_W induced by the above dynamic loads are to be calculated according to the requirements specified in Ch 5, Sec 6, [8].

3.2.6 In-plane hull girder normal stresses

The in-plane hull girder normal stresses to be considered for the strength check of plating are obtained, in N/mm², from the following formulae:

- for plating contributing to the hull girder longitudinal strength:

$$\sigma_{X1} = \gamma_{S1}\sigma_{S1} + \gamma_{W1}(C_{FV}\sigma_{WV1} + C_{FH}\sigma_{WH1})$$

- for plating not contributing to the hull girder longitudinal strength:

$$\sigma_{X1} = 0$$

where:

σ_{S1}, σ_{WV1}, σ_{WH1} : Hull girder normal stresses, in N/mm², defined in Tab 3

C_{FV}, C_{FH} : Combination factors defined in Tab 4.

Table 3 : Hull girder normal stresses

Condition	σ_{S1} , in N/mm² **(1)**	σ_{WV1} , in N/mm²	σ_{WH1} , in N/mm²
$\frac{\lvert\gamma_{S1}M_{SW,S}+0,625\gamma_{W1}C_{FV}M_{WV,S}\rvert}{\gamma_{S1}M_{SW,H}+0,625\gamma_{W1}C_{FV}M_{WV,H}} \geq 1$	$\left\lvert\frac{M_{SW,S}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\frac{0,625F_DM_{WV,S}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\frac{0,625M_{WH}}{I_Z}y\right\rvert 10^{-3}$
$\frac{\lvert\gamma_{S1}M_{SW,S}+0,625\gamma_{W1}C_{FV}M_{WV,S}\rvert}{\gamma_{S1}M_{SW,H}+0,625\gamma_{W1}C_{FV}M_{WV,H}} < 1$	$\left\lvert\frac{M_{SW,H}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\frac{0,625M_{WV,H}}{I_Y}(z-N)\right\rvert 10^{-3}$	

(1) When the ship in still water is always in hogging condition, $M_{SW,S}$ is to be taken equal to 0.
Note 1:
F_D : Coefficient defined in Ch 5, Sec 2, [4].

3.2.7 In-plane hull girder shear stresses

The in-plane hull girder shear stresses to be considered for the strength check of plating which contributes to the longitudinal strength are obtained, in N/mm², from the following formula:

$$\tau_1 = \gamma_{S1}\tau_{S1} + 0,625C_{FV}\gamma_{W1}\tau_{W1}$$

where:

τ_{S1} : Absolute value of the hull girder shear stresses, in N/mm², induced by the maximum still water hull girder vertical shear force.

τ_{W1} : Absolute value of the hull girder shear stresses, in N/mm², induced by the maximum wave hull girder vertical shear force.

:

C_{FV} : Combination factor defined in Tab 4 .

τ_{S1} and τ_{W1} may be calculated as indicated in Tab 5 where, at a preliminary design stage, the still water hull girder vertical shear force is not defined.

Table 4 : Combination factors C_{FV} and C_{FH}

Load case	C_{FV}	C_{FH}
"a"	1,0	0
"b"	1,0	0
"c"	0,4	1,0
"d"	0,4	1,0

3.3 Longitudinally framed plating contributing to the hull girder longitudinal strength

3.3.1 General

The net thickness of laterally loaded plate panels subjected to in-plane normal stress acting on the shorter sides is to be not less than the value obtained, in mm, from the following formula:

$$t = 14,9c_ac_rs\sqrt{\gamma_R\gamma_m\frac{\gamma_{S2}p_S+\gamma_{W2}p_W}{\lambda_LR_y}}$$

where:

- for bottom, bilge, inner bottom and decks (excluding possible longitudinal sloping plates):

$$\lambda_L = \sqrt{1-0,95\left(\gamma_m\frac{\sigma_{x1}}{R_y}\right)^2} - 0,225\gamma_m\frac{\sigma_{x1}}{R_y}$$

- for side, inner side and longitudinal bulkheads (including possible longitudinal sloping plates):

$$\lambda_L = \sqrt{1-3\left(\gamma_m\frac{\tau_1}{R_y}\right)^2 - 0,95\left(\gamma_m\frac{\sigma_{x1}}{R_y}\right)^2} - 0,225\gamma_m\frac{\sigma_{x1}}{R_y}$$

3.3.2 Flooding conditions

The plating of bulkheads or inner side which constitute the boundary of compartments not intended to carry liquids is to be checked in flooding conditions. To this end, its net thickness is to be not less than the value obtained, in mm, from the following formula:

$$t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{\lambda_L R_y}}$$

where λ_L is defined in [3.3.1].

Table 5 : Hull girder shear stresses

Structural element	τ_{S1}, τ_{W1} in N/mm²
Bottom, bilge, inner bottom and decks (excluding possible longitudinal sloping plates)	0
Side, inner side and longitudinal bulkheads (including possible longitudinal sloping plates):	
• $0 \le z \le 0{,}25D$	$\tau_0\left(0{,}5 + 2\frac{z}{D}\right)$
• $0{,}25D < z \le 0{,}75D$	τ_0
• $0{,}75D < z \le D$	$\tau_0\left(2{,}5 - 2\frac{z}{D}\right)$
Note 1: $\tau_0 = \frac{47}{k}\left\{1 - \frac{6,3}{\sqrt{L_1}}\right\}$ N/mm²	

3.3.3 Testing conditions *(1/1/2017)*

The plating of compartments or structures as defined in Ch 5, Sec 6, Tab 10 is to be checked in testing conditions. To this end, its net thickness is to be not less than the value obtained, in mm, from the following formula:

$$t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_T}{R_y}}$$

3.4 Transversely framed plating contributing to the hull girder longitudinal strength

3.4.1 General

The net thickness of laterally loaded plate panels subjected to in-plane normal stress acting on the longer sides is to be not less than the value obtained, in mm, from the following formula:

$$t = C_T c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{\lambda_T R_y}}$$

where:

- for bottom, bilge, inner bottom and decks (excluding possible longitudinal sloping plates):

  C_T : Coefficient equal to 17,2

  $$\lambda_T = 1 - 0{,}89 \gamma_m \frac{\sigma_{x1}}{R_y}$$

- for side, inner side and longitudinal bulkheads (including possible longitudinal sloping plates):

  C_T : Coefficient equal to:

  17,2 for side

  14,9 for inner side and longitudinal bulkheads (including possible longitudinal sloping plates)

  $$\lambda_T = \sqrt{1 - 3\left(\gamma_m \frac{\tau_1}{R_y}\right)^2} - 0{,}89 \gamma_m \frac{\sigma_{x1}}{R_y}$$

3.4.2 Flooding conditions

The plating of bulkheads or inner side which constitute the boundary of compartments not intended to carry liquids is to be checked in flooding conditions. To this end, its net thickness is to be not less than the value obtained, in mm, from the following formula:

$$t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{\lambda_T R_y}}$$

where λ_T is defined in [3.4.1].

3.4.3 Testing conditions *(1/1/2017)*

The plating of compartments or structures as defined in Ch 5, Sec 6, Tab 10 is to be checked in testing conditions. To this end, its net thickness is to be not less than the value obtained, in mm, from the following formula:

$$t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_T}{R_y}}$$

3.5 Plating not contributing to the hull girder longitudinal strength

3.5.1 General

The net thickness of plate panels subjected to lateral pressure is to be not less than the value obtained, in mm, from the following formula:

$$t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}}$$

3.5.2 Flooding conditions

The plating of bulkheads or inner side which constitute the boundary of compartments not intended to carry liquids is to be checked in flooding conditions. To this end, its net thickness is to be not less than the value obtained, in mm, from the following formula:

$$t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{R_y}}$$

3.5.3 Testing conditions *(1/1/2017)*

The plating of compartments or structures as defined in Ch 5, Sec 6, Tab 10 is to be checked in testing conditions. To this end, its net thickness is to be not less than the value obtained, in mm, from the following formula:

$$t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_T}{R_y}}$$

3.6 Plating subjected to weapon firing dynamic loads

3.6.1 The net thickness of plate panel subjected to weapon firing dynamic loads is to be not less than the value obtained, in mm, from the following formula:

$$t = 1{,}49 c_a c_r c_W s \sqrt{\gamma_R \gamma_m \frac{\gamma_{W2} p_W}{R_Y}}$$

where:

c_W : coefficient, equal to:

c_W = 1,45: for missile blast dynamic pressure or accidental missile ignition dynamic pressure

c_W = 1,35: for gun blast dynamic pressure.

4 Strength check of plating subjected to wheeled loads

4.1 General

4.1.1 The requirements of this Article apply for the strength check of plating subjected to wheeled loads.

4.2 Load model

4.2.1 General

The still water and inertial forces induced by the sea and the various types of wheeled vehicles are to be considered, depending on the location of the plating.

The inertial forces induced by the sea are to be calculated in load case "b", as defined in Ch 5, Sec 4.

4.2.2 Wheeled forces

The wheeled force applied by one wheel is constituted by still water force and inertial force.

Still water force is the vertical force (F_S) defined in Ch 5, Sec 6, [4.1].

Inertial force is the vertical force ($F_{W,Z}$) defined in Ch 5, Sec 6, [4.1], for load case "b", with the acceleration a_{Z1} calculated at x = 0,5L.

4.3 Plating

4.3.1 The net thickness of plate panels subjected to wheeled loads is to be not less than the value obtained, in mm, from the following formula:

$$t = C_{WL} (n P_0 k)^{0,5} - t_c$$

where:

C_{WL} : Coefficient to be taken equal to:

$$C_{WL} = 2{,}15 - \frac{0{,}05\ell}{s} + 0{,}02\left(4 - \frac{\ell}{s}\right)\alpha^{0,5} - 1{,}75\alpha^{0,25}$$

where ℓ/s is to be taken not greater than 3

$$\alpha = \frac{A_T}{\ell s}$$

A_T : Tyre print area, in m². In the case of double or triple wheels, the area is that corresponding to the group of wheels.

n : Number of wheels on the plate panel, taken equal to:

- 1 in the case of a single wheel
- the number of wheels in a group of wheels in the case of double or triple wheels

P_0 : wheeled force, in kN, taken equal to:

$$P_0 = \gamma_{S2} F_S + 0{,}4 \gamma_{W2} F_{W,Z}$$

4.3.2 When the tyre print area is not known, it may be taken equal to:

$$A_T = \frac{n Q_A}{n_W p_T}$$

where:

n : Number of wheels on the plate panel, defined in [4.3.1]

Q_A : Axle load, in t

n_W : Number of wheels for the axle considered

p_T : Tyre pressure, in kN/m². When the tyre pressure is not indicated by the designer, it may be taken as defined in Tab 6.

Table 6 : Tyre pressures p_T for vehicles

Vehicle type	Tyre pressure p_T, in kN/m²	
	Pneumatic tyres	Solid rubber tyres
Cars	250	Not applicable
Jeeps	600	Not applicable
Trucks and trailers	800	Not applicable
Handling machines	1100	1600

4.3.3 For vehicles with the four wheels of the axle located on a plate panel as shown in Fig 1, the net thickness of deck plating is to be not less than the greater of the values obtained, in mm, from the following formulae:

$$t = t_1$$

$$t = t_2(1 + \beta_2 + \beta_3 + \beta_4)^{0,5}$$

where:

- t_1 : Net thickness obtained from [4.3.1] for n = 2, considering one group of two wheels located on the plate panel
- t_2 : Net thickness obtained from [4.3.1] for n = 1, considering one wheel located on the plate panel
- β_2, β_3, β_4: Coefficients obtained from the following formula, by replacing i by 2, 3 and 4, respectively (see Fig 1):
  - for $x_i/b < 2$:

    $$\beta_i = 0,8(1,2 - 2,02\alpha_i + 1,17\alpha_i^2 - 0,23\alpha_i^3)$$

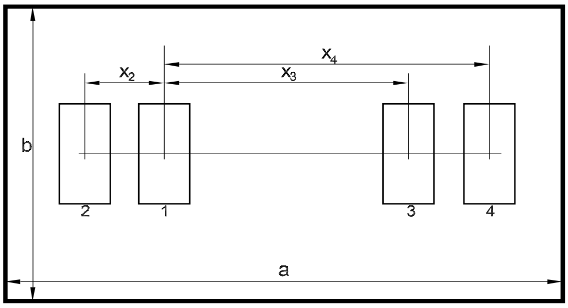
  - for $x_i/b \geq 2$:

    $$\beta_i = 0$$

- x_i : Distance, in m, from the wheel considered to the reference wheel (see Fig 1)
- b : Dimension, in m, of the plate panel side perpendicular to the axle

$$\alpha_i = \frac{x_i}{b}$$

Figure 1 : Four wheel axle located on a plate panel



5 Buckling check

5.1 General

5.1.1 Application

The requirements of this Article apply for the buckling check of plating subjected to in-plane compression stresses, acting on one or two sides, or to shear stress.

Rectangular plate panels are considered as being simply supported. For specific designs, other boundary conditions may be considered, at the Society's discretion, provided that the necessary information is submitted for review.

5.1.2 Compression and bending with or without shear

For plate panels subjected to compression and bending along one side, with or without shear, as shown in Fig 2, side "b" is to be taken as the loaded side. In such case, the compression stress varies linearly from σ_1 to $\sigma_2 = \psi\,\sigma_1$ ($\psi \leq 1$) along edge "b".

5.1.3 Shear

For plate panels subjected to shear, as shown in Fig 3, side "b" may be taken as either the longer or the shorter side of the panel.

5.1.4 Bi-axial compression and shear

For plate panels subjected to bi-axial compression along sides "a" and "b", and to shear, as shown in Fig 4, side "a" is to be taken as the side in the direction of the primary supporting members.

Figure 2 : Buckling of a simply supported rectangular plate panel subjected to compression and bending, with and without shear

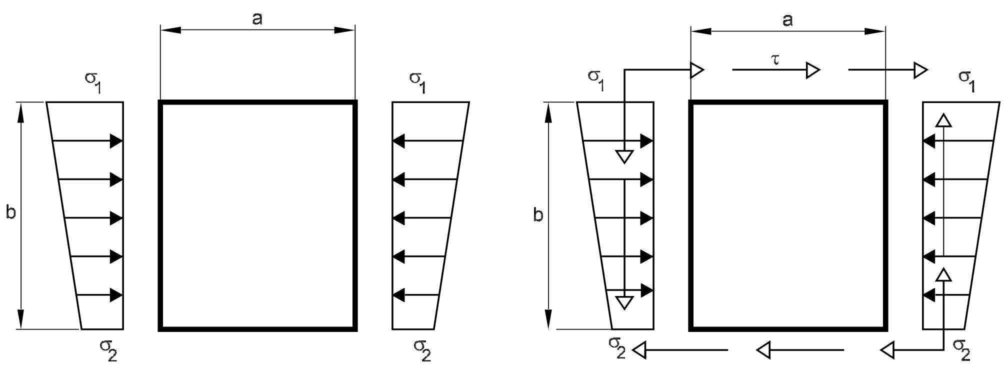


Figure 3 : Buckling of a simply supported rectangular plate panel subjected to shear

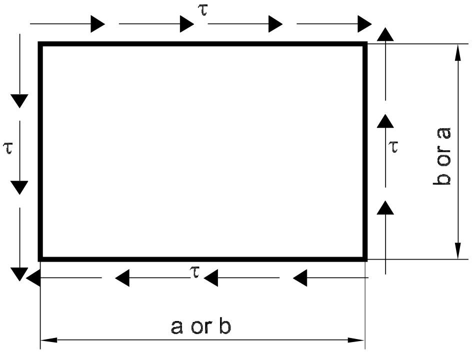
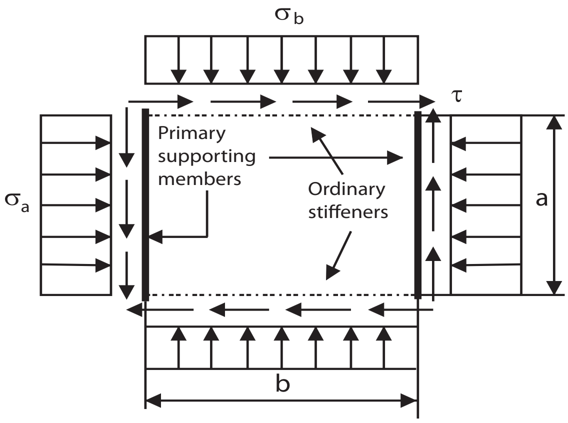


Figure 4 : Buckling of a simply supported rectangular plate panel subjected to bi-axial compression and shear *(1/1/2017)*



5.2 Load model

5.2.1 Sign convention for normal stresses

The sign convention for normal stresses is as follows:

- tension: positive
- compression: negative.

5.2.2 In-plane hull girder compression normal stresses

The in-plane hull girder compression normal stresses to be considered for the buckling check of plating contributing to the longitudinal strength are obtained, in N/mm², from the following formula:

$$\sigma_{X1} = \gamma_{S1}\sigma_{S1} + \gamma_{W1}(C_{FV}\sigma_{WV1} + C_{FH}\sigma_{WH1})$$

where:

σ_{S1}, σ_{WV1}, σ_{WH1} : Hull girder normal stresses, in N/mm², defined in Tab 7

C_{FV}, C_{FH} : Combination factors defined in Tab 4.

σ_{X1} is to be taken as the maximum compression stress on the plate panel considered.

In no case may σ_{X1} be taken less than 30/k N/mm².

When the ship in still water is always in hogging condition, σ_{X1} may be evaluated by means of direct calculations when justified on the basis of the ship's characteristics and intended service. The calculations are to be submitted to the Society for approval.

5.2.3 In-plane hull girder shear stresses

The in-plane hull girder shear stresses to be considered for the buckling check of plating are obtained as specified in [3.2.7] for the strength check of plating subjected to lateral pressure, which contributes to the longitudinal strength.

5.2.4 Combined in-plane hull girder and local compression normal stresses

The combined in-plane compression normal stresses to be considered for the buckling check of plating are to take into account the hull girder stresses and the local stresses resulting from the bending of the primary supporting members. These local stresses are to be obtained from a direct structural analysis using the design loads given in Chapter 5.

Table 7 : Hull girder normal compression stresses

Condition	σ_{S1} in N/mm² **(1)**	σ_{WV1} in N/mm²	σ_{WH1} in N/mm²
$z \geq N$	$\frac{M_{SW,S}}{I_Y}(z-N)10^{-3}$	$\frac{0,625F_D M_{WV,S}}{I_Y}(z-N)10^{-3}$	$-\left\lvert\frac{0,625M_{WH}}{I_Z}y\right\rvert 10^{-3}$
$z < N$	$\frac{M_{SW,H}}{I_Y}(z-N)10^{-3}$	$\frac{0,625M_{WV,H}}{I_Y}(z-N)10^{-3}$	

(1) When the ship in still water is always in hogging condition, σ_{S1} for $z \geq N$ is to be obtained, in N/mm², from the following formula, unless σ_{X1} is evaluated by means of direct calculations (see [5.2.2]):

$$\sigma_{S1} = \frac{M_{SW,Hmin}}{I_Y}(z-N)10^{-3}$$

Note 1:

F_D : Coefficient defined in Ch 5, Sec 2, [4].

With respect to the reference co-ordinate system defined in Ch 1, Sec 2, [10], the combined stresses in x and y direction are obtained, in N/mm², from the following formulae:

$$\sigma_X = \sigma_{X1} + \gamma_{S2}\sigma_{X2,S} + \gamma_{W2}\sigma_{X2,W}$$

$$\sigma_Y = \gamma_{S2}\sigma_{Y2,S} + \gamma_{W2}\sigma_{Y2,W}$$

where:

σ_{X1} : Compression normal stress, in N/mm², induced by the hull girder still water and wave loads, defined in [5.2.2]

$\sigma_{X2,S}$, $\sigma_{Y2,S}$: Compression normal stress in x and y direction, respectively, in N/mm², induced by the local bending of the primary supporting members and obtained from a direct structural analysis using the still water design loads given in Chapter 5

$\sigma_{X2,W}$, $\sigma_{Y2,W}$: Compression normal stress in x and y direction, respectively, in N/mm², induced by the local bending of the primary supporting members and obtained from a direct structural analysis using the wave design loads given in Chapter 5.

5.2.5 Combined in-plane hull girder and local shear stresses

The combined in-plane shear stresses to be considered for the buckling check of plating are to take into account the hull girder stresses and the local stresses resulting from the bending of the primary supporting members. These local stresses are to be obtained from a direct structural analysis using the design loads given in Chapter 5.

The combined stresses are obtained, in N/mm², from the following formula:

$$\tau = \tau_1 + \gamma_{S2}\tau_{2,S} + \gamma_{W2}\tau_{2,W}$$

where:

τ_1 : Shear stress, in N/mm², induced by the hull girder still water and wave loads, defined in [5.2.3]

$\tau_{2,S}$: Shear stress, in N/mm², induced by the local bending of the primary supporting members and obtained from a direct structural analysis using the still water design loads given in Chapter 5

$\tau_{2,W}$: Shear stress, in N/mm², induced by the local bending of the primary supporting members and obtained from a direct structural analysis using the wave design loads given in Chapter 5.

5.3 Critical stresses

5.3.1 Compression and bending for plane panel

The critical buckling stress is to be obtained, in N/mm², from the following formulae:

$$\sigma_c = \sigma_E \qquad \text{for} \quad \sigma_E \le \frac{R_{eH}}{2}$$

$$\sigma_c = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_E}\right) \qquad \text{for} \quad \sigma_E > \frac{R_{eH}}{2}$$

where:

σ_E : Euler buckling stress, to be obtained, in N/mm², from the following formula:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_{net}}{b}\right)^2 K_1 \varepsilon$$

K_1 : Buckling factor defined in Tab 8

Table 8 : Buckling factor K_1 for plate panels

Load pattern	Aspect ratio	Buckling factor K_1
$0 \le \psi \le 1$	$\alpha \ge 1$ $\alpha < 1$	$\frac{8,4}{\psi + 1,1}$ $\left(\alpha + \frac{1}{\alpha}\right)^2 \frac{2,1}{\psi + 1,1}$
$-1 < \psi < 0$		$(1+\psi)K_1' - \psi K_1'' + 10\psi(1+\psi)$
$\psi \le -1$	$\alpha\frac{1-\psi}{2} \ge \frac{2}{3}$ $\alpha\frac{1-\psi}{2} < \frac{2}{3}$	$23,9\left(\frac{1-\psi}{2}\right)^2$ $\left(15,87 + \frac{1,87}{\left(\alpha\frac{1-\psi}{2}\right)^2} + 8,6\left(\alpha\frac{1-\psi}{2}\right)^2\right)\left(\frac{1-\psi}{2}\right)^2$

Note 1:

$$\psi = \frac{\sigma_2}{\sigma_1}$$

K_1' : Value of K_1 calculated for $\psi = 0$

K_1'' : Value of K_1 calculated for $\psi = -1$

ε : Coefficient to be taken equal to:

- $\varepsilon = 1$ for $\alpha \geq 1$,
- $\varepsilon = 1,05$ for $\alpha < 1$ and side "b" stiffened by flat bar
- $\varepsilon = 1,10$ for $\alpha < 1$ and side "b" stiffened by bulb section
- $\varepsilon = 1,21$ for $\alpha < 1$ and side "b" stiffened by angle or T-section
- $\varepsilon = 1,30$ for $\alpha < 1$ and side "b" stiffened by primary supporting members.

$\alpha = a/b$

5.3.2 Shear for plane panel

The critical shear buckling stress is to be obtained, in N/mm², from the following formulae:

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

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

where:

τ_E : Euler shear buckling stress, to be obtained, in N/mm², from the following formula:

$$\tau_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_{net}}{b}\right)^2 K_2$$

K_2 : Buckling factor to be taken equal to:

$$K_2 = 5,34 + \frac{4}{\alpha^2} \quad \text{for} \quad \alpha > 1$$

$$K_2 = \frac{5,34}{\alpha^2} + 4 \quad \text{for} \quad \alpha \leq 1$$

α : Coefficient defined in [5.3.1].

5.3.3 Bi-axial compression and shear for plane panel

The critical buckling stress $\sigma_{c,a}$ for compression on side "a" of the panel is to be obtained, in N/mm², from the following formula:

$$\sigma_{c,a} = \left(\frac{2,25}{\beta} - \frac{1,25}{\beta^2}\right) R_{eH}$$

where:

β : Slenderness of the panel, to be taken equal to:

$$\beta = 10^3 \frac{a}{t_{net}} \sqrt{\frac{R_{eH}}{E}}$$

without being taken less than 1,25.

The critical buckling stress $\sigma_{c,b}$ for compression on side "b" of the panel is to be obtained, in N/mm², from the formulae in [5.3.1].

The critical shear buckling stress is to be obtained, in N/mm², from the formulae in [5.3.2].

5.3.4 Compression and shear for curved panels

For curved panels, the effects of lateral pressure are also to be taken into account.

The critical buckling stress of curved panels subjected to compression on curved edges and to lateral pressure is to be obtained, in N/mm², from the following formulae:

$$\sigma_c = \sigma_E \quad \text{for} \quad \sigma_E \leq \frac{R_{eH}}{2}$$

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

where:

σ_E : Euler buckling stress, to be obtained, in N/mm², from the following formula:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_{net}}{b}\right)^2 K_3$$

b : Width of curved panel, in mm, measured on arc

K_3 : Buckling factor defined in Tab 9, depending on the load acting on the panel.

Table 9 : Buckling factor K_3 for curved panels

Load	Buckling factor K_3
Compression stress perpendicular to the curved edges	$2\left\{1 + \sqrt{1 + \frac{12(1-\nu^2)}{\pi^4}\frac{b^4}{r^2 t_{net}^2}}\right\}$
Lateral pressure perpendicular to the panel	$4 - \left(\frac{b}{\pi r}\right)^2$
Note 1: r : radius of curvature, in mm.	

The critical shear buckling stress is to be obtained, in N/mm², from the following formulae:

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

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

where:

τ_E : Euler shear buckling stress, to be obtained, in N/mm², from the following formula:

$$\tau_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_{net}}{b}\right)^2 K_4$$

K_4 : Buckling factor to be taken equal to:

$$K_4 = \frac{12(1-\nu^2)}{\pi^2}\left(5 + 0,1\frac{b^2}{r t_{net}}\right)$$

b, r : Defined above.

5.3.5 Compression for corrugation flanges

The critical buckling stress is to be obtained, in N/mm², from the following formulae:

$\sigma_c = \sigma_E \quad$ for $\quad \sigma_E \le \frac{R_{eH}}{2}$

$\sigma_c = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_E}\right) \quad$ for $\quad \sigma_E > \frac{R_{eH}}{2}$

where:

σ_E : Euler buckling stress, to be obtained, in N/mm², from the following formula:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_f}{V}\right)^2 K_5$$

K_5 : Buckling factor to be taken equal to:

$$K_5 = \left(1 + \frac{t_w}{t_f}\right)\left\{3 + 0{,}5\frac{V'}{V} - 0{,}33\left(\frac{V'}{V}\right)^2\right\}$$

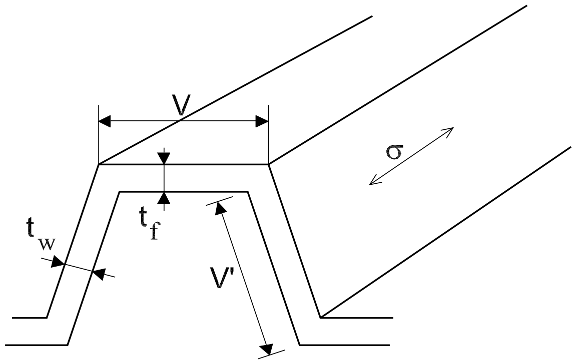
t_f : Net thickness, in mm, of the corrugation flange

t_w : Net thickness, in mm, of the corrugation web

V, V′ : Dimensions of a corrugation, in mm, shown in Fig 5.

When the thicknesses t_f and t_w of the corrugation flange and web varies along the corrugation span, σ_C is to be calculated for every adjacent actual pair of t_f and t_w.

Figure 5 : Dimensions of a corrugation



5.4 Checking criteria

5.4.1 Acceptance of results

The net thickness of plate panels is to be such as to satisfy the buckling check, as indicated in [5.4.2] to [5.4.5] depending on the type of stresses acting on the plate panel considered. When the buckling criteria is exceeded by less than 15 %, the scantlings may still be considered as acceptable, provided that the stiffeners located on the plate panel satisfy the buckling and the ultimate strength checks as specified in Sec 2, [4] and Sec 2, [5].

5.4.2 Compression and bending

For plate panels subjected to compression and bending on one side, the critical buckling stress is to comply with the following formula:

$$\frac{\sigma_c}{\gamma_R \gamma_m} \ge |\sigma_b|$$

where:

σ_c : Critical buckling stress, in N/mm², defined in [5.3.1], [5.3.4] or [5.3.5], as the case may be

σ_b : Compression stress, in N/mm², acting on side "b" of the plate panel, to be calculated, as specified in [5.2.2] or [5.2.4], as the case may be.

In the case of corrugation flanges, when the thicknesses t_f and t_w of the corrugation flange and web varies along the corrugation span, σ_b is to be taken as the maximum compression stress calculated in each zone of adjacent actual pairs of t_f and t_w.

5.4.3 Shear

For plate panels subjected to shear, the critical shear buckling stress is to comply with the following formula:

$$\frac{\tau_c}{\gamma_R \gamma_m} \ge |\tau_b|$$

where:

τ_c : Critical shear buckling stress, in N/mm², defined in [5.3.2] or [5.3.4], as the case may be

τ_b : Shear stress, in N/mm², acting on the plate panel, to be calculated as specified in [5.2.3] or [5.2.5], as the case may be.

5.4.4 Compression, bending and shear

For plate panels subjected to compression, bending and shear, the combined critical stress is to comply with the following formulae:

$F \le 1 \quad$ for $\quad \frac{\sigma_{comb}}{F} \le \frac{R_{eH}}{2\gamma_R \gamma_m}$

$F \le \frac{4\sigma_{comb}}{R_{eH}/\gamma_R\gamma_m}\left(1 - \frac{\sigma_{comb}}{R_{eH}/\gamma_R\gamma_m}\right) \quad$ for $\quad \frac{\sigma_{comb}}{F} > \frac{R_{eH}}{2\gamma_R \gamma_m}$

where:

$$\sigma_{comb} = \sqrt{\sigma_1^2 + 3\tau^2}$$

$$F = \gamma_R \gamma_m \left[\frac{1+\psi}{4}\frac{|\sigma_1|}{\sigma_E} + \sqrt{\left(\frac{3-\psi}{4}\right)^2\left(\frac{\sigma_1}{\sigma_E}\right)^2 + \left(\frac{\tau}{\tau_E}\right)^2}\right]$$

σ_E : Euler buckling stress, in N/mm², defined in [5.3.1], [5.3.4] or [5.3.5] as the case may be,

τ_E : Euler shear buckling stress, in N/mm², defined in [5.3.2] or [5.3.4], as the case may be,

$$\psi = \frac{\sigma_2}{\sigma_1}$$

σ_1, σ_2 and τ are defined in Fig 2 and are to be calculated, in N/mm², as specified in [5.2].

5.4.5 Bi-axial compression, taking account of shear stress

For plate panels subjected to bi-axial compression and shear, the critical buckling stresses are to comply with the following formula:

$$\left|\frac{\sigma_a}{\frac{\sigma_{c,a}}{\gamma_R\gamma_m}R_a}\right|^n + \left|\frac{\sigma_b}{\frac{\sigma_{c,b}}{\gamma_R\gamma_m}R_b}\right|^n \le 1$$

where:

$\sigma_{c,a}$: Critical buckling stress for compression on side "a", in N/mm², defined in [5.3.3]

$\sigma_{c,b}$: Critical buckling stress for compression on side "b", in N/mm², defined in [5.3.3]

σ_a : Compression stress acting on side "a", in N/mm², to be calculated as specified in [5.2.2] or [5.2.4], as the case may be

σ_b : Compression stress acting on side "b", in N/mm², to be calculated as specified in [5.2.2] or [5.2.4], as the case may be

n : Coefficient to be taken equal to:

$n = 1$ for $\alpha \ge 1/\sqrt{2}$

$n = 2$ for $\alpha < 1/\sqrt{2}$

$\alpha = a/b$

$$R_a = 1 - \left|\frac{\tau}{\tau_c}\right|^{n_a}$$

$$R_b = 1 - \left|\frac{\tau}{\tau_c}\right|^{n_b}$$

τ : Shear stress, in N/mm², to be calculated as specified in [5.2.3] or [5.2.5], as the case may be

τ_c : Critical shear buckling stress, in N/mm², defined in [5.3.2]

n_a : Coefficient to be taken equal to:

$n_a = 1 + 1/\alpha$ for $\alpha \ge 0,5$

$n_a = 3$ for $\alpha < 0,5$

n_b : Coefficient to be taken equal to:

$n_b = 1,9 + 0,1/\alpha$ for $\alpha \ge 0,5$

$n_b = 0,7(1 + 1/\alpha)$ for $\alpha < 0,5$

SECTION 2 ORDINARY STIFFENERS

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

p_S : Still water pressure, in kN/m^2, see [3.3.2] and [5.3.2]

p_W : Wave pressure and, if necessary, dynamic pressures, according to the criteria in Ch 5, Sec 5, [2] and Ch 5, Sec 6, [2], in kN/m^2 (see [3.3.2] and [5.3.2])

p_{SF}, p_{WF} : Still water and wave pressures, in kN/m^2, in flooding conditions, defined in Ch 5, Sec 6, [7]

F_S : Still water wheeled force, in kN, see [3.3.5]

$F_{W,Z}$: Inertial wheeled force, in kN, see [3.3.5]

σ_{X1} : Hull girder normal stress, in N/mm^2, defined in:

- [3.3.7] for the yielding check of ordinary stiffeners
- [4.2.2] for the buckling check of ordinary stiffeners
- [5.3.3] for the ultimate strength check of ordinary stiffeners

σ_N : Normal stress, in N/mm^2, defined in [3.3.7]

$R_{eH,P}$: Minimum yield stress, in N/mm^2, of the plating material, defined in Ch 4, Sec 1, [2]

$R_{eH,S}$: Minimum yield stress, in N/mm^2, of the stiffener material, defined in Ch 4, Sec 1, [2]

s : Spacing, in m, of ordinary stiffeners

ℓ : Span, in m, of ordinary stiffeners, measured between the supporting members, see Ch 4, Sec 3, [3.2]

ℓ_b : Length, in m, of one bracket, see [3.2.2], Ch 4, Sec 3, Fig 4 and Ch 4, Sec 3, Fig 5

h_w : Web height, in mm

t_w : Net web thickness, in mm

b_f : Face plate width, in mm

t_f : Net face plate thickness, in mm

b_p : Width, in m, of the plating attached to the stiffener, for the yielding check, defined in Ch 4, Sec 3, [3.3.1]

b_e : Width, in m, of the plating attached to the stiffener, for the buckling check, defined in [4.1]

b_U : Width, in m, of the plating attached to the stiffener, for the ultimate strength check, defined in [5.2]

t_p : Net thickness, in mm, of the attached plating

w : Net section modulus, in cm^3, of the stiffener, with an attached plating of width b_p, to be calculated as specified in Ch 4, Sec 3, [3.4]

A_S : Net sectional area, in cm^2, of the stiffener with attached plating of width s

A_e : Net sectional area, in cm^2, of the stiffener with attached plating of width b_e

A_U : Net sectional area, in cm^2, of the stiffener with attached plating of width b_U

A_{Sh} : Net shear sectional area, in cm^2, of the stiffener, to be calculated as specified in Ch 4, Sec 3, [3.4]

I : Net moment of inertia, in cm^4, of the stiffener without attached plating, about its neutral axis parallel to the plating (see Ch 4, Sec 3, Fig 4 and Ch 4, Sec 3, Fig 5)

I_S : Net moment of inertia, in cm^4, of the stiffener with attached shell plating of width s, about its neutral axis parallel to the plating

I_e : Net moment of inertia, in cm^4, of the stiffener with attached shell plating of width b_e, about its neutral axis parallel to the plating

I_U : Net moment of inertia, in cm^4, of the stiffener with attached shell plating of width b_U, about its neutral axis parallel to the plating

I_B : Net moment of inertia, in cm^4, of the stiffener with bracket and without attached plating, about its neutral axis parallel to the plating, calculated at mid-length of the bracket (see Ch 4, Sec 3, Fig 4 and Ch 4, Sec 3, Fig 5)

ρ_S : Radius of gyration, in cm, of the stiffener with attached plating of width s

ρ_U : Radius of gyration, in cm, of the stiffener with attached plating of width b_U

c_c : Coefficient which takes into account the effects of stiffener connections, equal to:

c_c = 1,0 in general,

c_c = 0,9 when the stiffener is provided with a soft toe connection with the supporting structure and no brackets are fitted.

$\chi = I_B / I$

$\alpha = \ell_b / \ell$

1 General

1.1 Net scantlings

1.1.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 4, Sec 2.

1.2 Partial safety factors

1.2.1 The partial safety factors to be considered for the checking of ordinary stiffeners are specified in Tab 1.

Table 1 : Ordinary stiffeners - Partial safety factors *(1/1/2017)*

Partial safety factors covering uncertainties regarding:	Symbol	Yielding check			Buckling check (see [4])	Ultimate strength check of ordinary stiffeners contributing to the longitudinal strength (see [5])
		General (see [3.3] to [3.7])	Flooding pressure **(1)** (see [3.3], [3.8])	Testing check (see [3.3], [3.9])		
Still water hull girder loads	γ_{S1}	1,00	1,00	N.A.	1,00	1,00
Wave hull girder loads	γ_{W1}	1,15	1,15	N.A.	1,15	1,30
Still water pressure	γ_{S2}	1,00	1,00	1,00	N.A.	1,00
Wave pressure	γ_{W2}	1,20	1,05	N.A.	N.A.	1,40
Material	γ_m	1,02	1,02	1,02	1,02	1,02
Resistance	γ_R	1,02	1,02 **(2)**	1,20	1,10	1,02

(1) Applies only to ordinary stiffeners to be checked in flooding conditions.
(2) For ordinary stiffeners of the collision bulkhead, γ_R =1,25.

1.3 Load point

1.3.1 Lateral pressure

Unless otherwise specified, lateral pressure is to be calculated at mid-span of the ordinary stiffener considered.

1.3.2 Hull girder stresses

For longitudinal ordinary stiffeners contributing to the hull girder longitudinal strength, the hull girder normal stresses are to be calculated in way of the neutral axis of the stiffener considered.

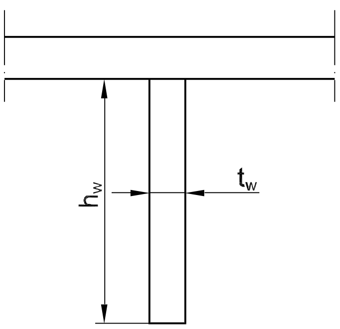
1.4 Net dimensions of ordinary stiffeners

1.4.1 Flat bar

The net dimensions of a flat bar ordinary stiffener (see Fig 1) are to comply with the following requirement:

$$\frac{h_w}{t_w} \leq 20\sqrt{k}$$

Figure 1 : Net dimensions of a flat bar



1.4.2 T-section

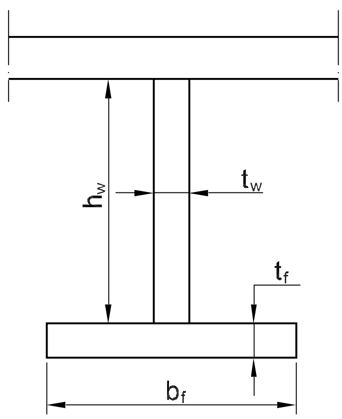
The net dimensions of a T-section ordinary stiffener (see Fig 2) are to comply with the following two requirements:

$$\frac{h_w}{t_w} \leq 55\sqrt{k}$$

$$\frac{b_f}{t_f} \leq 33\sqrt{k}$$

$$b_f t_f \geq \frac{h_w t_w}{6}$$

Figure 2 : Net dimensions of a T-section



1.4.3 Angle

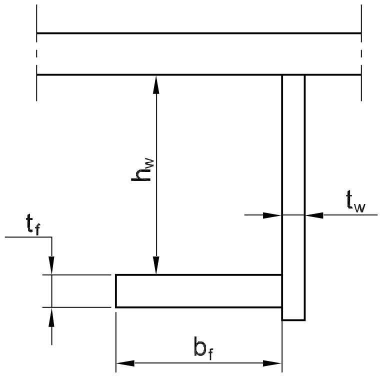
The net dimensions of an angle ordinary stiffener (see Fig 3) are to comply with the following two requirements:

$$\frac{h_w}{t_w} \leq 55\sqrt{k}$$

$$\frac{b_f}{t_f} \leq 16,5\sqrt{k}$$

$$b_f t_f \geq \frac{h_w t_w}{6}$$

Figure 3 : Net dimensions of an angle



2 General requirements

2.1 General

2.1.1 The requirements in [2.2] and [2.3] are to be applied to ordinary stiffeners in addition of those in [3] to [5].

2.2 Minimum net thicknesses

2.2.1 The net thickness of the web of ordinary stiffeners is to be not less than the lesser of:

- the value obtained, in mm, from the following formulae:

  $t_{MIN} = 0,8 + 0,004Lk^{1/2} + 4,5s$ for L < 120 m

  $t_{MIN} = 1,6 + 2,2k^{1/2} + s$ for L ≥ 120 m

- the net as built thickness of the attached plating.

2.3 Struts of open floors

2.3.1 The sectional area A_{ST}, in cm², and the moment of inertia I_{ST} about the main axes, in cm⁴, of struts of open floors are to be not less than the values obtained from the following formulae:

$$A_{ST} = \frac{p_{ST} s \ell}{20}$$

$$I_{ST} = \frac{0,75 s \ell (p_{STB} + p_{STU}) A_{AST} \ell_{ST}^2}{47,2 A_{AST} - s \ell (p_{STB} + p_{STU})}$$

where:

p_{ST} : Pressure to be taken equal to the greater of the values obtained, in kN/m², from the following formulae:

$p_{ST} = 0,5\ (p_{STB} + p_{STU})$

$p_{ST} = p_{STD}$

p_{STB} : Sea pressure, in kN/m², acting on the bottom in way of the strut equal to:

$p_{STB} = \gamma_{S2} p_S + \gamma_{W2} p_W$

p_{STU} : Pressure, in kN/m², acting on the inner bottom in way of the strut due to the load in the tank or hold above, equal to:

$p_{STU} = \gamma_{S2} p_S + \gamma_{W2} p_W$

p_{STD} : Pressure, in kN/m², in double bottom at mid-span of the strut equal to:

$p_{STD} = \gamma_{S2} p_S + \gamma_{W2} p_W$

ℓ : Span, in m, of transverse ordinary stiffeners constituting the open floor (see Ch 4, Sec 3, [3.2.2])

ℓ_{ST} : Length, in m, of the strut

A_{AST} : Actual net sectional area, in cm², of the strut.

3 Yielding check

3.1 General

3.1.1 The requirements of this Article apply for the yielding check of ordinary stiffeners subjected to lateral pressure, wheeled loads or weapon firing dynamic loads and, for ordinary stiffeners contributing to the hull girder longitudinal strength, to hull girder normal stresses.

3.1.2 The yielding check is also to be carried out for ordinary stiffeners subjected to specific loads, such as concentrated loads.

3.2 Structural model

3.2.1 Boundary conditions

The requirements in [3.4], [3.7.3], [3.7.4] and [3.8] apply to stiffeners considered as clamped at both ends, whose end connections comply with the requirements in [3.2.2].

The requirements in [3.5] and [3.7.5] and [3.7.6] apply to stiffeners considered as simply supported at both ends. Other boundary conditions may be considered by the Society on a case by case basis, depending on the distribution of wheeled loads or weapon firing loads, as the case may be.

For other boundary conditions, the yielding check is to be considered on a case by case basis.

3.2.2 Bracket arrangement

The requirements of this Article apply to ordinary stiffeners without end brackets, with a bracket at one end or with two equal end brackets, where the bracket length is not greater than $0,2\ell$.

In the case of ordinary stiffeners with two different end brackets of length not greater than $0,2\ell$, the determination of normal and shear stresses due to design loads and the required section modulus and shear sectional area are considered by the Society on a case by case basis. In general, an acceptable solution consists in applying the criteria for equal brackets, considering both brackets as having the length of the smaller one.

In the case of ordinary stiffeners with end brackets of length greater than $0,2\ell$, the determination of normal and shear stresses due to design loads and the required section modulus and shear sectional area are considered by the Society on a case by case basis.

3.3 Load model

3.3.1 General

The still water and wave lateral loads induced by the sea and the various types of cargoes and ballast in intact conditions are to be considered, depending on the location of the ordinary stiffener under consideration and the type of compartments adjacent to it, in accordance with Ch 5, Sec 1, [2.4].

Ordinary stiffeners of bulkheads or inner side which constitute the boundary of compartments not intended to carry liquids are to be subjected to the lateral pressure in flooding conditions.

The wave lateral loads and hull girder loads are to be calculated in the mutually exclusive load cases "a", "b", "c" and "d" in Ch 5, Sec 4.

3.3.2 Lateral pressure in intact conditions

The lateral pressure in intact conditions is constituted by still water pressure and wave pressure.

Still water pressure (p_S) includes:

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

Wave pressure (p_W) includes:

- the wave pressure, defined in Ch 5, Sec 5, [2] for each load case "a", "b", "c" and "d"
- the inertial pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast, and for each load case "a", "b", "c" and "d"
- the dynamic pressures, according to the criteria in Ch 5, Sec 6, [2].

3.3.3 Lateral pressure in flooding conditions

The lateral pressure in flooding conditions is constituted by the still water pressure p_{SF} and wave pressure p_{WF} defined in Ch 5, Sec 6, [7].

3.3.4 Lateral pressure in testing conditions *(1/1/2017)*

The lateral pressure (pT) in testing conditions is taken equal to:

- p_{ST} - pS for bottom shell plating and side shell plating
- p_{ST} otherwise,

where p_S is the still water sea pressure defined in Ch 5, Sec 5, [1.1.1] for the draught T_1 at which the testing is carried out.

If the draught T_1 is not defined by the Designer, it may be taken equal to the light ballast draught T_B defined in Ch 5, Sec 1, [2.4.3]

3.3.5 Wheeled forces

The wheeled force applied by one wheel is constituted by still water force and inertial force:

- Still water force is the vertical force (F_S) defined in Ch 5, Sec 6, [4.1]
- Inertial force is the vertical force ($F_{W,Z}$) defined in Ch 5, Sec 6, [4.1], for load case "b".

3.3.6 Weapon loads

- missile blast dynamic pressure
- accidental missile ignition dynamic pressure
- gun blast dynamic pressure.

3.3.7 Normal stresses

The normal stresses to be considered for the yielding check of ordinary stiffeners are obtained, in N/mm², from the following formulae:

- for longitudinal stiffeners contributing to the hull girder longitudinal strength:

$$\sigma_N = \sigma_{X1} = \gamma_{S1}\sigma_{S1} + \gamma_{W1}(C_{FV}\sigma_{WV1} + C_{FH}\sigma_{WH1})$$

  to be taken not less than 60/k N/mm².

- for longitudinal stiffeners not contributing to the hull girder longitudinal strength, transverse stiffeners and vertical stiffeners, excluding side frames:

$$\sigma_N = 45/kN/mm^2$$

- for side frames:

  $\sigma_N = 0$ for load cases "a" and "c"

  $\sigma_N = 30/k$ for load cases "b" and "d"

where:

σ_{S1}, σ_{WV1}, σ_{WH1} : Hull girder normal stresses, in N/mm², defined in:

- Tab 2 for ordinary stiffeners subjected to lateral pressure,
- Tab 3 for ordinary stiffeners subjected to wheeled loads

C_{FV}, C_{FH} : Combination factors defined in Tab 4.

Table 2 : Hull girder normal stresses - Ordinary stiffeners subjected to lateral pressure

Condition	σ_{S1} , in N/mm² **(1)**	σ_{WV1} , in N/mm²	σ_{WH1} , in N/mm²
Lateral pressure applied on the side opposite to the ordinary stiffener, with respect to the plating:			$\left\lvert\frac{0{,}625 M_{WH}}{I_Z} y\right\rvert 10^{-3}$
• $z \geq N$	$\left\lvert\frac{M_{SW,S}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\frac{0{,}625 F_D M_{WV,S}}{I_Y}(z-N)\right\rvert 10^{-3}$	
• $z < N$	$\left\lvert\frac{M_{SW,H}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\frac{0{,}625 M_{WV,H}}{I_Y}(z-N)\right\rvert 10^{-3}$	
Lateral pressure applied on the same side as the ordinary stiffener:			
• $z \geq N$	$\left\lvert\frac{M_{SW,H}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\frac{0{,}625 M_{WV,H}}{I_Y}(z-N)\right\rvert 10^{-3}$	
• $z < N$	$\left\lvert\frac{M_{SW,S}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\frac{0{,}625 F_D M_{WV,S}}{I_Y}(z-N)\right\rvert 10^{-3}$	

(1) When the ship in still water is always in hogging condition, $M_{SW,S}$ is to be taken equal to 0.
Note 1:
F_D : Coefficient defined in Ch 5, Sec 2, [4].

Table 3 : Hull girder normal stresses - Ordinary stiffeners subjected to wheeled loads

Condition	σ_{S1} in N/mm² **(1)**	σ_{WV1} in N/mm²	σ_{WH1} in N/mm²
• $z \geq N$	$\left\lvert\frac{M_{SW,H}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\frac{0{,}625 M_{WV,H}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\frac{0{,}625 M_{WH}}{I_Z} y\right\rvert 10^{-3}$
• $z < N$	$\left\lvert\frac{M_{SW,S}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\frac{0{,}625 F_D M_{WV,S}}{I_Y}(z-N)\right\rvert 10^{-3}$	

(1) When the ship in still water is always in hogging condition, $M_{SW,S}$ is to be taken equal to 0.
Note 1:
F_D : Coefficient defined in Ch 5, Sec 2, [4].

Table 4 : Combination factors C_{FV} and C_{FH}

Load case	C_{FV}	C_{FH}
“a”	1,0	0
“b”	1,0	0
“c”	0,4	1,0
“d”	0,4	1,0

3.4 Normal and shear stresses due to lateral pressure in intact conditions

3.4.1 General

Normal and shear stresses, induced by lateral pressures, in ordinary stiffeners without end brackets are to be obtained from the formulae in:

- [3.4.2] in the case of longitudinal and transverse stiffeners
- [3.4.5] in the case of vertical stiffeners.

Normal and shear stresses, induced by lateral pressures, in ordinary stiffeners with a bracket at one end or with two equal end brackets, are to be obtained from the formulae in:

- [3.4.3] and [3.4.4] in the case of longitudinal and transverse stiffeners
- [3.4.6] and [3.4.7] in the case of vertical stiffeners.

Normal and shear stresses, induced by lateral pressures, in multispan ordinary stiffeners are to be obtained from the formulae in [3.4.8].

3.4.2 Longitudinal and transverse ordinary stiffeners without brackets at ends

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm², from the following formulae:

$$\sigma = c_c \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{12 w}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3 + \sigma_N$$

$$\tau = 5 \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{A_{Sh}}\left(1 - \frac{s}{2\ell}\right) s \ell$$

3.4.3 Longitudinal and transverse ordinary stiffeners with a bracket at one end

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm², from the following formulae:

$$\sigma = \beta_{b1}\frac{\gamma_{S2}p_S + \gamma_{W2}p_W}{12w}\left(1-\frac{s}{2\ell}\right)s\ell^2 10^3 + \sigma_N$$

$$\tau = 5\beta_{s1}\frac{\gamma_{S2}p_S + \gamma_{W2}p_W}{A_{Sh}}\left(1-\frac{s}{2\ell}\right)s\ell$$

where:

$$\beta_{b1} = \frac{\chi(1-\alpha)^5 + \alpha(1-\alpha)(6-3\alpha+8\alpha^2)}{\chi(1-\alpha)^3 + 2\alpha(2-\alpha)}$$

to be taken not less than 0,55

$$\beta_{s1} = \frac{\chi(1-\alpha)^4 + 5\alpha(1-\alpha+\alpha^2)}{\chi(1-\alpha)^3 + 2\alpha(2-\alpha)}$$

3.4.4 Longitudinal and transverse ordinary stiffeners with equal brackets at ends

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm², from the following formulae:

$$\sigma = \beta_{b2}\frac{\gamma_{S2}p_S + \gamma_{W2}p_W}{12w}\left(1-\frac{s}{2\ell}\right)s\ell^2 10^3 + \sigma_N$$

$$\tau = 5\beta_{s2}\frac{\gamma_{S2}p_S + \gamma_{W2}p_W}{A_{Sh}}\left(1-\frac{s}{2\ell}\right)s\ell$$

where:

$$\beta_{b2} = \frac{\chi(1-2\alpha)^3 + 2\alpha^2(4\alpha-3)}{\chi(1-2\alpha) + 2\alpha}$$

to be taken not less than 0,55

$$\beta_{s2} = 1 - 2\alpha$$

3.4.5 Vertical ordinary stiffeners without brackets at ends

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm², from the following formulae:

$$\sigma = c_c\frac{\gamma_{S2}\lambda_{bS}p_S + \gamma_{W2}\lambda_{bW}p_W}{12w}\left(1-\frac{s}{2\ell}\right)s\ell^2 10^3 + \sigma_N$$

$$\tau = 5\frac{\gamma_{S2}\lambda_{sS}p_S + \gamma_{W2}\lambda_{sW}p_W}{A_{Sh}}\left(1-\frac{s}{2\ell}\right)s\ell$$

where:

$$\lambda_{bS} = 1 + 0,2\frac{p_{Sd} - p_{Su}}{p_{Sd} + p_{Su}}$$

$$\lambda_{bW} = 1 + 0,2\frac{p_{Wd} - p_{Wu}}{p_{Wd} + p_{Wu}}$$

$$\lambda_{sS} = 1 + 0,4\frac{p_{Sd} - p_{Su}}{p_{Sd} + p_{Su}}$$

$$\lambda_{sW} = 1 + 0,4\frac{p_{Wd} - p_{Wu}}{p_{Wd} + p_{Wu}}$$

p_{Sd} : Still water pressure, in kN/m², at the lower end of the ordinary stiffener considered

p_{Su} : Still water pressure, in kN/m², at the upper end of the ordinary stiffener considered

p_{Wd} : Wave pressure, in kN/m², at the lower end of the ordinary stiffener considered.

p_{Wu} : Wave pressure, in kN/m², at the upper end of the ordinary stiffener considered

3.4.6 Vertical ordinary stiffeners with a bracket at lower end

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm², from the following formulae:

$$\sigma = \beta_{b1}\frac{\gamma_{S2}\lambda_{bS}p_S + \gamma_{W2}\lambda_{bW}p_W}{12w}\left(1-\frac{s}{2\ell}\right)s\ell^2 10^3 + \sigma_N$$

$$\tau = 5\beta_{s1}\frac{\gamma_{S2}\lambda_{sS}p_S + \gamma_{W2}\lambda_{sW}p_W}{A_{Sh}}\left(1-\frac{s}{2\ell}\right)s\ell$$

where:

β_{b1}, β_{s1} : Coefficients defined in [3.4.3]

λ_{bS}, λ_{bW}, λ_{sS}, λ_{sW}: Coefficients defined in [3.4.5].

3.4.7 Vertical ordinary stiffeners with equal brackets at ends

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm², from the following formulae:

$$\sigma = \beta_{b2}\frac{\gamma_{S2}\lambda_{bS}p_S + \gamma_{W2}\lambda_{bW}p_W}{12w}\left(1-\frac{s}{2\ell}\right)s\ell^2 10^3 + \sigma_N$$

$$\tau = 5\beta_{s2}\frac{\gamma_{S2}\lambda_{sS}p_S + \gamma_{W2}\lambda_{sW}p_W}{A_{Sh}}\left(1-\frac{s}{2\ell}\right)s\ell$$

where:

β_{b2}, β_{s2} : Coefficients defined in [3.4.4]

λ_{bS}, λ_{bW}, λ_{sS}, λ_{sW}: Coefficients defined in [3.4.5].

3.4.8 Multispan ordinary stiffeners

The maximum normal stress σ and shear stress τ in a multispan ordinary stiffener are to be determined by a direct calculation taking into account:

- the distribution of still water and wave pressure and forces, to be determined on the basis of the criteria specified in Ch 5, Sec 5 and Ch 5, Sec 6
- the number of intermediate decks or girders
- the condition of fixity at the ends of the stiffener and at intermediate supports
- the geometrical characteristics of the stiffener on the intermediate spans.

3.5 Normal and shear stresses due to wheeled loads

3.5.1 General

Normal and shear stresses, induced by the wheeled loads, in ordinary stiffeners are to be determined from the formulae given in [3.5.2] for longitudinal and transverse stiffeners.

3.5.2 Longitudinal and transverse ordinary stiffeners subjected to wheeled loads

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm², from the following formulae:

$$\sigma = \frac{\alpha_S P_0 \ell}{4w}10^3 + \sigma_N$$

$$\tau = 5\frac{\alpha_T P_0}{A_{Sh}}$$

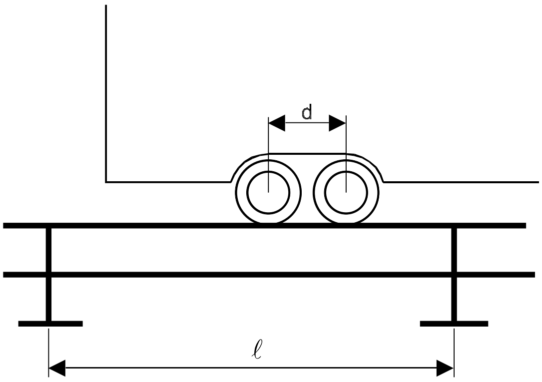
where:

P_0 : Wheeled force, in kN, taken equal to:

$$P_0 = \gamma_{S2} F_S + 0{,}4 \gamma_{W2} F_{W,Z}$$

α_S, α_T : Coefficients taking account of the number of axles and wheels per axle considered as acting on the stiffener, defined in Tab 5 (see Fig 4).

Figure 4 : Wheeled load on stiffeners - Double axles



3.6 Checking criteria

3.6.1 General

It is to be checked that the normal stress σ and the shear stress τ, calculated according to [3.4] and [3.5], are in compliance with the following formulae:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma$$

$$0{,}5 \frac{R_y}{\gamma_R \gamma_m} \geq \tau$$

3.7 Net section modulus and net shear sectional area of ordinary stiffeners, complying with the checking criteria

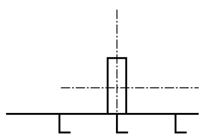
3.7.1 General

The requirements in [3.7.3] and [3.7.4] provide the minimum net section modulus and net shear sectional area of ordinary stiffeners subjected to lateral pressure in intact conditions, complying with the checking criteria indicated in [3.6].

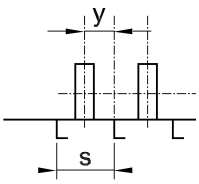
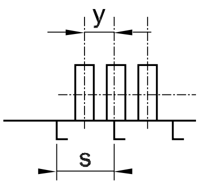
The requirements in [3.7.5] provide the minimum net section modulus and net shear sectional area of ordinary stiffeners subjected to wheeled loads, complying with the checking criteria indicated in [3.6].

The requirements in [3.7.6] provide the minimum net section modulus and net shear sectional area of ordinary stiffeners subjected to weapon firing dynamic loads.

Table 5 : Wheeled loads - Coefficients α_S and α_T

Configuration	Single axle		Double axles	
	α_S	α_T	α_S	α_T
Single wheel 	1	1	$0{,}5\left(2 - \frac{d}{\ell}\right)^2$	$2 + \frac{d}{\ell}$

Note 1:
d : Distance, in m, between two axles (see Fig 4)
y : Distance, in m, from the external wheel of a group of wheels to the stiffener under consideration, to be taken equal to the distance from the external wheel to the centre of the group of wheels.

<table>
<tr><th rowspan="2">Configuration</th><th colspan="2">Single axle</th><th colspan="2">Double axles</th></tr>
<tr><th>α_S</th><th>α_T</th><th>α_S</th><th>α_T</th></tr>
<tr><td>Double wheels

</td><td>$2\left(1-\frac{y}{s}\right)$</td><td>$2\left(1-\frac{y}{s}\right)$</td><td>$\left(1-\frac{y}{s}\right)\left(2-\frac{d}{\ell}\right)^2$</td><td>$2\left(1-\frac{y}{s}\right)\left(2+\frac{d}{\ell}\right)$</td></tr>
<tr><td>Triple wheels

</td><td>$3-2\frac{y}{s}$</td><td>$3-2\frac{y}{s}$</td><td>$0{,}5\left(3-2\frac{y}{s}\right)\left(2-\frac{d}{\ell}\right)^2$</td><td>$\left(3-2\frac{y}{s}\right)\left(2+\frac{d}{\ell}\right)$</td></tr>
<tr><td colspan="5">Note 1:
d : Distance, in m, between two axles (see Fig 4)
y : Distance, in m, from the external wheel of a group of wheels to the stiffener under consideration, to be taken equal to the distance from the external wheel to the centre of the group of wheels.</td></tr>
</table>

3.7.2 Groups of equal ordinary stiffeners

Where a group of equal ordinary stiffeners is fitted, it is acceptable that the minimum net section modulus in [3.7.1] is calculated as the average of the values required for all the stiffeners of the same group, but this average is to be taken not less than 90% of the maximum required value.

The same applies for the minimum net shear sectional area.

3.7.3 Longitudinal and transverse ordinary stiffeners subjected to lateral pressure

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh} , in cm^2, of longitudinal or transverse ordinary stiffeners subjected to lateral pressure are to be not less than the values obtained from the following formulae:

$$w = c_c \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{12(R_y - \gamma_R \gamma_m \sigma_N)} \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} \left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b : Coefficient to be taken equal to:

$\beta_b = 1$ in the case of an ordinary stiffener without brackets at ends

$\beta_b = \beta_{b1}$ defined in [3.4.3], in the case of an ordinary stiffener with a bracket of length not greater than $0{,}2\ell$ at one end

$\beta_b = \beta_{b2}$ defined in [3.4.4], in the case of an ordinary stiffener with equal brackets of length not greater than $0{,}2\ell$ at ends

β_s : Coefficient to be taken equal to:

$\beta_s = 1$ in the case of an ordinary stiffener without brackets at ends

$\beta_s = \beta_{s1}$ defined in [3.4.3], in the case of an ordinary stiffener with a bracket of length not greater than $0{,}2\ell$ at one end

$\beta_s = \beta_{s2}$ defined in [3.4.4], in the case of an ordinary stiffener with equal brackets of length not greater than $0{,}2\ell$ at ends.

3.7.4 Vertical ordinary stiffeners subjected to lateral pressure

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh} , in cm^2, of vertical ordinary stiffeners subjected to lateral pressure are to be not less than the values obtained from the following formulae:

$$w = c_c \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} \lambda_{bS} p_S + \gamma_{W2} \lambda_{bW} p_W}{12(R_y - \gamma_R \gamma_m \sigma_N)} \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} \lambda_{sS} p_S + \gamma_{W2} \lambda_{sW} p_W}{R_y} \left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b, β_s : Coefficients defined in [3.7.3]

λ_{bS}, λ_{bW}, λ_{sS}, λ_{sW}:Coefficients defined in [3.4.5].

3.7.5 Ordinary stiffeners subjected to wheeled loads

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh} , in cm^2, of ordinary stiffeners subjected to wheeled loads are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \frac{\alpha_S P_0 \ell}{4(R_y - \gamma_R \gamma_m \sigma_N)} 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \frac{\alpha_T P_0}{R_y}$$

where:

P_0 : Wheeled force, in kN, defined in [3.5.2]

α_S, α_T : Coefficients defined in [3.5.2].

3.7.6 Ordinary stiffeners subjected to weapon firing dynamic loads

The net section modulus w, in cm³, and the net shear sectional area A_{Sh}, in cm², of ordinary stiffeners subjected to weapon firing dynamic loads are to be not less than the values obtained from the following formulae:

$$w = c_C \gamma_R \gamma_m \beta_b \frac{\gamma_{W2} p_W s \ell^2}{8 R_y} 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{W2} p_W s \ell^2}{R_y}$$

where:

β_b, β_s : Coefficients defined in [3.7.3].

3.8 Net section modulus and net shear sectional area of ordinary stiffeners subjected to lateral pressure in flooding conditions

3.8.1 General

The requirements in [3.8.1] to [3.8.4] apply to ordinary stiffeners of bulkheads or inner side which constitute boundary of compartments not intended to carry liquids.

These ordinary stiffeners are to be checked in flooding conditions as specified in [3.8.3] and [3.8.4], depending on the type of stiffener.

3.8.2 Groups of equal ordinary stiffeners

Where a group of equal ordinary stiffeners is fitted, it is acceptable that the minimum net section modulus in [3.8.1] is calculated as the average of the values required for all the stiffeners of the same group, but this average is to be taken not less than 90% of the maximum required value.

The same applies for the minimum net shear sectional area.

3.8.3 Longitudinal and transverse ordinary stiffeners

The net section modulus w, in cm³, and the net shear sectional area A_{Sh}, in cm², of longitudinal or transverse ordinary stiffeners are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_0 \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{SF}}{12 C_P (R_y - \gamma_R \gamma_m \sigma_N)} \left(1 - \frac{s}{2l}\right) s l^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{R_y} \left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b, β_s : Coefficients defined in [3.7.3]

c_P : Ratio of the plastic section modulus to the elastic section modulus of the ordinary stiffeners with an attached shell plating b_p, to be taken equal to 1,16 in the absence of more precise evaluation.

3.8.4 Vertical ordinary stiffeners *(1/1/2017)*

The net section modulus w, in cm³, and the net shear sectional area A_{Sh}, in cm², of vertical ordinary stiffeners are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} \gamma_{bS} p_{SF} + \gamma_{W2} \gamma_{bW} p_{WF}}{12 C_P (R_y - \gamma_R \gamma_m \sigma_N)} \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} \lambda_{sS} p_{SF} + \gamma_{W2} \lambda_{sW} p_{WF}}{R_y} \left(1 - \frac{s}{21\ell}\right) s \ell$$

where:

β_b, β_s : Coefficients defined in [3.7.3]

c_P : Ratio defined in [3.8.3]

$$\lambda_{bS} = 1 + 0,2 \frac{p_{SFd} - p_{SFu}}{p_{SFd} + p_{SFu}}$$

$$\lambda_{bW} = 1 + 0,2 \frac{p_{WFd} - p_{WFu}}{p_{WFd} + p_{WFu}}$$

$$\lambda_{sS} = 1 + 0,4 \frac{p_{SFd} - p_{SFu}}{p_{SFd} + p_{SFu}}$$

$$\lambda_{sW} = 1 + 0,4 \frac{p_{WFd} - p_{WFu}}{p_{WFd} + p_{WFu}}$$

p_{SFd} : Still water pressure, in kN/m², in flooding conditions, at the lower end of the ordinary stiffener considered

p_{SFu} : Still water pressure, in kN/m², in flooding conditions, at the upper end of the ordinary stiffener considered

p_{WFd} : Wave pressure, in kN/m², in flooding conditions, at the lower end of the ordinary stiffener considered.

p_{WFu} : Wave pressure, in kN/m², in flooding conditions, at the upper end of the ordinary stiffener considered

3.9 Net section modulus and net shear sectional area of ordinary stiffeners subjected to lateral pressure in testing conditions

3.9.1 General *(1/1/2017)*

The requirements in [3.9.3] to [3.9.5] provide the minimum net section modulus and net shear sectional area of ordinary stiffeners of compartments subject to testing conditions.

3.9.2 Groups of equal ordinary stiffeners *(1/1/2017)*

Where a group of equal ordinary stiffeners is fitted, it is acceptable that the minimum net section modulus in [3.9.1] is calculated as the average of the values required for all the stiffeners of the same group, but this average is to be taken not less than 90% of the maximum required value.

The same applies for the minimum net shear sectional area.

3.9.3 Single span longitudinal and transverse ordinary stiffeners *(1/1/2017)*

The net section modulus w, in cm3, and the net shear sectional area A_{Sh}, in cm^2, of longitudinal or transverse ordinary stiffeners are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_T}{12 R_y}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_T}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b , β_s : Coefficients defined in [3.4.2]

3.9.4 Single span vertical ordinary stiffeners *(1/1/2017)*

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh} , in cm^2, of vertical ordinary stiffeners are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \lambda_b \beta_b \frac{\gamma_{S2} p_T}{12 R_y}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \lambda_s \beta_s \frac{\gamma_{S2} p_T}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b , β_s : Coefficients defined in [3.4.2]

λ_b : Coefficient taken equal to the greater of the following values:

$$\lambda_b = 1 + 0{,}2 \frac{p_{Td} - p_{Tu}}{p_{Td} + p_{Tu}}$$

$$\lambda_b = 1 - 0{,}2 \frac{p_{Td} - p_{Tu}}{p_{Td} + p_{Tu}}$$

λ_s : Coefficient taken equal to the greater of the following values:

$$\lambda_s = 1 + 0{,}4 \frac{p_{Td} - p_{Tu}}{p_{Td} + p_{Tu}}$$

$$\lambda_s = 1 - 0{,}4 \frac{p_{Td} - p_{Tu}}{p_{Td} + p_{Tu}}$$

p_{Td} : Still water pressure, in kN/m^2, in testing conditions, at the lower end of the ordinary stiffener considered

p_{Tu} : Still water pressure, in kN/m^2, in testing conditions, at the upper end of the ordinary stiffener considered.

3.9.5 Multispan ordinary stiffeners *(1/1/2017)*

The minimum net section modulus and the net shear sectional area of multispan ordinary stiffeners are to be obtained from [3.4.8], considering the pressure in testing conditions and taking account of the checking criteria indicated in [3.6].

4 Buckling check

4.1 Width of attached plating

4.1.1 The width of the attached plating to be considered for the buckling check of ordinary stiffeners is to be obtained, in m, from the following formulae:

- where no local buckling occurs on the attached plating (see Sec 1, [5.3.1]):

  $b_e = s$

- where local buckling occurs on the attached plating (see Sec 1, [5.3.1]):

  $$b_e = \left(\frac{2{,}25}{\beta_e} - \frac{1{,}25}{\beta_e^2}\right) s$$

  to be taken not greater than s

where:

$$\beta_e = \frac{s}{t_p}\sqrt{\frac{\sigma_b}{E}} 10^3$$

σ_b : Compression stress σ_X or σ_Y, in N/mm^2, acting on the plate panel, defined in Sec 1, [5.2.2], according to the direction x or y considered.

Table 6 : Hull girder normal compression stresses

Condition	σ_{S1} in N/mm^2 **(1)**	σ_{WV1} in N/mm^2	σ_{WH1} in N/mm^2
$z \geq N$	$\frac{M_{SW,S}}{I_Y}(z - N) 10^{-3}$	$\frac{0{,}625 F_D M_{WV,S}}{I_Y}(z - N) 10^{-3}$	$-\left\lvert\frac{0{,}625 M_{WH}}{I_Z} y\right\rvert 10^{-3}$
$z < N$	$\frac{M_{SW,H}}{I_Y}(z - N) 10^{-3}$	$\frac{0{,}625 M_{WV,H}}{I_Y}(z - N) 10^{-3}$	

(1) When the ship in still water is always in hogging condition, σ_{S1} for $z \geq N$ is to be obtained, in N/mm^2, from the following formula, unless σ_{X1} is evaluated by means of direct calculations (see [4.2.2]):

$$\sigma_{S1} = \frac{M_{SW,Hmin}}{I_Y}(z - N) 10^{-3}$$

Note 1:

F_D : Coefficient defined in Ch 5, Sec 2, [4].

4.2 Load model

4.2.1 Sign convention for normal stresses

The sign convention for normal stresses is as follows:

- tension: positive
- compression: negative.

4.2.2 Hull girder compression normal stresses

The hull girder compression normal stresses to be considered for the buckling check of ordinary stiffeners contributing to the hull girder longitudinal strength are obtained, in N/mm², from the following formula:

$$\sigma_{X1} = \gamma_{S1}\sigma_{S1} + \gamma_{W1}(C_{FV}\sigma_{WV1} + C_{FH}\sigma_{WH1})$$

where:

σ_{S1}, σ_{WV1}, σ_{WH1} : Hull girder normal stresses, in N/mm², defined in Tab 6

C_{FV}, C_{FH} : Combination factors defined in Tab 4.

For longitudinal stiffeners, σ_{X1} is to be taken as the maximum compression stress on the stiffener considered.

In no case may σ_{X1} be taken less than 30/k N/mm².

When the ship in still water is always in hogging condition, σ_{X1} may be evaluated by means of direct calculations when justified on the basis of the ship's characteristics and intended service. The calculations are to be submitted to the Society for approval.

4.2.3 Combined hull girder and local compression normal stresses

The combined compression normal stresses to be considered for the buckling check of ordinary stiffeners are to take into account the hull girder stresses and the local stresses resulting from the bending of the primary supporting members. These local stresses are to be obtained from a direct structural analysis using the design loads as given in Chapter 5.
With respect to the reference co-ordinate system defined in Ch 1, Sec 2, [10.1], the combined stresses in x and y direction are obtained, in N/mm², from the following formulae:

$$\sigma_X = \sigma_{X1} + \gamma_{S2}\sigma_{X2,S} + \gamma_{W2}\sigma_{X2,W}$$

$$\sigma_Y = \gamma_{S2}\sigma_{Y2,S} + \gamma_{W2}\sigma_{Y2,W}$$

where:

σ_{X1} : Compression normal stress, in N/mm², induced by the hull girder still water and wave loads, defined in [4.2.2]

$\sigma_{X2,S}$, $\sigma_{Y2,S}$: Compression normal stress in x and y direction, respectively, in N/mm², induced by the local bending of the primary supporting members and obtained from a direct structural analysis using the still water design loads as given in Chapter 5

$\sigma_{X2,W}$, $\sigma_{Y2,W}$: Compression normal stress in x and y direction, respectively, in N/mm², induced by the local bending of the primary supporting members and obtained from a direct structural analysis using the wave design loads as given in Chapter 5.

4.3 Critical stress

4.3.1 General

The critical buckling stress is to be obtained, in N/mm², from the following formulae:

$$\sigma_c = \sigma_E \qquad \text{for } \sigma_E \le \frac{R_{eH,S}}{2}$$

$$\sigma_c = R_{eH,S}\left(1 - \frac{R_{eH,S}}{4\sigma_E}\right) \qquad \text{for } \sigma_E > \frac{R_{eH,S}}{2}$$

where:

$\sigma_E = \min(\sigma_{E1}, \sigma_{E2}, \sigma_{E3})$

σ_{E1} : Euler column buckling stress, in N/mm², given in [4.3.2]

σ_{E2} : Euler torsional buckling stress, in N/mm², given in [4.3.3]

σ_{E3} : Euler web buckling stress, in N/mm², given in [4.3.4].

4.3.2 Column buckling of axially loaded stiffeners

The Euler column buckling stress is obtained, in N/mm², from the following formula:

$$\sigma_E = \pi^2 E \frac{I_e}{A_e \ell^2} 10^{-4}$$

4.3.3 Torsional buckling of axially loaded stiffeners

The Euler torsional buckling stresses is obtained, in N/mm², from the following formula:

$$\sigma_E = \frac{\pi^2 E I_w}{10^4 I_p \ell^2}\left(\frac{K_C}{m^2} + m^2\right) + 0{,}385 E \frac{I_t}{I_p}$$

where:

I_w : Net sectorial moment of inertia, in cm⁶, of the stiffener about its connection to the attached plating:

- for flat bars:

$$I_w = \frac{h_w^3 t_w^3}{36} 10^{-6}$$

- for T-sections:

$$I_w = \frac{t_f b_f^3 h_w^2}{12} 10^{-6}$$

- for angles and bulb sections:

$$I_w = \frac{b_f^3 h_w^2}{12(b_f + h_w)^2}[t_f b_f^2 + 2 b_f h_w + 4 h_w^2 + 3 t_w b_f h_w] 10^{-6}$$

I_p : Net polar moment of inertia, in cm⁴, of the stiffener about its connection to the attached plating:

- for flat bars:

$$I_p = \frac{h_w^3 t_w}{3} 10^{-4}$$

- for stiffeners with face plate:

$$I_p = \left(\frac{h_w^3 t_w}{3} + h_w^2 b_f t_f\right) 10^{-4}$$

I_t : St. Venant's net moment of inertia, in cm⁴, of the stiffener without attached plating:

- for flat bars:

$$I_t = \frac{h_w t_w^3}{3} 10^{-4}$$

- for stiffeners with face plate:

$$I_t = \frac{1}{3}\left[h_w t_w^3 + b_f t_f^3\left(1 - 0{,}63\frac{t_f}{b_f}\right)\right]10^{-4}$$

m : Number of half waves, to be taken equal to the integer number such that (see also Tab 7):

$$m^2(m-1)^2 \le K_C < m^2(m+1)^2$$

$$K_C = \frac{C_0 \ell^4}{\pi^4 E I_w} 10^6$$

C_0 : Spring stiffness of the attached plating:

$$C_0 = \frac{E t_p^3}{2{,}73 s} 10^{-3}$$

Table 7 : Torsional buckling of axially loaded stiffeners - Number m of half waves

K_C	$0 \le K_C < 4$	$4 \le K_C < 36$	$36 \le K_C < 144$
m	1	2	3

4.3.4 Web buckling of axially loaded stiffeners

The Euler buckling stress of the stiffener web is obtained, in N/mm^2, from the following formulae:

- for flat bars:

$$\sigma_E = 16\left(\frac{t_W}{h_W}\right)^2 10^4$$

- for stiffeners with face plate:

$$\sigma_E = 78\left(\frac{t_W}{h_W}\right)^2 10^4$$

4.4 Checking criteria

4.4.1 Stiffeners parallel to the direction of compression

The critical buckling stress of the ordinary stiffener is to comply with the following formula:

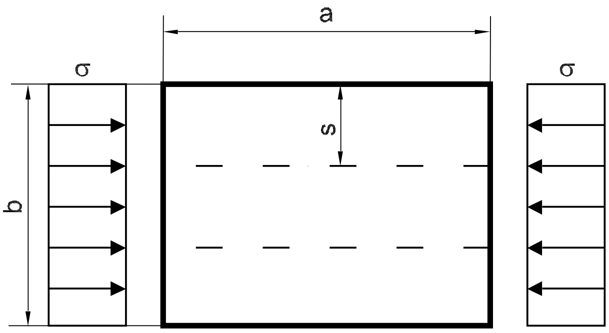
$$\frac{\sigma_c}{\gamma_R \gamma_m} \ge |\sigma_b|$$

where:

σ_c : Critical buckling stress, in N/mm^2, as calculated in [4.3.1]

σ_b : Compression stress σ_{xb} or σ_{yb} , in N/mm^2, in the stiffener, as calculated in [4.2.2] or [4.2.3].

Figure 5 : Buckling of stiffeners parallel to the direction of compression



4.4.2 Stiffeners perpendicular to the direction of compression

The net moment of inertia of stiffeners, in cm^4, is to be not less than the greatest value obtained from the following formulae:

- $I = 360\ell^2$
- for $\sigma \le R_{eH,P}/2$:

$$I = \frac{s t_p^3}{485}\left[\frac{\left(\frac{\ell}{s}\right)^4 - 4}{\sigma_{E,1} - \sigma_{E,0}}\right](\sigma - \sigma_{E,0})$$

- for $\sigma > R_{eH,P}/2$:

$$I = \frac{s t_p^3}{485}\left[\frac{\left(\frac{\ell}{s}\right)^4 - 4}{\sigma_{E,1} - \sigma_{E,0}}\right]\left[\frac{R_{eH,P}}{4\left(1 - \frac{\sigma}{R_{eH,P}}\right)} - \sigma_{E,0}\right]$$

where:

ℓ/s : Ratio to be taken not less than 1,41

$\sigma_{E,0}$: Euler buckling stress, in N/mm^2, of the unstiffened plate taken equal to:

$$\sigma_{E,0} = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_p}{\ell}\right)^2 \varepsilon K_{1,0}$$

$K_{1,0}$: Coefficient defined in Sec 1, Tab 8 for:

$0 \le \Psi \le 1$ and $\alpha = a/\ell$

ε : Coefficient defined in Sec 1, [5.3.1]

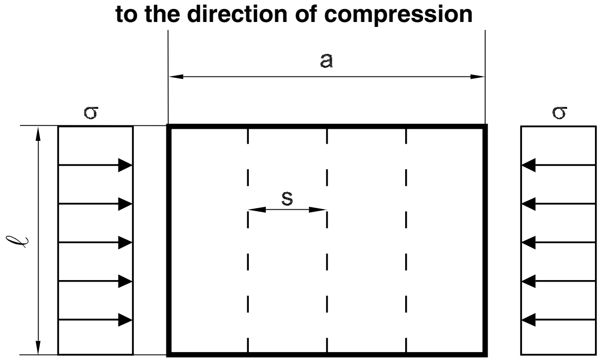
$\sigma_{E,1}$: Euler buckling stress, in N/mm^2, of the plate panel taken equal to:

$$\sigma_{E,1} = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_p}{\ell}\right)^2 \varepsilon K_{1,1}$$

$K_{1,1}$: Coefficient defined in Sec 1, Tab 8 for:

$0 \le \Psi \le 1$ and $\alpha = s/\ell$.

Figure 6 : Buckling of stiffeners perpendicular to the direction of compression

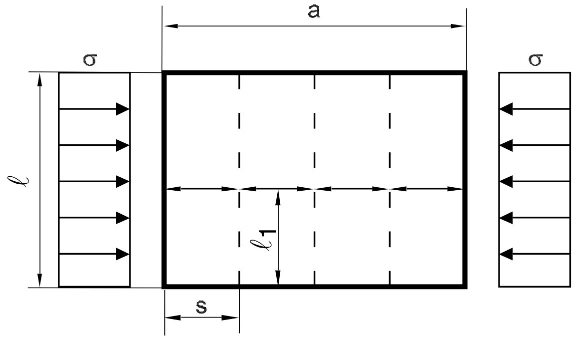


Where intercostal stiffeners are fitted, as shown in Fig 7, the check of the moment of inertia of stiffeners perpendicular to the direction of compression is to be carried out with the equivalent net thickness $t_{eq,net}$, in mm, obtained from the following formula:

$$t_{eq,net} = \frac{1+\left(\frac{s}{\ell_1}\right)^2}{1+\left(\frac{s}{\ell}\right)^2} t_{net}$$

where ℓ_1 is to be taken not less than s.

Figure 7 : Buckling of stiffeners perpendicular to the direction of compression (intercostal stiffeners)



5 Ultimate strength check of ordinary stiffeners contributing to the hull girder longitudinal strength

5.1 Application

5.1.1 The requirements of this Article apply to ships equal to or greater than 90 m in length. For such ships, the ultimate strength of stiffeners subjected to lateral pressure and to hull girder normal stresses is to be checked.

Table 8 : Ultimate strength stress

Symbol	Resultant load pressure acting on the side opposite to the ordinary stiffener, with respect to the plating, in N/mm²	Resultant load pressure acting on the same side as the ordinary stiffener, in N/mm²
σ_U	$f\dfrac{A_U}{A_S}\left(1-\dfrac{s}{10b_U}\right)R_{eH,P}$	$R_{eH,S}\, f$
f	$\dfrac{\zeta}{2}-\sqrt{\dfrac{\zeta^2}{4}-\dfrac{1-\mu}{(1+\eta_P)\lambda_U^2}}$	
ζ	$\dfrac{1-\mu}{1+\eta_P}+\dfrac{1+\eta_P+\eta}{(1+\eta_P)\lambda_U^2}$	
μ	$\dfrac{125ps\ell^2 d_{P,U}}{R_{eH,P}I_U\left(1-\dfrac{s}{10b_U}\right)}$	$\dfrac{41,7ps\ell^2 d_{F,S}}{R_{eH,S}I_S}$
η	$\left(\delta_0+\dfrac{13ps\ell^4}{E_T I_S}10^4\right)\dfrac{d_{P,U}}{\rho_U^2}$	$\left(0,577\delta_0+\dfrac{1,5ps\ell^4}{E_T I_S}10^4\right)\dfrac{d_{F,S}}{\rho_S^2}$
η_P	$d_P A\left(\dfrac{1}{A_U}-\dfrac{1}{A_S}\right)\dfrac{d_{P,U}}{\rho_U^2}$	0
λ_U	$\dfrac{31,8\ell}{\rho_U}\sqrt{\dfrac{R_{eH,P}}{E_T}\left(1-\dfrac{s}{10b_U}\right)}$	$\dfrac{18,4\ell}{\rho_S}\sqrt{\dfrac{R_{eH,S}}{E_T}}$

Note 1:

σ_{C2} : Critical torsional buckling stress, in N/mm², defined in [4.3.1]

$d_{P,U}$: Distance, in cm, between the neutral axis of the cross-section of the stiffener with attached plating of width b_U and the fibre at half-thickness of the plating

$d_{F,S}$: Distance, in cm, between the neutral axis of the cross-section of the stiffener with attached plating of width s and the fibre at half-thickness of the face plate of the stiffener

d_P : Distance, in cm, between the neutral axis of the ordinary stiffener without attached plating and the fibre at half-thickness of the attached plating

A : Net sectional area, in cm², of the stiffener without attached plating

p : Lateral pressure acting on the stiffener, equal to: $p = \gamma_{S2}\, p_S + \gamma_{W2U}\, p_W$

δ_0 : Pre-deformation, in cm, of the ordinary stiffener, to be assumed, in the absence of more accurate evaluation: $\delta_0 = 0,2\,\ell$

E_T : Structural tangent modulus, equal to:

$$E_T = 4E\frac{\sigma_{X1E}}{R_{eH,P}}\left(1-\frac{\sigma_{X1E}}{R_{eH,P}}\right) \quad \text{for} \quad \sigma_{X1E} > 0,5R_{eH,P}$$

$$E_T = E \quad \text{for} \quad \sigma_{X1E} \le 0,5R_{eH,P}$$

σ_{X1E} : Stress to be obtained, in N/mm², from the following formulae:

$$\sigma_{X1E} = \left\{\frac{-\dfrac{22,5st_P}{\alpha}+\sqrt{\left(\dfrac{22,5st_P}{\alpha}\right)^2+4A\left[(A_S+10st_P)\sigma_{X1}+\dfrac{12,5st_P}{\alpha^2}\right]}}{2A}\right\}^2 \quad \text{if} \quad \alpha > \frac{1,25}{\sqrt{|\sigma_{X1}|}}$$

$$\sigma_{X1E} = \sigma_{X1} \quad \text{if} \quad \alpha \le \frac{1,25}{\sqrt{|\sigma_{X1}|}}$$

$$\alpha = 1000\frac{s}{t_P\sqrt{E}}$$

σ_{X1} : Compression stress, in N/mm², acting on the stiffener, as defined in [5.3.3].

5.2 Width of attached plating

5.2.1 The width of the attached plating to be considered for the ultimate strength check of ordinary stiffeners is to be obtained, in m, from the following formulae:

- if $\beta_U \le 1,25$:

$b_U = s$

- if $\beta_U > 1{,}25$:

$$b_U = \left(\frac{2{,}25}{\beta_U} - \frac{1{,}25}{\beta_U^2}\right)s$$

where:

$$\beta_U = \frac{s}{t_p}\sqrt{\frac{\sigma_{X1E}}{E}}10^3$$

σ_{X1E} : Stress defined in Tab 8.

5.3 Load model

5.3.1 General

The still water and wave lateral pressures induced by the sea and the various types of cargoes and ballast in intact conditions are to be considered, depending on the location of the ordinary stiffener under consideration and the type of compartments adjacent to it, in accordance with Ch 5, Sec 2.

The wave lateral pressures and hull girder loads are to be calculated in the mutually exclusive load cases "a", "b", "c" and "d" in Ch 5, Sec 4.

5.3.2 Lateral pressure

Lateral pressure is constituted by still water pressure and wave pressure.

Still water pressure (p_S) includes:

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

Wave induced pressure (p_W) includes:

- the wave pressure, defined in Ch 5, Sec 5, [2] for each load case "a", "b", "c" and "d"
- the inertial pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast, and for each load case "a", "b", "c" and "d".

5.3.3 Hull girder compression normal stresses

The hull girder compression normal stresses σ_{X1} to be considered for the ultimate strength check of stiffeners contributing to the longitudinal strength are those given in [4.2.2], where the partial safety factors are those specified in Tab 1 for the ultimate strength check.

5.4 Ultimate strength stress

5.4.1 The ultimate strength stress σ_U is to be obtained, in N/mm^2, from the formulae in Tab 8, for resultant lateral pressure acting either on the side opposite to the ordinary stiffener, with respect to the plating, or on the same side as the ordinary stiffener.

5.5 Checking criteria

5.5.1 The ultimate strength stress of the ordinary stiffener is to comply with the following formula:

$$\frac{\sigma_U}{\gamma_R \gamma_m} \geq |\sigma_{X1}|$$

where:

σ_U : Ultimate strength stress, in N/mm^2, as calculated in [5.4.1]

σ_{X1} : Compression stress, in N/mm^2, as calculated in [5.3.3].

SECTION 3 PRIMARY SUPPORTING MEMBERS

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

p_S : Still water pressure, in kN/m², see [3.4.2] and [3.4.4]

p_W : Wave pressure, in kN/m², see [3.4.2] and [3.4.4]

p_{SF}, p_{WF} : Still water and wave pressures, in kN/m², in flooding conditions, defined in Ch 5, Sec 6, [7]

σ_{X1} : Hull girder normal stress, in N/mm², defined in [3.4.6]

σ_N : Normal stress, in N/mm², defined in [3.4.6]

s : Spacing, in m, of primary supporting members

ℓ : Span, in m, of primary supporting members, measured between the supporting elements, see Ch 4, Sec 3, [4.1]

ℓ_b : Length, in m, of one bracket, see [3.2] and Ch 4, Sec 3, [4.4]

b_p : Width, in m, of the plating attached to the primary supporting member, for the yielding check, defined in Ch 4, Sec 3, [4.2]

w : Net section modulus, in cm³, of the primary supporting member, with an attached plating of width b_p, to be calculated as specified in Ch 4, Sec 3, [4.3]

A_{Sh} : Net shear sectional area, in cm², of the primary supporting member, to be calculated as specified in Ch 4, Sec 3, [4.3]

m : Boundary coefficient, to be taken equal to:

- m = 10 in general
- m = 12 for bottom and side girders

I : Net moment of inertia, in cm⁴, of the primary supporting member without attached plating, about its neutral axis parallel to the plating

I_B : Net moment of inertia, in cm⁴, of the primary supporting member with bracket and without attached plating, about its neutral axis parallel to the plating, calculated at mid-length of the bracket

$\chi = I_B/I$

$\alpha = \ell_b/\ell$

1 General

1.1 Application

1.1.1 Analysis criteria

The requirements of this Section apply for the yielding and buckling checks of primary supporting members.

Depending on their arrangement, primary supporting members are to be analysed through one of the following models:

- an isolated beam structural model
- a three dimensional structural model
- a complete ship structural model.

1.1.2 Structural models

Depending on the length, primary structural models are to be adopted as specified in Tab 1.

Table 1 : Selection of structural models

Ship length, in m	Calculation model
L < 90	Isolated beam model, or three dimensional beam model for grillage or complex arrangements
L ≥ 90	Three dimensional beam model **(1)**
(1) A three dimensional finite element model or a complete ship model may also be used	

1.1.3 Yielding check

The yielding check is to be carried out according to:

- [3] for primary supporting members analysed through isolated beam models
- [4] for primary supporting members analysed through three dimensional models
- [5] for primary supporting members analysed through complete ship models.

1.1.4 Buckling check

The buckling check is to be carried out according to [6], on the basis of the stresses in primary supporting members calculated according to [3], [4] or [5], depending on the structural model adopted.

Table 2 : Primary supporting members analysed through isolated beam models - Partial safety factors

Partial safety factors covering uncertainties regarding:	Symbol	Yielding check		Buckling check	
		General (see [3.4] to [3.7])	Watertight bulkhead primary supporting members **(1)** (see [3.8])	Plate panels (see [6.1])	Pillars (see [6.2] and [6.3])
Still water hull girder loads	γ_{S1}	1,00	1,00	1,00	1,00
Wave hull girder loads	γ_{W1}	1,15	1,15	1,15	1,15
Still water pressure	γ_{S2}	1,00	1,00	1,00	1,00
Wave pressure	γ_{W2}	1,20	1,05	1,20	1,20
Material	γ_m	1,02	1,02	1,02	1,02
Resistance	γ_R	• 1,02 in general • 1,15 for bottom and side girders	1,02 **(2)**	1,10	For [6.2]: see Tab 12 For [6.3]: 1,15

(1) Applies also to primary supporting members of bulkheads or inner side which constitute boundary of compartments not intended to carry liquids.
(2) For primary supporting members of the collision bulkhead, γ_R =1,25

Table 3 : Primary supporting members analysed through three dimensional models - Partial safety factors

Partial safety factors covering uncertainties regarding:	Symbol	Yielding check (see [4])		Buckling check	
		General	Watertight bulkhead primary supporting members **(1)**	Plate panels (see [6.1])	Pillars (see [6.2] and [6.3])
Still water hull girder loads	γ_{S1}	1,05	1,05	1,05	1,05
Wave hull girder loads	γ_{W1}	1,05	1,05	1,05	1,05
Still water pressure	γ_{S2}	1,00	1,00	1,00	1,00
Wave pressure	γ_{W2}	1,10	1,10	1,10	1,10
Material	γ_m	1,02	1,02	1,02	1,02
Resistance	γ_R	Defined in Tab 5 and Tab 6	Defined in Tab 5 and Tab 6	1,02	For [6.2]: see Tab 12 For [6.3]: 1,15

(1) Applies also to primary supporting members of bulkheads or inner side which constitute boundary of compartments not intended to carry liquids.
Note 1: For primary supporting members of the collision bulkhead, γ_R =1,25

Table 4 : Primary supporting members analysed through complete ship models - Partial safety factors

Partial safety factors covering uncertainties regarding:	Symbol	Yielding check (see [5])	Buckling check	
			Plate panels (see [6.1])	Pillars (see [6.2] and [6.3])
Still water hull girder loads	γ_{S1}	1,00	1,00	1,00
Wave hull girder loads	γ_{W1}	1,10	1,10	1,10
Still water pressure	γ_{S2}	1,00	1,00	1,00
Wave pressure	γ_{W2}	1,10	1,10	1,10
Material	γ_m	1,02	1,02	1,02
Resistance	γ_R	Defined in Tab 5 and Tab 6	1,02	For [6.2]: see Tab 12 For [6.3]: 1,15

Table 5 : Primary supporting members analysed through three dimensional or complete ship models Resistance partial safety factor

Type of three dimensional model (see App 1)	Resistance partial safety factor γ_R (see [4.3.1] and [5.3.1])	
	General	Watertight bulkhead primary supporting members
Beam model	1,20	1,02
Coarse mesh finite element model	1,20	1,02
Fine mesh finite element model	1,10	1,02

Table 6 : Additional criteria for analyses based on fine mesh finite element models Resistance partial safety factor

Symbol	Resistance partial safety factor (see [4.3.2] and [5.3.2])	
	General	Watertight bulkhead primary supporting members
γ_R	1,10	1,02

1.1.5 Minimum net thicknesses

In addition to the above, the scantlings of primary supporting members are to comply with the requirements in [2].

1.1.6 Normal mode analysis

A normal mode analysis of primary supporting members may be required by the Society to be carried out, when deemed necessary on the basis of the expected frequency of cyclic loads.

1.2 Net scantlings

1.2.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 4, Sec 2.

1.3 Partial safety factors

1.3.1 The partial safety factors to be considered for checking primary supporting members are specified in:

- Tab 2 for analyses based on isolated beam models
- Tab 3 for analyses based on three dimensional models
- Tab 4 for analyses based on complete ship models.

2 Minimum net thicknesses

2.1 General

2.1.1 The net thickness of plating which forms the webs of primary supporting members is to be not less than the value obtained, in mm, from the following formulae:

$t_{MIN} = 3,7 + 0,015Lk^{1/2}$ for $L < 120$ m

$t_{MIN} = 3,7 + 1,8k^{1/2}$ for $L \geq 120$ m

3 Yielding check of primary supporting members analysed through an isolated beam structural model

3.1 General

3.1.1 The requirements of this Article apply for the yielding check of primary supporting members subjected to lateral pressure, wheeled loads or weapon firing dynamic loads and, for primary supporting members contributing to the hull girder longitudinal strength, to hull girder normal stresses, which are to be analysed through an isolated beam model, according to [1.1.2].

3.1.2 The yielding check is also to be carried out for primary supporting members subjected to specific loads, such as concentrated loads.

3.2 Bracket arrangement

3.2.1 The requirements of this Article apply to primary supporting members with brackets at both ends of length not greater than $0,2\ell$.

In the case of a significantly different bracket arrangement, the determination of normal and shear stresses due to design loads and the required section modulus and shear sectional area are considered by the Society on a case by case basis.

3.3 Load point

3.3.1 Lateral pressure

Unless otherwise specified, lateral pressure is to be calculated at mid-span of the primary supporting member considered.

3.3.2 Hull girder normal stresses

For longitudinal primary supporting members contributing to the hull girder longitudinal strength, the hull girder normal stresses are to be calculated in way of the face plate of the primary supporting member considered.

For bottom and deck girders, it may generally be assumed that the hull girder normal stresses in the face plate are equal to 0,75 times those in the relevant plating.

3.4 Load model

3.4.1 General

The still water and wave lateral pressures induced by the sea and the various types of cargoes and ballast in intact conditions are to be considered, depending on the location of the primary supporting member under consideration and the type of compartments adjacent to it, in accordance with Ch 5, Sec 1, [2.4].

Primary supporting members of bulkheads or inner side which constitute the boundary of compartments not intended to carry liquids are to be subjected to the lateral pressure in flooding conditions.

The wave lateral pressures and hull girder loads are to be calculated in the mutually exclusive load cases “a”, “b”, “c” and “d” in Ch 5, Sec 4.

3.4.2 Lateral pressure in intact conditions

The lateral pressure in intact conditions is constituted by still water pressure and wave pressure.

Still water pressure (p_S) includes:

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

Wave pressure (p_W) includes:

- the wave pressure, defined in Ch 5, Sec 5, [2] for each load case “a”, “b”, “c” and “d”
- the inertial pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast, and for each load case “a”, “b”, “c” and “d”.

3.4.3 Lateral pressure in flooding conditions

The lateral pressure in flooding conditions is constituted by the still water pressure p_{SF} and the wave pressure p_{WF} defined in Ch 5, Sec 6, [7].

3.4.4 Wheeled loads

For primary supporting members subjected to wheeled loads, the yielding check may be carried out according to [3.5] to [3.7] considering uniform pressures equivalent to the distribution of vertical concentrated forces, when such forces are closely located.

For the determination of the equivalent uniform pressures, the most unfavourable case, i.e. where the maximum number of axles are located on the same primary supporting member, according to Fig 1 to Fig 3, is to be considered.

The equivalent still water pressure and inertial pressure are indicated in Tab 7.

For arrangements different from those shown in Fig 1 to Fig 3, the yielding check of primary supporting members is to be carried out by a direct calculation, taking into account the distribution of concentrated loads induced by vehicle wheels.

Table 7 : Wheeled loads
Equivalent uniform still water and inertial pressures

Ship condition	Load case	Still water pressure p_S and inertial pressure p_W, in kN/m²
Still water condition		$p_S = 10\ p_{eq}$
Upright condition	“a”	No inertial pressure
	“b”	$p_W = p_{eq} a_{Z1}$
Inclined condition	“c”	The inertial pressure may be disregarded
	“d”	$p_W = p_{eq} a_{Z2}$

Note 1:

$$p_{eq} = \frac{n_V Q_A}{\ell s}\left(3 - \frac{X_1 + X_2}{s}\right)$$

n_V : Maximum number of vehicles possible located on the primary supporting member

Q_A : Maximum axle load, in t, defined in Ch 5, Sec 6, Tab 5

X_1 : Minimum distance, in m, between two consecutive axles (see Fig 2 and Fig 3)

X_2 : Minimum distance, in m, between axles of two consecutive vehicles (see Fig 3).

Figure 1 : Wheeled loads - Distribution of vehicles on a primary supporting member

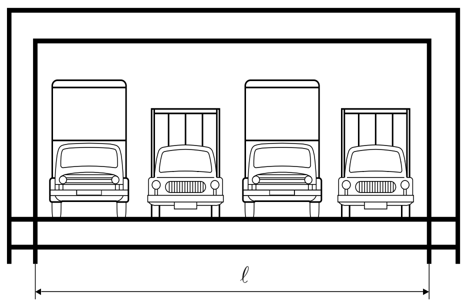


Figure 2 : Wheeled loads
Distance between two consecutive axles

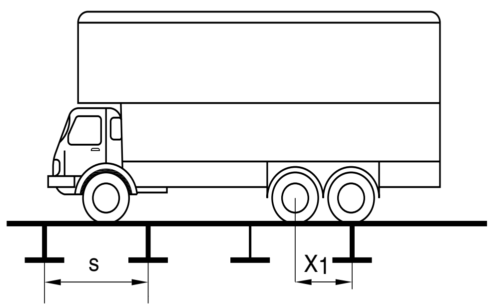
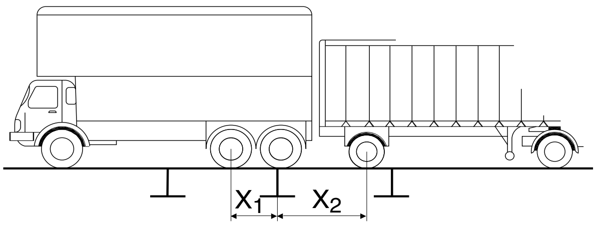


Figure 3 : Wheeled loads
Distance between axles of two consecutive vehicles



3.4.5 Weapon firing dynamic loads

For primary supporting members subjected to weapon firing dynamic loads, the yielding check may be carried out according to [3.7.4] considering uniform pressure distribution.

The pressure p_W is to be calculated according to the requirements specified in Ch 5, Sec 6, [8] for the following weapon firing dynamic loads:

- missile blast dynamic pressure
- accidental missile ignition dynamic pressure
- gun blast dynamic pressure.

For primary supporting members subjected to the gun recoil dynamic force and, in general, when the weapon firing dynamic loads cannot be considered as uniformly distributed, the yielding check is to be carried out taking into account the actual load distribution.

3.4.6 Normal stresses

The normal stresses to be considered for the yielding check of primary supporting members are obtained, in N/mm², from the following formulae:

- for longitudinal primary supporting members contributing to the hull girder longitudinal strength:

$$\sigma_N = \sigma_{X1} = \gamma_{S1}\sigma_{S1} + \gamma_{W1}(C_{FV}\sigma_{WV1} + C_{FH}\sigma_{WH1})$$

- for longitudinal primary supporting members not contributing to the hull girder longitudinal strength and for transverse primary supporting members:

$$\sigma_N = 45/kN/mm^2$$

where:

σ_{S1}, σ_{WV1}, σ_{WH1} : Hull girder normal stresses, in N/mm², defined in:
- Tab 8 for primary supporting members subjected to lateral pressure,
- Tab 9 for primary supporting members subjected to wheeled loads

C_{FV}, C_{FH} : Combination factors defined in Tab 10.

3.5 Normal and shear stresses due to lateral pressure in intact conditions

3.5.1 General

Normal and shear stresses, induced by lateral pressures, in primary supporting members are to be determined from the formulae given in:

- [3.5.2] in the case of longitudinal and transverse primary supporting members
- [3.5.3] in the case of vertical primary supporting members.

Table 8 : Hull girder normal stresses - Primary supporting members subjected to lateral pressure

Condition		σ_{S1} , in N/mm² **(1)**	σ_{WV1} , in N/mm²	σ_{WH1} , in N/mm²
Lateral pressure applied on the side opposite to the primary supporting member, with respect to the plating:	$z \geq N$	$\left\|\frac{M_{SW,S}}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\frac{0{,}625 F_D M_{WV,S}}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\frac{0{,}625 M_{WH}}{I_Z}y\right\|10^{-3}$
	$z < N$	$\left\|\frac{M_{SW,H}}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\frac{0{,}625 M_{WV,H}}{I_Y}(z-N)\right\|10^{-3}$	
Lateral pressure applied on the same side as the primary supporting member:	$z \geq N$	$\left\|\frac{M_{SW,H}}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\frac{0{,}625 M_{WV,H}}{I_Y}(z-N)\right\|10^{-3}$	
	$z < N$	$\left\|\frac{M_{SW,S}}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\frac{0{,}625 F_D M_{WV,S}}{I_Y}(z-N)\right\|10^{-3}$	

(1) When the ship in still water is always in hogging condition, $M_{SW,S}$ is to be taken equal to 0.
Note 1:
F_D : Coefficient defined in Ch 5, Sec 2, [4].

Table 9 : Hull girder normal stresses - Primary supporting members subjected to wheeled loads

Condition	σ_{S1} in N/mm² **(1)**	σ_{WV1} in N/mm²	σ_{WH1} in N/mm²
$z \geq N$	$\left\lvert \frac{M_{SW,H}}{I_Y}(z-N) \right\rvert 10^{-3}$	$\left\lvert \frac{0,625 M_{WV,H}}{I_Y}(z-N) \right\rvert 10^{-3}$	$\left\lvert \frac{0,625 M_{WH}}{I_Z} y \right\rvert 10^{-3}$
$z < N$	$\left\lvert \frac{M_{SW,S}}{I_Y}(z-N) \right\rvert 10^{-3}$	$\left\lvert \frac{0,625 F_D M_{WV,S}}{I_Y}(z-N) \right\rvert 10^{-3}$	

(1) When the ship in still water is always in hogging condition, $M_{SW,S}$ is to be taken equal to 0.
Note 1:
F_D : Coefficient defined in Ch 5, Sec 2, [4].

Table 10 : Combination factors C_{FV} and C_{FH}

Load case	C_{FV}	C_{FH}
"a"	1,0	0
"b"	1,0	0
"c"	0,4	1,0
"d"	0,4	1,0

3.5.2 Longitudinal and transverse primary supporting members

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm², from the following formulae:

$$\sigma = \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m w} s \ell^2 10^3 + \sigma_N$$

$$\tau = 5\beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{A_{Sh}} s \ell$$

where:

$$\beta_b = \frac{\chi(1-2\alpha)^3 + 2\alpha^2(4\alpha - 3)}{\chi(1-2\alpha) + 2\alpha}$$

to be taken not less than 0,55.

$$\beta_s = 1 - 2\alpha$$

3.5.3 Vertical primary supporting members

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm², from the following formulae:

$$\sigma = \beta_b \frac{\gamma_{S2}\lambda_{bS} p_S + \gamma_{W2}\lambda_{bW} p_W}{m w} s \ell^2 10^3 + \sigma_A$$

$$\tau = 5\beta_s \frac{\gamma_{S2}\lambda_{sS} p_S + \gamma_{W2}\lambda_{sW} p_W}{A_{Sh}} s \ell$$

where:

β_b, β_s : Coefficients defined in [3.5.2]

$$\lambda_{bS} = 1 + 0,2\frac{p_{Sd} - p_{Su}}{p_{Sd} + p_{Su}}$$

$$\lambda_{bW} = 1 + 0,2\frac{p_{Wd} - p_{Wu}}{p_{Wd} + p_{Wu}}$$

$$\lambda_{sS} = 1 + 0,4\frac{p_{Sd} - p_{Su}}{p_{Sd} + p_{Su}}$$

$$\lambda_{sW} = 1 + 0,4\frac{p_{Wd} - p_{Wu}}{p_{Wd} + p_{Wu}}$$

p_{Sd} : Still water pressure, in kN/m², at the lower end of the primary supporting member considered

p_{Su} : Still water pressure, in kN/m², at the upper end of the primary supporting member considered

p_{Wd} : Wave pressure, in kN/m², at the lower end of the primary supporting member considered

p_{Wu} : Wave pressure, in kN/m², at the upper end of the primary supporting member considered

σ_A : Axial stress, to be obtained, in N/mm², from the following formula:

$$\sigma_A = 10\frac{F_A}{A}$$

F_A : Axial load (still water and wave) transmitted to the vertical primary supporting members by the structures above. For multideck ships, the criteria in [6.2.1] for pillars are to be adopted.

A : Net sectional area, in cm², of the vertical primary supporting members with attached plating of width b_P.

3.6 Checking criteria

3.6.1 General

It is to be checked that the normal stress σ and the shear stress τ, calculated according to [3.5], are in compliance with the following formulae:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma$$

$$0,5\frac{R_y}{\gamma_R \gamma_m} \geq \tau$$

3.7 Net section modulus and net sectional shear area complying with the checking criteria

3.7.1 General

The requirements in [3.7.2] and [3.7.3] provide the minimum net section modulus and net shear sectional area of primary supporting members subjected to lateral pressure in intact conditions, complying with the checking criteria indicated in [3.6].

The requirements in [3.7.4] provide the minimum net section modulus and net shear sectional area of primary supporting members subjected to weapon firing dynamic loads.

3.7.2 Longitudinal and transverse primary supporting members

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh} , in cm^2, of longitudinal or transverse primary supporting members are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m(R_y - \gamma_R \gamma_m \sigma_N)} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} s \ell$$

where β_b and β_s are the coefficients defined in [3.5.2].

3.7.3 Vertical primary supporting members

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh} , in cm^2, of vertical primary supporting members are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} \lambda_{bS} p_S + \gamma_{W2} \lambda_{bW} p_W}{m(R_y - \gamma_R \gamma_m \sigma_A)} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} \lambda_{sS} p_S + \gamma_{W2} \lambda_{sW} p_W}{R_y} s \ell$$

where:

β_b, β_s : Coefficients defined in [3.5.2]

λ_{bs}, λ_{bW}, λ_{sS}, λ_{sW} : Coefficients defined in [3.5.3]

σ_A : Defined in [3.5.3].

3.7.4 Primary supporting members subjected to weapon firing dynamic loads

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of primary supporting members subjected to weapon firing dynamic loads are to be not less than the values obtained from the following formulae:

$$w = c_C \gamma_R \gamma_m \beta_b \frac{\gamma_{W2} p_W s \ell^2}{8 R_y} 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{W2} p_W s \ell^2}{R_y}$$

where:

β_b, β_s : Coefficients defined in [3.5.2].

3.8 Net section modulus and net shear sectional area of primary supporting members subjected to lateral pressure in flooding conditions

3.8.1 General

The requirements in [3.8.1] to [3.8.3] apply to primary supporting members of bulkheads or inner side which constitute the boundary of compartments not intended to carry liquids.

These primary supporting members are to be checked in flooding conditions as specified in [3.8.2] and [3.8.3], depending on the type of member.

3.8.2 Longitudinal and transverse primary supporting members

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh} , in cm^2, of longitudinal or transverse primary supporting members are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{16 c_P (R_y - \gamma_R \gamma_m \sigma_N)} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{R_y} s \ell$$

where:

β_b, β_s : Coefficients defined in [3.5.2]

c_P : Ratio of the plastic section modulus to the elastic section modulus of the primary supporting members with an attached plating b_p , to be taken equal to 1,16 in the absence of more precise evaluation.

3.8.3 Vertical primary supporting members

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh} , in cm^2, of vertical primary supporting members are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} \lambda_{bS} p_{SF} + \gamma_{W2} \lambda_{bW} p_{WF}}{16 c_P (R_y - \gamma_R \gamma_m \sigma_A)} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} \lambda_{sS} p_{SF} + \gamma_{W2} \lambda_{sW} p_{WF}}{R_y} s \ell$$

where:

β_b, β_s : Coefficients defined in [3.5.2]

c_P : Ratio defined in [3.8.2]

$$\lambda_{bS} = 1 + 0{,}2 \frac{p_{SFd} - p_{SFu}}{p_{SFd} + p_{SFu}}$$

$$\lambda_{bW} = 1 + 0{,}2 \frac{p_{WFd} - p_{WFu}}{p_{WFd} + p_{WFu}}$$

$$\lambda_{sS} = 1 + 0{,}4 \frac{p_{SFd} - p_{SFu}}{p_{SFd} + p_{SFu}}$$

$$\lambda_{sW} = 1 + 0{,}4 \frac{p_{WFd} - p_{WFu}}{p_{WFd} + p_{WFu}}$$

p_{SFd} : Still water pressure, in kN/m^2, in flooding conditions, at the lower end of the primary supporting member considered

p_{SFu} : Still water pressure, in kN/m^2, in flooding conditions, at the upper end of the primary supporting member considered

p_{WFd} : Wave pressure, in kN/m^2, in flooding conditions, at the lower end of the primary supporting member considered.

p_{WFu} : Wave pressure, in kN/m^2, in flooding conditions, at the upper end of the primary supporting member considered

σ_A : Defined in [3.5.3].

4 Yielding check of primary supporting members analysed through a three dimensional structural model

4.1 General

4.1.1 The requirements of this Article apply for the yielding check of primary supporting members subjected to lateral pressure, wheeled loads or weapon firing dynamic loads and, for those contributing to the hull girder longitudinal strength, to hull girder normal stresses, which are to be analysed through a three dimensional structural model, according to [1.1.2].

4.1.2 The yielding check is also to be carried out for primary supporting members subjected to specific loads, such as concentrated loads.

4.2 Analysis criteria

4.2.1 The analysis of primary supporting members based on three dimensional models is to be carried out according to:

- the requirements in App 1 for primary supporting members subjected to lateral pressure or weapon firing dynamic loads
- the requirements in App 2 for primary supporting members subjected to wheeled loads.

These requirements apply for:

- the structural modelling
- the load modelling
- the stress calculation.

4.3 Checking criteria

4.3.1 General

For all types of analysis (see App 1, [2]), it is to be checked that the equivalent stress σ_{VM} , calculated according to App 1, [5] is in compliance with the following formula:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma_{VM}$$

4.3.2 Additional criteria for analyses based on fine mesh finite element models

Fine mesh finite element models are defined with reference to App 1, [3.4].

For all the elements of the fine mesh models, it is to be checked that the normal stresses σ_1 and σ_2 and the shear stress τ_{12}, calculated according to App 1, [5], are in compliance with the following formulae:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \max(\sigma_1, \sigma_2)$$

$$0{,}5\frac{R_y}{\gamma_R \gamma_m} \geq \tau_{12}$$

4.3.3 Specific case of primary supporting members subjected to wheeled loads

For all types of analysis (see App 2, [2]), it is to be checked that the equivalent stress σ_{VM}, calculated according to App 2, [5] is in compliance with the following formula:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma_{VM}$$

5 Yielding check of primary supporting members analysed through a complete ship structural model

5.1 General

5.1.1 The requirements of this Article apply for the yielding check of primary supporting members which are to be analysed through a complete ship structural model.

5.1.2 A complete ship structural model is to be carried out, when deemed necessary by the Society, to analyse primary supporting members of ships with one or more of the following characteristics:

- ships having large deck openings
- ships having large space arrangements
- multideck ships having series of openings in side or longitudinal bulkheads, when the stresses due to the different contribution of each deck to the hull girder strength are to be taken into account.

5.2 Analysis criteria

5.2.1 The analysis of primary supporting members based on complete ship models is to be carried out according to App 3.

These requirements apply for:

- the structural modelling
- the load modelling
- the stress calculation.

5.3 Checking criteria

5.3.1 General

It is to be checked that the equivalent stress σ_{VM} , calculated according to App 3, [4] is in compliance with the following formula:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma_{VM}$$

5.3.2 Additional criteria for elements modelled with fine meshes

Fine meshes are defined with reference to App 3, [2.4].

For all the elements modelled with fine meshes, it is to be checked that the normal stresses σ_1 and σ_2 and the shear stress τ_{12} , calculated according to App 3, [4], are in compliance with the following formulae:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \max(\sigma_1, \sigma_2)$$

$$0,5\frac{R_y}{\gamma_R\gamma_m} \geq \tau_{12}$$

6 Buckling check

6.1 Local buckling of plate panels

6.1.1 A local buckling check is to be carried out, according to Sec 1, [5], for plate panels which constitute primary supporting members.

In carrying out this check, the stresses in the plate panels are to be calculated according to [3], [4] or [5], depending on the structural model adopted for the analysis of primary supporting members.

6.2 Buckling of pillars subjected to compression axial load

6.2.1 Compression axial load

The compression axial load in the pillar is to be obtained, in kN, from the following formula:

$$F_A = A_D(\gamma_{S2}p_S + \gamma_{W2}p_W) + \sum_i r(\gamma_{S2}Q_{i,S} + \gamma_{W2}Q_{i,W})$$

where:

A_D : Area, in m², of the portion of the deck or the platform supported by the pillar considered

r : Coefficient which depends on the relative position of each pillar above the one considered, to be taken equal to:

- $r = 1,0$ for the pillar considered
- $r = 0,9$ for the pillar immediately above that considered
- $r = 0,9^i$ for the i^{th} pillar of the line above the pillar considered, to be taken not less than 0,478

$Q_{i,S}$, $Q_{i,W}$: Still water and wave load, respectively, in kN, from the i^{th} pillar of the line above the pillar considered, if any.

6.2.2 Critical column buckling stress of pillars

The critical column buckling stress of pillars is to be obtained, in N/mm², from the following formulae:

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

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

where:

σ_{E1} : Euler column buckling stress, to be obtained, in N/mm², from the following formula:

$$\sigma_{E1} = \pi^2 E\frac{I}{A(f\ell)^2}10^{-4}$$

I : Minimum net moment of inertia, in cm⁴, of the pillar

A : Net cross-sectional area, in cm², of the pillar

ℓ : Span, in m, of the pillar

f : Coefficient, to be obtained from Tab 11.

6.2.3 Critical torsional buckling stress of built-up pillars

The critical torsional buckling stress of built-up pillars is to be obtained, in N/mm², from the following formulae:

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

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

where:

σ_{E2} : Euler torsional buckling stress, to be obtained, in N/mm², from the following formula:

$$\sigma_{E2} = \frac{\pi^2 E I_w}{10^4 I_p \ell^2} + 0,41 E\frac{I_t}{I_p}$$

I_w : Net sectorial moment of inertia of the pillar, to be obtained, in cm⁶, from the following formula:

$$I_w = \frac{t_f b_f^3 h_w^2}{24}10^{-6}$$

h_W : Web height of built-up section, in mm

t_W : Net web thickness of built-up section, in mm

b_F : Face plate width of built-up section, in mm

t_F : Net face plate thickness of built-up section, in mm

I_p : Net polar moment of inertia of the pillar, to be obtained, in cm⁴, from the following formula:

$$I_P = I_{XX} + I_{YY}$$

I_{XX} : Net moment of inertia about the XX axis of the pillar section (see Fig 4)

I_{YY} : Net moment of inertia about the YY axis of the pillar section (see Fig 4)

I_t : St. Venant's net moment of inertia of the pillar, to be obtained, in cm⁴, from the following formula:

$$I_t = \frac{1}{3}[h_w t_w^3 + 2b_f t_f^3]10^{-4}$$

Table 11 : Coefficient f

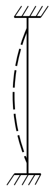
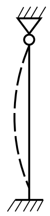
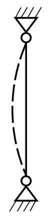
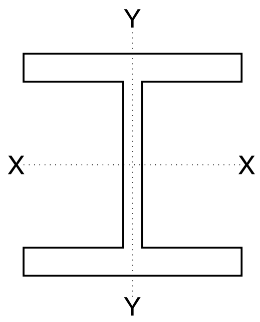
Boundary conditions of the pillar	f
Both ends fixed 	0,5
One end fixed, one end pinned 	$\frac{\sqrt{2}}{2}$
Both ends pinned 	1

Figure 4 : Reference axes for the calculation of the moments of inertia of a built-up section



6.2.4 Critical local buckling stress of built-up pillars

The critical local buckling stress of built-up pillars is to be obtained, in N/mm², from the following formulae:

$$\sigma_{cL} = \sigma_{E3} \quad \text{for} \quad \sigma_{E3} \le \frac{R_{eH}}{2}$$

$$\sigma_{cL} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E3}}\right) \quad \text{for} \quad \sigma_{E3} > \frac{R_{eH}}{2}$$

where:

σ_{E3} : Euler local buckling stress, to be taken equal to the lesser of the values obtained, in N/mm², from the following formulae:

- $\sigma_{E3} = 78\left(\frac{t_W}{h_W}\right)^2 10^4$
- $\sigma_{E3} = 32\left(\frac{t_F}{b_F}\right)^2 10^4$

t_W, h_W, t_F, b_F : Dimensions, in mm, of the built-up section, defined in [6.2.3].

6.2.5 Critical local buckling stress of pillars having hollow rectangular section

The critical local buckling stress of pillars having hollow rectangular section is to be obtained, in N/mm², from the following formulae:

$$\sigma_{cL} = \sigma_{E4} \quad \text{for} \quad \sigma_{E4} \le \frac{R_{eH}}{2}$$

$$\sigma_{cL} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E4}}\right) \quad \text{for} \quad \sigma_{E4} > \frac{R_{eH}}{2}$$

where:

σ_{E4} : Euler local buckling stress, to be taken equal to the lesser of the values obtained, in N/mm², from the following formulae:

- $\sigma_{E4} = 78\left(\frac{t_2}{b}\right)^2 10^4$
- $\sigma_{E4} = 78\left(\frac{t_1}{h}\right)^2 10^4$

b : Length, in mm, of the shorter side of the section

t_2 : Net web thickness, in mm, of the shorter side of the section

h : Length, in mm, of the longer side of the section

t_1 : Net web thickness, in mm, of the longer side of the section.

6.2.6 Checking criteria

The net scantlings of the pillar loaded by the compression axial stress F_A defined in [6.2.1] are to comply with the formulae in Tab 12.

6.3 Buckling of pillars subjected to compression axial load and bending moments

6.3.1 Checking criteria

In addition to the requirements in [6.2], the net scantlings of the pillar loaded by the compression axial load and bending moments are to comply with the following formula:

$$10F\left(\frac{1}{A} + \frac{\Phi e}{w_P}\right) + \left(10^3\frac{M_{max}}{w_P}\right) \le \frac{R_{eH}}{\gamma_R \gamma_m}$$

where:

F : Compression load, in kN, acting on the pillar

A : Net cross-sectional area, in cm², of the pillar

e : Eccentricity, in cm, of the compression load with respect to the centre of gravity of the cross-section

$$\Phi = \frac{1}{1 - \frac{F}{\sigma_{E1} A}}$$

σ_{E1} : Euler column buckling stress, in N/mm², defined in [6.2.2]

w_P : Minimum net section modulus, in cm³, of the cross-section of the pillar

M_{max} : Max (M_1, M_2, M_0)

M_1 : Bending moment, in kN.m, at the upper end of the pillar

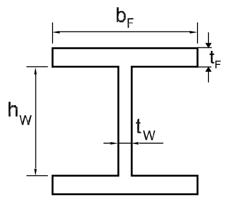
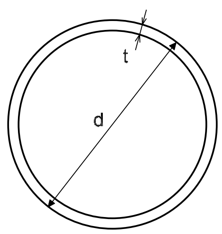
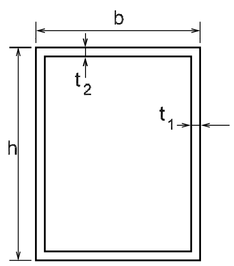
M_2 : Bending moment, in kN.m, at the lower end of the pillar

$$M_0 = \frac{0,5(\sqrt{1 + t^2})(M_1 + M_2)}{\cos(u)}$$

$$u = 0,5\pi \sqrt{\frac{F}{\sigma_{E1} A}}$$

$$t = \frac{1}{\tan(u)}\left(\frac{M_2 - M_1}{M_2 + M_1}\right)$$

Table 12 : Buckling check of pillars subject to compression axial load *(1/1/2017)*

Pillar cross-section	Column buckling check	Torsional buckling check	Local buckling check	Geometric condition
Built-up 	$\frac{\sigma_{cB}}{\gamma_R \gamma_m} \geq 10\frac{F_A}{A}$	$\frac{\sigma_{cT}}{\gamma_R \gamma_m} \geq 10\frac{F_A}{A}$	$\frac{\sigma_{cL}}{\gamma_R \gamma_m} \geq 10\frac{F_A}{A}$	$\frac{b_F}{t_F} \leq 40$
Hollow tubular 	$\frac{\sigma_{cB}}{\gamma_R \gamma_m} \geq 10\frac{F_A}{A}$	Not required	Not required	$\frac{d}{t} \leq 55$ $t \geq 5,5$ mm
Hollow rectangular 	$\frac{\sigma_{cB}}{\gamma_R \gamma_m} \geq 10\frac{F_A}{A}$	Not required	$\frac{\sigma_{cL}}{\gamma_R \gamma_m} \geq 10\frac{F_A}{A}$	$\frac{b}{t_2} \leq 55$ $\frac{h}{t_1} \leq 55$ $t_1 \geq 5,5$ mm $t_2 \geq 5,5$ mm

Note 1:

σ_{cB} : Critical column buckling stress, in N/mm², defined in [6.2.2]

σ_{cT} : Critical torsional buckling stress, in N/mm², defined in [6.2.3]

σ_{cL} : Critical local buckling stress, in N/mm², defined in [6.2.4] for built-up section or in [6.2.5] for hollow rectangular section

γ_R : Resistance partial safety factor, to be taken equal to:
- 1,50 for column buckling
- 1,05 for torsional and local buckling

F_A : compression axial load in the pillar, in kN, defined in [6.2.1]

A : Net sectional area, in cm², of the pillar.

7 Dynamic analysis of main weapon mount supporting structure

7.1 Application

7.1.1 The requirements of this Article apply for the dynamic analysis of main weapon mount supporting structure subjected to dynamic loads.

7.2 Dynamic analysis

7.2.1 Analysis criteria

The dynamic analysis of main weapon mount supporting structure is to be based on direct calculations performed through three-dimensional models.

The criteria adopted for structural modelling are to comply with the requirements specified in App 1.

In any case, the mesh accuracy is to be such that the stiffness and the mass distribution of the model elements of the mount supporting structure and of the surrounding hull structure properly represent those of the actual structure.

Dynamic analysis of special weapons, such as vertical missile launching system (VLS) and rocket or missile launching system with elevation and slewing capabilities, are to be considered by the Society on a case-by-case basis. When deemed necessary, the Society may also require that finite element model transient analyses be performed.

7.2.2 Normal mode analysis

It is to be checked that each normal mode frequency f_{Ni}, in Hz, of the weapon mount supporting structure is in compliance with one of the following formulae:

$$F_{Ni} < 0,7 f_{E,MIN}$$

$$F_{Ni} > 1,3 f_{E,MAX}$$

where:

$F_{E,MIN}$, $F_{E,MAX}$: the lesser and the greater values, in Hz, respectively, among the possible excitations frequencies due to the weapon (e.g. hail) or the propulsion system.

The normal mode calculation method and the number of normal modes to be taken into account are considered by the Society on a case by case basis.

When at least one of the normal mode frequencies does not comply with the above formulae, a dynamic analysis is to be carried out according to the requirements in [7.2.3].

7.2.3 Dynamic analysis

It is to be checked that the dynamic effects induced in the weapon mounting supporting structure by the weapon or the propulsion system are within allowable limits, when this is required according to [7.2.2].

The dynamic effects are to be calculated by means of a dynamic analysis aiming at evaluating:

- the response of the weapon system in the time domain to possible excitations due to the weapon (e.g. hail)
- the response amplitude operators (RAOs) of the weapon system versus possible excitations due to the propulsion system.

When the dynamic analysis is based on normal models, their number is, in general, to be such that the modal effective mass is not less than 95% of the mass of the system constituted by the weapon and its mounting supporting structure.

The modal effective mass is defined as:

$$\sum_{i=1}^{N} \gamma_i^2$$

where γ_i is the i^th modal participation factor and N is the number of the considered normal modes.

The dynamic analysis criteria and the relevant allowable limits are considered by the Society on a case by case basis.

SECTION 4 FATIGUE CHECK OF STRUCTURAL DETAILS

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

p_W : Wave pressure, in kN/m², see [2.2]

s : Spacing, in m, of ordinary stiffeners

ℓ : Span, in m, of ordinary stiffeners, measured between the supporting members, see Ch 4, Sec 3, [3.2]

w : Net section modulus, in cm³, of the stiffener, with an attached plating of width b_p , to be calculated as specified in Ch 4, Sec 3, [3.4]

K_h, $K\ell$: Stress concentration factors, defined in Ch 11, Sec 2 for the special structural details there specified

K_F : Fatigue notch factor, defined in [3.3.1]

K_m : Stress concentration factor, taking account of misalignment, defined in [3.3.1]

$\Delta\sigma_{P0}$: Allowable stress range, defined in [4].

1 General

1.1 Net scantlings

1.1.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 4, Sec 2.

1.2 Application

1.2.1 Structural details to be checked

The requirements of this Section apply for the fatigue check of special structural details, according to Ch 11, Sec 2.

The Society may require other details to be checked, when deemed necessary on the basis of the detail geometry and stress level.

1.2.2 Categorisation of details

With respect to the method to be adopted to calculate the stresses acting on structural members, the details for which the fatigue check is to be carried out may be grouped as follows:

- details where the stresses are to be calculated through a three dimensional structural model (e.g. connections between primary supporting members)
- details located at ends of ordinary stiffeners, for which an isolated structural model can be adopted.

1.2.3 Details where the stresses are to be calculated through a three dimensional structural model

The requirements of App 1, [6] apply, in addition of those of [1] to [5] of this Section.

1.2.4 Details located at ends of ordinary stiffeners

The requirements of [1] to [6] of this Section apply.

1.2.5 Other details

In general, for details other than those in [1.2.2], the stresses are to be calculated through a method agreed by the Society on a case by case basis, using the load model defined in [2].

The checking criterion in [5] is generally to be applied.

1.3 Definitions

1.3.1 Hot spots

Hot spots are the locations where fatigue cracking may occur. They are indicated in the relevant figures of special structural details in Ch 11, Sec 2.

1.3.2 Nominal stress

Nominal stress is the stress in a structural component taking into account macro-geometric effects but disregarding the stress concentration due to structural discontinuities and to the presence of welds (see Fig 1).

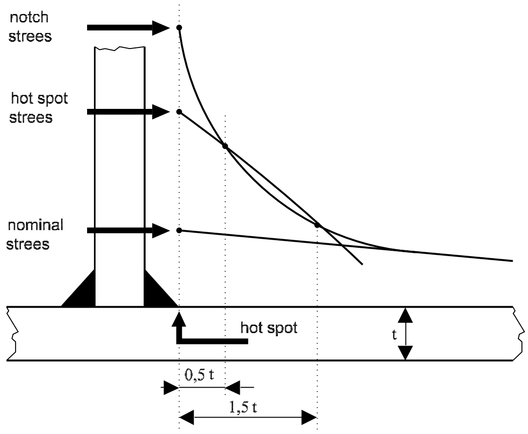
1.3.3 Hot spot stress

Hot spot stress is a local stress at the hot spot taking into account the influence of structural discontinuities due to the geometry of the detail, but excluding the effects of welds (see Fig 1).

1.3.4 Notch stress

Notch stress is a peak stress in a notch such as the root of a weld or the edge of a cut-out. This peak stress takes into account the stress concentrations due to the presence of notches (see Fig 1).

Figure 1 : Nominal, hot spot and notch stresses



1.3.5 Elementary stress range

Elementary stress range is the stress range determined for one of the load cases "a", "b", "c" or "d" (see Ch 5, Sec 4, [2]) and for either of the loading conditions (see Ch 5, Sec 1, [2.4] and Ch 5, Sec 1, [2.5]).

1.3.6 Equivalent stress range

Equivalent stress range is a stress range obtained from a combination of elementary stress ranges, as indicated in [3.3.2] for notch stress and [6.2.1] for hull girder nominal stress.

1.4 Partial safety factors

1.4.1 The partial safety factors to be considered for the fatigue check of structural details are specified in Tab 1.

Table 1 : Fatigue check - Partial safety factors

Partial safety factors covering uncertainties regarding:	Symbol	Value	
		General	Details at ends of ordinary stiffeners
Still water hull girder loads	γ_{S1}	1,00	1,00
Wave hull girder loads	γ_{W1}	1,05	1,15
Still water pressure	γ_{S2}	1,00	1,00
Wave pressure	γ_{W2}	1,10	1,20
Resistance	γ_R	1,02	1,10

2 Load model

2.1 General

2.1.1 Load point

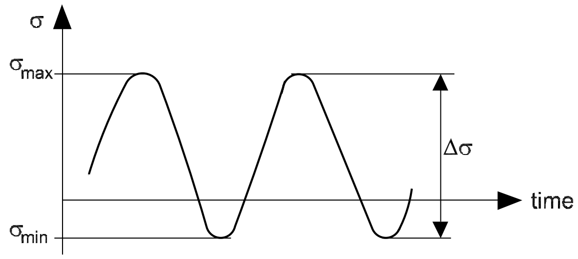
Unless otherwise specified, design loads are to be determined at points defined in:

- Sec 2, [1.3] for ordinary stiffeners
- Sec 3, [1] for primary supporting members.

2.1.2 Local and hull girder loads

The fatigue check is based on the stress range induced at the hot spot by the time variation of local and hull girder loads in each load case "a", "b", "c" and "d" defined in [2.2] for the loading conditions defined in [2.1.4] and [2.1.3] (see Fig 2).

Figure 2 : Stress range



2.1.3 Loading conditions for details where the stresses are to be calculated through a three dimensional structural model

The most severe full load and operational load conditions for the detail concerned are to be considered in accordance with Ch 5, Sec 1, [2.5].

2.1.4 Loading conditions for details located at ends of ordinary stiffeners

The load distribution is to be considered in accordance with Ch 5, Sec 1, [2.4].

2.1.5 Spectral fatigue analysis

For ships with non-conventional shapes or with restricted navigation, the Society may require a spectral fatigue analysis to be carried out.

In this analysis, the loads and stresses are to be evaluated through long-term stochastic analysis taking into account the characteristics of the ship and the navigation notation.

The load calculations and fatigue analysis are to be submitted to the Society for approval.

2.2 Lateral pressure

2.2.1 General

Lateral pressure is constituted by the wave pressure.

2.2.2 Upright ship conditions (Load cases "a" and "b")

Wave pressure (p_W) includes:

- maximum and minimum wave pressures obtained from Tab 2
- inertial pressures:
  - no inertial pressures are considered for load case "a"
  - maximum and minimum inertial pressures for load case "b" are to be obtained from Tab 3 for the various types of cargoes.

Table 2 : Load cases “a” and “b” - Maximum and minimum wave pressures for fatigue check

Case	Wave pressures, in kN/m²	
Load case “a”	p_{Wmax}	p_W defined in Ch 5, Sec 5, [2.1.1] for “load case a, crest”
	p_{Wmin}	p_W defined in Ch 5, Sec 5, [2.1.1] for “load case a, trough”
Load case “b”	p_{Wmax}	p_W defined in Ch 5, Sec 5, [2.1.1] for “load case b, crest”
	p_{Wmin}	p_W defined in Ch 5, Sec 5, [2.1.1] for “load case b, trough”

Table 3 : Load case “b” - Maximum and minimum inertial pressures for fatigue check

Cargo	Inertial pressures, in kN/m²	
	p_{Wmax}	p_{Wmin}
Liquids	p_W defined in Ch 5, Sec 6, Tab 1 for: • load case “b” • $a_{X1} > 0$ and $a_{Z1} > 0$	p_W defined in Ch 5, Sec 6, Tab 1 for: • load case “b” • $a_{X1} < 0$ and $a_{Z1} < 0$
Dry uniform cargoes	p_W defined in Ch 5, Sec 6, Tab 3 for: • load case “b” • $a_{Z1} > 0$	p_W defined in Ch 5, Sec 6, Tab 3 for: • load case “b” • $a_{Z1} < 0$

2.2.3 Inclined ship conditions (Load cases “c” and “d”)

Wave pressure (p_W) includes:

- maximum and minimum wave pressures obtained from Tab 4
- maximum and minimum inertial pressures obtained from Tab 5 for liquid cargoes.

  For dry bulk cargoes and dry uniform cargoes, no inertial pressures are to be considered.

Table 4 : Load cases “c” and “d” - Maximum and minimum wave pressures for fatigue check

Case	Wave pressures, in kN/m²	
Load case “c”	p_{Wmax}	p_W defined in Ch 5, Sec 5, [2.2.1] for: • load case “c” • negative roll angle
	p_{Wmin}	p_W defined in Ch 5, Sec 5, [2.2.1] for: • load case “c” • positive roll angle
Load case “d”	p_{Wmax}	p_W defined in Ch 5, Sec 5, [2.2.1] for: • load case “d” • negative roll angle
	p_{Wmin}	p_W defined in Ch 5, Sec 5, [2.2.1] for: • load case “d” • positive roll angle

2.3 Hull girder normal stresses

2.3.1 The hull girder normal stresses to be considered for the fatigue check are the following, multiplied by γ_{W1}:

$\sigma_{WV,H}$, $\sigma_{WV,S}$, σ_{WH}: Hull girder normal stresses, in N/mm², defined in Tab 6

Table 5 : Load cases “c” and “d” - Maximum and minimum inertial pressures (liquid cargoes) for fatigue check

Load case	Inertial pressures, in kN/m²	
Load case “c”	p_{Wmax}	p_W defined in Ch 5, Sec 6, Tab 1 for: • load case “c” • negative roll angle
	p_{Wmin}	p_W defined in Ch 5, Sec 6, Tab 1 for: • load case “c” • positive roll angle
Load case “d”	p_{Wmax}	p_W defined in Ch 5, Sec 6, Tab 1 for: • load case “d” • negative roll angle
	p_{Wmin}	p_W defined in Ch 5, Sec 6, Tab 1 for: • load case “d” • positive roll angle

Table 6 : Hull girder normal stresses for fatigue check

Load condition	Symbol	Normal stress, in N/mm²
Vertical wave bending moment in hogging	$\sigma_{WV,H}$	$\left\vert\frac{0,625M_{WV,H}}{I_Y}(z-N)\right\vert 10^{-3}$
Vertical wave bending moment in sagging	$\sigma_{WV,S}$	$\left\vert\frac{0,625M_{WV,S}}{I_Y}(z-N)\right\vert 10^{-3}$
Horizontal wave bending moment	σ_{WH}	$\left\vert\frac{0,625M_{WH}}{I_Z}y\right\vert 10^{-3}$

3 Stress range

3.1 General

3.1.1 Calculation point

Unless otherwise specified, stresses are to be determined at the hot spots indicated, for each detail, in the relevant figures in Ch 11, Sec 2.

3.1.2 Stress components

For the details in [1.2.2], the stresses to be used in the fatigue check are the normal stresses in the directions indicated, for each detail, in the relevant figures in Ch 11, Sec 2.

Where the fatigue check is required for details other than those in [1.2.2], the stresses to be used are the principal stresses at the hot spots which form the smallest angle with the crack rising surface.

3.2 Hot spot stress range

3.2.1 Elementary hot spot stress range

The elementary hot spot stress range $\Delta\sigma_{S,ij}$ is to be obtained, in N/mm², in accordance with:

- App 1, [6] for details where the stresses are to be calculated through a three dimensional structural models
- [6.2] for details located at ends of ordinary stiffeners.

3.3 Notch stress range

3.3.1 Elementary notch stress range

The elementary notch stress range is to be obtained, in N/mm², from the following formula:

$$\Delta\sigma_{N,ij} = 0{,}7 K_F K_m K_{C,ij} \Delta\sigma_{S,ij}$$

where:

i : Denotes the load case "a"; "b", "c" or "d"

j : Denotes the loading condition "Full load" or "Operational load"

K_F : Fatigue notch factor, equal to:

$$K_F = \lambda\sqrt{\frac{\theta}{30}}$$

for flame-cut edges, K_F may be taken equal to 1,4

λ : Coefficient depending on the weld configuration, and given in Tab 7

θ : Mean weld toe angle, in degrees, without being taken less than 30°. Unless otherwise specified, θ may be taken equal to:

- 30° for butt joints
- 45° for T joints or cruciform joints

K_m : Additional stress concentration factor, taking account of misalignment, defined in Tab 9, and to be taken not less than 1

$\Delta\sigma_{S,ij}$: Elementary hot spot stress range, defined in [3.2.1]

$$K_{C,ij} = \frac{0{,}4 R_y}{\Delta\sigma_{S,ij}} + 0{,}6 \quad \text{with} \quad 0{,}8 \le K_{C,ij} \le 1$$

Table 7 : Weld coefficient λ

Weld configuration	Coefficient λ	
	Grind welds	Other cases
Butt joints:		
• Stresses parallel to weld axis		
- full penetration	1,85	2,10
- partial penetration	1,85	2,10
• Stresses perpendicular to weld axis		
- full penetration	2,10	2,40
- partial penetration	3,95	4,50
T joints:		
• Stresses parallel to weld axis; fillet weld and partial penetration	1,60	1,80
• Stresses perpendicular to weld axis and in plane of continuous element **(1)**; fillet weld and partial penetration	1,90	2,15
• Stresses perpendicular to weld axis and in plane of welded element; fillet weld and partial penetration	3,95	4,50
Cruciform joints:		
• Full penetration	1,85	2.10
• Partial penetration	2,05	2,35

(1) This case includes the hot spots indicated in the sheets of special structural details in Ch 11, Sec 2 , relevant to the connections of longitudinal ordinary stiffeners with transverse primary supporting members.

3.3.2 Equivalent notch stress range

The equivalent notch stress range is to be obtained, in N/mm², from the following formula:

$$\Delta\sigma_{N,eq} = \left(\frac{\alpha}{2}\Sigma_{3N,F} + \frac{1-\alpha}{2}\Sigma_{3N,B}\right)^{1/3}$$

where:

α : Part of the ship's life in full load condition, given in Tab 8 for various ship types.

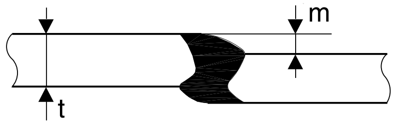
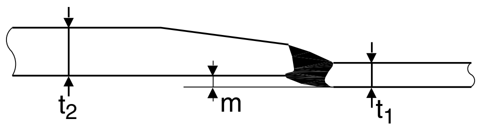
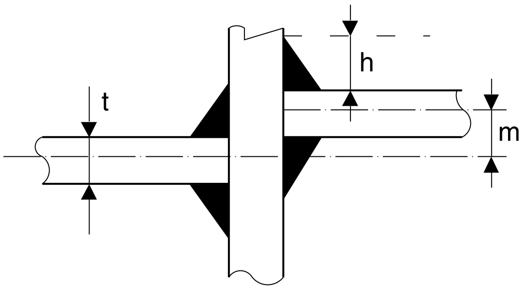
Table 8 : Part of the ship's life in full load condition

Service notation	Coefficient α
Auxiliary ship	0,5
Others	0,75

$$\Sigma_{3N,F} = \max(\mu_{aF}\Delta\sigma^3_{N,aF};\mu_{bF}\Delta\sigma^3_{N,bF}) + \max(\mu_{cF}\Delta\sigma^3_{N,cF};\mu_{dF}\Delta\sigma^3_{N,dF})$$

$$\Sigma_{3N,B} = \max(\mu_{aB}\Delta\sigma^3_{N,aB};\mu_{bB}\Delta\sigma^3_{N,bB}) + \max(\mu_{cB}\Delta\sigma^3_{N,cB};\mu_{dB}\Delta\sigma^3_{N,dB})$$

Table 9 : Stress concentration factor K_m for misalignment

Geometry	K_m
Axial misalignment between flat plates 	$1 + \frac{3(m - m_0)}{t}$
Axial misalignment between flat plates of different thicknesses 	$1 + \frac{6(m - m_0)}{t_1} \frac{t_1^{3/2}}{t_1^{3/2} + t_2^{3/2}}$
Axial misalignment in fillet welded cruciform joints 	$1 + \frac{m - m_0}{t + h}$
Note 1: m : Actual misalignment between two abutting members m_0 : Permissible misalignment for the detail considered, given in Ch 11, Sec 2.	

$\Delta\sigma_{N,aF}$, $\Delta\sigma_{N,bF}$, $\Delta\sigma_{N,cF}$, $\Delta\sigma_{N,dF}$: Elementary notch stress ranges for load cases "a", "b", "c" and "d", respectively, in "Full load" condition, defined in [3.3.1]

$\Delta\sigma_{N,aB}$, $\Delta\sigma_{N,bB}$, $\Delta\sigma_{N,cB}$, $\Delta\sigma_{N,dB}$: Elementary notch stress ranges for load cases "a", "b", "c" and "d", respectively, in "Operational load" condition, defined in [3.3.1]

$$\mu_{ij} = 1 - \frac{\Gamma_N\left[\frac{3}{\xi} + 1, \nu_{ij}\right] - \Gamma_N\left[\frac{5}{\xi} + 1, \nu_{ij}\right]\nu_{ij}^{-2/\xi}}{\Gamma_C\left[\frac{3}{\xi} + 1\right]}$$

$$\xi = \frac{73 - 0{,}07L}{60}$$

without being less than 0,85 ; for $C_B < 0{,}6$

$$\xi = \frac{73 - 0{,}07L}{60} \cdot \frac{C_B}{0{,}6}$$

without being less than 0,85 ; for $C_B < 0{,}6$

$$\nu_{ij} = \left(\frac{S_q}{\Delta\sigma_{N,ij}}\right)^{\xi} \ln N_R$$

$$S_q = (K_p 10^{-7})^{1/3}$$

$$K_p = 5{,}802\left(\frac{16}{t}\right)^{0,9} 10^{12}$$

$$N_R = 10^5$$

t : Net thickness, in mm, of the element under consideration not being taken less than 16 mm

$\Gamma_N[X+1, \nu_{ij}]$: Incomplete Gamma function, calculated for $X = 3/\xi$ or $X = 5/\xi$ and equal to:

$$\Gamma_N[X + 1, \nu_{ij}] = \int_0^{\nu_{ij}} t^X e^{-t} dt$$

Values of $\Gamma_N[X+1, \nu_{ij}]$ are also indicated in Tab 10. For intermediate values of X and ν_{ij}, Γ_N may be obtained by linear interpolation

$\Gamma_C[X+1]$: Complete Gamma function, calculated for $X=3/\xi$, equal to:

$$\Gamma_C[X + 1] = \int_0^{\infty} t^X e^{-t} dt$$

Values of $\Gamma_C[X+1]$ are also indicated in Tab 11. For intermediate values of X, Γ_C may be obtained by linear interpolation.

Table 10 : Function Γ_N [X+1, ν_{ij}]

X	ν_{ij} = 1,5	ν_{ij} = 2	ν_{ij} = 2,5	ν_{ij} = 3	ν_{ij} = 3,5	ν_{ij} = 4	ν_{ij} = 4,5
2,6	0,38	0,75	1,19	1,63	2,04	2,41	2,71
2,7	0,39	0,78	1,25	1,73	2,20	2,62	2,97
2,8	0,39	0,80	1,31	1,85	2,38	2,85	3,26
2,9	0,39	0,83	1,38	1,98	2,57	3,11	3,58
3,0	0,39	0,86	1,45	2,12	2,78	3,40	3,95
3,1	0,40	0,89	1,54	2,27	3,01	3,72	4,35
3,2	0,40	0,92	1,62	2,43	3,27	4,08	4,81
3,3	0,41	0,95	1,72	2,61	3,56	4,48	5,32
3,4	0,41	0,99	1,82	2,81	3,87	4,92	5,90
3,5	0,42	1,03	1,93	3,03	4,22	5,42	6,55
3,6	0,42	1,07	2,04	3,26	4,60	5,97	7,27
3,7	0,43	1,12	2,17	3,52	5,03	6,59	8,09
3,8	0,43	1,16	2,31	3,80	5,50	7,28	9,02
3,9	0,44	1,21	2,45	4,10	6,02	8,05	10,06
4,0	0,45	1,26	2,61	4,43	6,59	8,91	11,23
4,1	0,45	1,32	2,78	4,80	7,22	9,87	12,55
4,2	0,46	1,38	2,96	5,20	7,93	10,95	14,05
4,3	0,47	1,44	3,16	5,63	8,70	12,15	15,73
4,4	0,48	1,51	3,37	6,11	9,56	13,50	17,64
4,5	0,49	1,57	3,60	6,63	10,52	15,01	19,79
4,6	0,49	1,65	3,85	7,20	11,57	16,70	22,23
4,7	0,50	1,73	4,12	7,82	12,75	18,59	24,98
4,8	0,52	1,81	4,40	8,50	14,04	20,72	28,11
4,9	0,52	1,90	4,71	9,25	15,49	23,11	31,64
5,0	0,53	1,99	5,04	10,07	17,09	25,78	35,65
5,1	0,55	2,09	5,40	10,97	18,86	28,79	40,19
5,2	0,56	2,19	5,79	11,95	20,84	32,17	45,34
5,3	0,57	2,30	6,21	13,03	23,03	35,96	51,19
5,4	0,58	2,41	6,66	14,21	25,46	40,23	57,83
5,5	0,59	2,54	7,14	15,50	28,17	45,03	65,37
5,6	0,61	2,67	7,67	16,92	31,18	50,42	73,93
5,7	0,62	2,80	8,23	18,48	34,53	56,49	83,66
5,8	0,64	2,95	8,84	20,19	38,25	63,33	94,73
5,9	0,65	3,10	9,50	22,07	42,39	71,02	107,32

4 Allowable stress range

4.1 General

4.1.1 The allowable notch stress range $\Delta\sigma_{p0}$ is to be obtained, in N/mm², from the following formula:

$$\Delta\sigma_{p0} = (\ln N_R)^{1/\xi}\left(\frac{K_p}{N_t \Gamma_C\left[\frac{3}{\xi}+1\right]}\right)^{1/3}$$

where:

N_R, K_p : Coefficients defined in [3.3.2]

N_t : Number of cycles, to be taken equal to:

$$N_t = \frac{473}{T_A}10^6$$

T_A : Average period, in seconds, to be taken equal to:

$$T_A = 4\log L$$

Γ_C[X+1] : Complete Gamma function, defined in [3.3.2] and calculated for X = 3/ξ .

Table 11 : Function Γ_C [X+1]

X	Γ_C [X+1]
2,6	3,717
2,7	4,171
2,8	4,694
2,9	5,299
3,0	6,000
3,1	6,813
3,2	7,757
3,3	8,855
3,4	10,136
3,5	11,632
3,6	13,381

5 Checking criteria

5.1 General

5.1.1 The equivalent notch stress range $\Delta\sigma_{N,eq}$, calculated according to [3.3.2], is to comply with the following formula:

$$\Delta\sigma_{N,eq} \le \frac{\Delta\sigma_{p0}}{\gamma_R^{1/3}}$$

6 Structural details located at ends of ordinary stiffeners

6.1 General

6.1.1 For the fatigue check of connections located at ends of ordinary stiffeners, an approach equivalent to the checking criteria indicated in [5] is given in [6.3] in terms of the net section modulus of the stiffener.

6.2 Determination of equivalent stress and pressure ranges

6.2.1 Hull girder equivalent stress range

The hull girder equivalent stress range is to be obtained, in N/mm², from the following formula:

$$\Delta\sigma_{h,eq} = \left(\frac{\max(\Delta\sigma_{h,a};\Delta\sigma_{h,b})^3}{2} + \frac{\max(\Delta\sigma_{h,c};\Delta\sigma_{h,d})^3}{2}\right)^{1/3}$$

where $\Delta\sigma_{h,a}$, $\Delta\sigma_{h,b}$, $\Delta\sigma_{h,c}$, $\Delta\sigma_{h,d}$ are the hull girder elementary stress ranges for load cases "a", "b", "c" and "d", respectively, obtained, in N/mm², from the following formulae:

- for members contributing to the hull girder longitudinal strength:

$$\Delta\sigma_{h,i} = \{C_{FV}|\sigma_{WV,H}| + C_{FV}|\sigma_{WV,S}| + 2C_{FH}|\sigma_{WH}|\}_i$$

- for members not contributing to the hull girder longitudinal strength:

$$\Delta\sigma_{h,i} = 0$$

where:

$\sigma_{WV,H}$, $\sigma_{WV,S}$, σ_{WH}: Hull girder normal stresses defined in [2.3]

C_{FV}, C_{FH} : Combination factors defined in Tab 12.

Table 12 : Combination factors C_{FV} and C_{FH}

Load case	C_{FV}	C_{FH}
"a"	1,0	0
"b"	1,0	0
"c"	0,4	1,0
"d"	0,4	1,0

6.2.2 Equivalent pressure range

The equivalent pressure range is to be obtained, in kN/m², from the following formula:

$$\Delta P_{W,eq} = \left(\frac{\alpha}{2}\Sigma_{3P,F} + \frac{1-\alpha}{2}\Sigma_{3P,B}\right)^{1/3}$$

where:

α : Part of the ship's life in full load condition, given in Tab 8

$$\Sigma_{3P,F} = \max(\Delta P_{W,aF};\Delta P_{W,bF})^3 + \max(\Delta P_{W,cF};\Delta P_{W,dF})^3$$

$$\Sigma_{3P,B} = \max(\Delta P_{W,aB};\Delta P_{W,bB})^3 + \max(\Delta P_{W,cB};\Delta P_{W,dB})^3$$

$\Delta P_{W,ij}$: Elementary pressure range for load case "i" (i.e. "a" , "b", "c" or "d"), in "j" load condition (i.e. "Full load" condition or "Operational load" condition), obtained, in kN/m², from the following formula:

$$\Delta P_{W,ij} = \{|P_{Wmax} - P_{Wmin}|\}_{ij}$$

P_{Wmax}, P_{Wmin}: Maximum and minimum resultant wave or inertial pressures, in kN/m², defined in [2.2].

6.3 Net section modulus of ordinary stiffeners

6.3.1 Longitudinal ordinary stiffeners contributing to the hull girder longitudinal strength

It is to be checked that the equivalent range of hull girder equivalent stress $\Delta\sigma_{h,eq}$, calculated according to [6.2.1] complies with the following formula:

$$\Delta\sigma_{h,eq} < \frac{\Delta\sigma_{p0}}{0{,}287 K_F K_m K_h \gamma_R^{1/3}}$$

Moreover, the stiffener net section modulus is to be not less than the value obtained, in cm³, from the following formula:

$$w = 0{,}7 K_F K_m K_G K_\ell \frac{\beta_b \gamma_{W2} \Delta P_{W,eq}}{12\left(\frac{\Delta\sigma_{p0}}{0{,}41\gamma_R^{1/3}} - 0{,}7 K_F K_m K_h \Delta\sigma_{h,eq}\right)}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

where:

K_G : Coefficient taking account of the stiffener section geometry, equal to:

$$K_G = 1 + \left[\frac{t_f(a^2 - b^2)}{2 w_B}\right]\left[1 - \frac{b}{a+b}\left(1 + \frac{w_B}{w_A}\right)\right] 10^{-3}$$

t_f : Face plate net thickness, in mm

a, b : Eccentricities of the stiffener, in mm, defined in Fig 3

w_A, w_B : Net section moduli of the stiffener, in cm³, in A and B, respectively, about its vertical axis and without attached plating

β_b : Coefficient to be taken equal to:

$\beta_b = 1$ in the case of an ordinary stiffener without brackets at ends

$\beta_b = \beta_{b1}$ defined in Sec 2, [3.4.3], in the case of an ordinary stiffener with a bracket of length not greater than $0,2\ell$ at one end

$\beta_b = \beta_{b2}$ defined in Sec 2, [3.4.4], in the case of an ordinary stiffener with symmetrical brackets of length not greater than $0,2\ell$ at both ends.

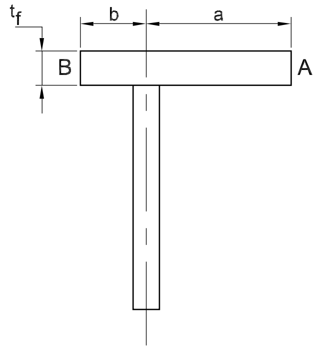
6.3.2 Longitudinal ordinary stiffeners not contributing to the hull girder longitudinal strength and transverse stiffeners

The stiffener net section modulus is to be not less than the value obtained, in cm³, from the following formula:

$$w = 0{,}287 K_F K_m K_G K_\ell \frac{\beta_b \gamma_{W2} \gamma_R^{1/3} \Delta P_{W,eq}}{12 \Delta\sigma_{p0}} \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

where K_G and β_b are the coefficients defined in [6.3.1].

Figure 3 : Geometry of a stiffener section



6.3.3 Vertical ordinary stiffeners

The stiffener net section modulus is to be not less than the value obtained, in cm³, from the following formula:

$$w = 0{,}287 K_F K_m K_G K_\ell \frac{\beta_b \lambda_{bW} \gamma_{W2} \gamma_R^{1/3} \Delta P_{W,eq}}{12 \Delta\sigma_{p0}} \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

where:

K_G, β_b : Coefficients defined in [6.3.1]

λ_{bW} : Coefficient defined in Sec 2, [3.4.5].

APPENDIX 1 ANALYSES BASED ON THREE DIMENSIONAL MODELS

Symbols

For symbols not defined in this Appendix, refer to the list at the beginning of this Chapter.

ρ : Sea water density, taken equal to 1,025 t/m³

g : Gravity acceleration, in m/s²:

$g = 9,81$ m/s²

h_1 : Reference values of the ship relative motions in the upright ship condition, defined in Ch 5, Sec 3, [3.3]

h_2 : Reference values of the ship relative motions in the inclined ship conditions, defined in Ch 5, Sec 3, [3.3]

$$\alpha = \frac{T_1}{T}$$

T_1 : draught, in m, corresponding to the loading condition considered

M_{SW} : Still water bending moment, in kN.m, at the hull transverse section considered

M_{WV} : Vertical wave bending moment, in kN.m, at the hull transverse section considered, defined in Ch 5, Sec 2, [3.1], having the same sign as M_{SW}

Q_{SW} : Still water shear force, in kN, at the hull transverse section considered

Q_{WV} : Vertical wave shear force, in kN, at the hull transverse section considered, defined in Ch 5, Sec 2, [3.4], having sign:

- where M_{WV} is positive (hogging condition):
  - positive for $x < 0,5L$
  - negative for $x \geq 0,5L$
- where M_{WV} is negative (sagging condition):
  - negative for $x < 0,5L$
  - positive for $x \geq 0,5L$

γ_{S1}, γ_{W1} : Partial safety factors, defined in Sec 3.

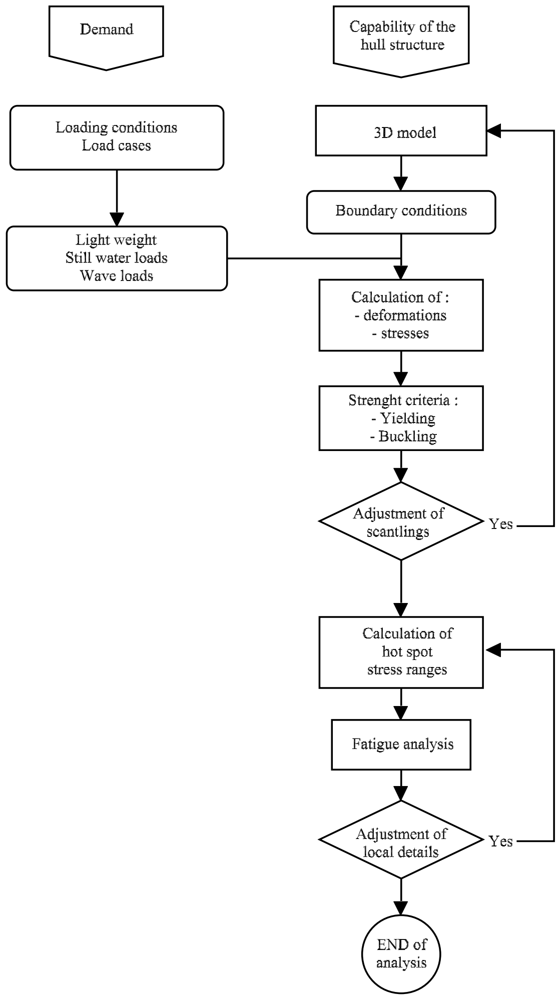
1 General

1.1 Application

1.1.1 The requirements of this Appendix apply for the analysis criteria, structural modelling, load modelling and stress calculation of primary supporting members which are to be analysed through three dimensional structural models, according to Sec 3.

The analysis application procedure is shown graphically in Fig 1.

Figure 1 : Application procedure of the analyses based on three dimensional models



1.1.2 This Appendix deals with that part of the structural analysis which aims at:

- calculating the stresses in the primary supporting members in the midship area and, when necessary, in other areas, which are to be used in the yielding and buckling checks
- calculating the hot spot stress ranges in the structural details which are to be used in the fatigue check.

1.1.3 The yielding and buckling checks of primary supporting members are to be carried out according to Sec 3.

The fatigue check of structural details is to be carried out according to Sec 4.

1.2 Information required

1.2.1 The following information is necessary to perform these structural analyses:

- general arrangement
- capacity plan
- structural plans of the areas involved in the analysis
- longitudinal sections and decks.

2 Analysis criteria

2.1 General

2.1.1 All primary supporting members in the midship regions are normally to be included in the three dimensional model, with the purpose of calculating their stress level and verifying their scantlings.

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.

2.2 Finite element model analyses

2.2.1 For ships more than 150 m in length, finite element models, built according to [3.2] and [3.4], are generally to be adopted.

The analysis of primary supporting members is to be carried out on fine mesh models, as defined in [3.4.3].

2.3 Beam model analyses

2.3.1 Beam models may be adopted in lieu of the finite element models for cases specified in Sec 3, [1.1.2] provided that:

- primary supporting members are not so stout that the beam theory is deemed inapplicable by the Society
- their behaviour is not substantially influenced by the transmission of shear stresses through the shell plating.

In any case, finite element models may need to be adopted when deemed necessary by the Society on the basis of the ship's structural arrangement.

2.4 Structural detail analysis

2.4.1 Structural details in Sec 4, [1.2.3], for which a fatigue analysis is to be carried out, are to be modelled as specified in [6].

3 Primary supporting members structural modelling

3.1 Model construction

3.1.1 Elements

The structural model is to represent the primary supporting members with the plating to which they are connected.

Ordinary stiffeners are also to be represented in the model in order to reproduce the stiffness and inertia of the actual hull girder structure. The way ordinary stiffeners are represented in the model depends on the type of model (beam or finite element), as specified in [3.4] and [3.5].

3.1.2 Net scantlings

All the elements in [3.1.1] are to be modelled with their net scantlings according to Ch 4, Sec 2, [1]. Therefore, also the hull girder stiffness and inertia to be reproduced by the model are those obtained by considering the net scantlings of the hull structures.

3.2 Model extension

3.2.1 The longitudinal extension of the structural model is to be such that:

- the hull girder stresses in the area to be analysed are properly taken into account in the structural analysis
- the results in the areas to be analysed are not influenced by the unavoidable inaccuracy in the modelling of the boundary conditions.

3.2.2 In the case of structural symmetry with respect to the ship's centreline longitudinal plane, the hull structures may be modelled over half the ship's breadth.

3.3 Finite element modelling criteria

3.3.1 Modelling of primary supporting members

The analysis of primary supporting members based on fine mesh models, as defined in [3.4.3], is to be carried out by applying one of the following procedures (see Fig 2), depending on the computer resources:

- an analysis of the whole three dimensional model based on a fine mesh
- an analysis of the whole three dimensional model based on a coarse mesh, as defined in [3.4.2], from which the nodal displacements or forces are obtained to be used as boundary conditions for analyses based on fine mesh models of primary supporting members, e.g.:
  - transverse rings
  - double bottom girders
  - side girders
  - deck girders
  - primary supporting members of transverse bulkheads
  - primary supporting members which appear from the analysis of the whole model to be highly stressed.

3.3.2 Modelling of the most highly stressed areas

The areas which appear from the analyses based on fine mesh models to be highly stressed may be required to be further analysed, using the mesh accuracy specified in [3.4.4].

3.4 Finite element models

3.4.1 General

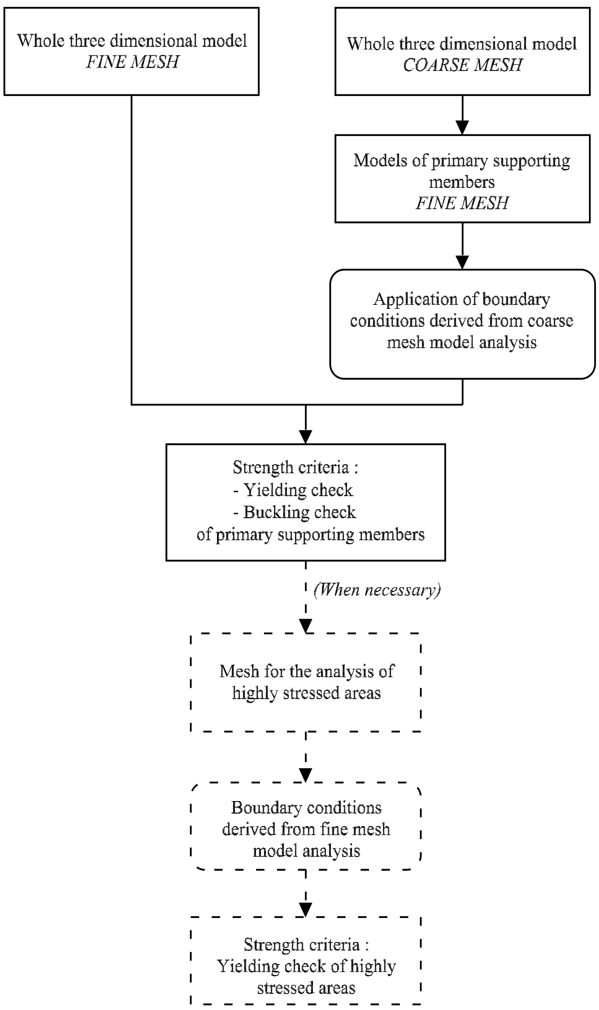
Finite element models are generally to be based on linear assumptions. The mesh is to be executed using membrane or shell elements, with or without mid-side nodes.

Meshing is to be carried out following uniformity criteria among the different elements.

In general, for some of the most common elements, the quadrilateral elements are to be such that the ratio between the longer side length and the shorter side length does not exceed 4 and, in any case, is less than 2 for most elements. Their angles are to be greater than 60° and less than 120°. The triangular element angles are to be greater than 30° and less than 120°.

Further modelling criteria depend on the accuracy level of the mesh, as specified in [3.4.2] to [3.4.4].

Figure 2 : Finite element modelling criteria



3.4.2 Coarse mesh

The number of nodes and elements is to be such that the stiffness and inertia of the model properly represent those of the actual hull girder structure, and the distribution of loads among the various load carrying members is correctly taken into account.

To this end, the structural model is to be built on the basis of the following criteria:

- ordinary stiffeners contributing to the hull girder longitudinal strength and which are not individually represented in the model are to be modelled by rod elements and grouped at regular intervals
- webs of primary supporting members may be modelled with only one element on their height
- face plates may be simulated with bars having the same cross-section
- the plating between two primary supporting members may be modelled with one element stripe
- holes for the passage of ordinary stiffeners or small pipes may be disregarded
- manholes (and similar discontinuities) in the webs of primary supporting members may be disregarded, but the element thickness is to be reduced in proportion to the hole height and the web height ratio.

In some specific cases, some of the above simplifications may not be deemed acceptable by the Society in relation to the type of structural model and the analysis performed.

3.4.3 Fine mesh

The ship's structure may be considered as finely meshed when each longitudinal ordinary stiffener is modelled; as a consequence, the standard size of finite elements used is based on the spacing of ordinary stiffeners.

The structural model is to be built on the basis of the following criteria:

- webs of primary members are to be modelled with at least three elements on their height
- the plating between two primary supporting members is to be modelled with at least two element stripes
- the ratio between the longer side and the shorter side of elements is to be less than 3 in the areas expected to be highly stressed
- holes for the passage of ordinary stiffeners may be disregarded.

In some specific cases, some of the above simplifications may not be deemed acceptable by the Society in relation to the type of structural model and the analysis performed.

3.4.4 Mesh for the analysis of structural details

The structural modelling is to be accurate; the mesh dimensions are to be such as to enable a faithful representation of the stress gradients. The use of membrane elements is only allowed when significant bending effects are not present; in other cases, elements with general behaviour are to be used.

3.5 Beam models

3.5.1 Beams representing primary supporting members

Primary supporting members are to be modelled by beam elements with shear strain, positioned on their neutral axes, whose inertia characteristics are to be calculated as specified in Ch 4, Sec 3, [4].

3.5.2 Torsional moments of inertia

Whenever the torsional effects of the modelling beams are to be taken into account (e.g. for modelling the double bottom, hopper tanks and lower stools), their net torsional moments of inertia are obtained, in cm[4], from the following formulae:

- for open section beams (see Fig 3):

$$I_T = \frac{1}{3}\sum_i (t_i^3 \ell_i) 10^{-4}$$

- for beams of double skin structures (see Fig 4):

$$I_T = \frac{t_1 t_2 (b_1 + b_2) H_D^2}{2(t_1 + t_2)} 10^{-4}$$

where:

Σi : Sum of all the profile segments that constitute the beam section

t_i, ℓ_i : Net thickness and length, respectively, in mm, of the i-th profile segment of the beam section (see Fig 3)

t_1, t_2 : Net thickness, in mm, of the inner and outer plating, respectively, (see Fig 4)

b_1, b_2 : Distances, in mm, from the beam considered to the two adjacent beams (see Fig 4)

H_D : Height, in mm, of the double skin (see Fig 4).

Figure 3 : Open section beams

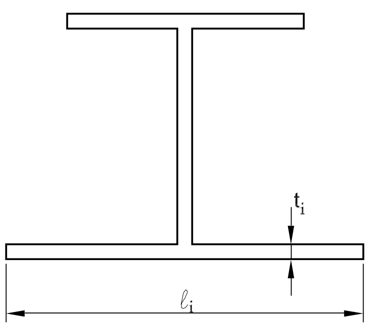
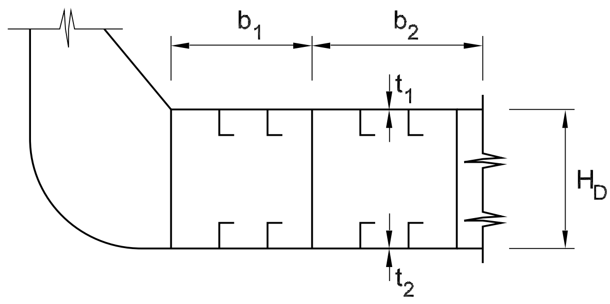


Figure 4 : Beams of double skin structures



3.5.3 Variable cross-section primary supporting members

In the case of variable cross-section primary supporting members, the inertia characteristics of the modelling beams may be assumed as a constant and equal to their average value along the length of the elements themselves.

3.5.4 Modelling of primary supporting members ends

The presence of end brackets may be disregarded; in such case their presence is also to be neglected for the evaluation of the beam inertia characteristics.

Rigid end beams are generally to be used to connect ends of the various primary supporting members, such as:

- floors and side vertical primary supporting members
- bottom girders and vertical primary supporting members of transverse bulkheads
- cross ties and side/longitudinal bulkhead primary supporting members.

3.5.5 Beams representing hull girder characteristics

The stiffness and inertia of the hull girder are to be taken into account by longitudinal beams positioned as follows:

- on deck and bottom in way of side shell and longitudinal bulkheads, if any, for modelling the hull girder bending strength
- on deck, side shell, longitudinal bulkheads, if any, and bottom for modelling the hull girder shear strength.

3.6 Boundary conditions of the whole three dimensional model

3.6.1 Structural model extended over at least three cargo tank/hold lengths

The whole three dimensional model is assumed to be fixed at its aft end, while shear forces and bending moments are applied at its fore end to ensure equilibrium (see [4]).

At the fore end section, rigid constraint conditions are to be applied to all nodes located on longitudinal members, in such a way that the transverse section remains plane after deformation.

When the hull structure is modelled over half the ship's breadth (see [3.2.2]), in way of the ship's centreline longitudinal plane, symmetry or anti-symmetry boundary conditions as specified in Tab 1 are to be applied, depending on the loads applied to the model (symmetrical or anti-symmetrical, respectively).

Table 1 : Symmetry and anti-symmetry conditions in way of the ship's centreline longitudinal plane

Boundary conditions	DISPLACEMENTS in directions **(1)**		
	X	Y	Z
Symmetry	free	fixed	free
Anti-symmetry	fixed	free	fixed

Boundary conditions	ROTATION around axes **(1)**		
	X	Y	Z
Symmetry	fixed	free	fixed
Anti-symmetry	free	fixed	free
(1) X, Y and Z directions and axes are defined with respect to the reference co-ordinate system in Ch 1, Sec 2, [10].			

4 Primary supporting members load model

4.1 General

4.1.1 Loading conditions and load cases in intact conditions

The still water and wave loads are to be calculated for the most severe loading conditions as given in the loading manual, with a view to maximising the stresses in the longitudinal structure and primary supporting members.

The following loading conditions are generally to be considered:

- homogeneous loading conditions at draught T
- non-homogeneous loading conditions at draught T, when applicable
- partial loading conditions at the relevant draught
- ballast conditions at the relevant draught.

The wave local and hull girder loads are to be calculated in the mutually exclusive load cases "a", "b", "c" and "d" in Ch 5, Sec 4.

4.1.2 Loading conditions and load cases in flooding conditions

When applicable, the pressures in flooding conditions are to be calculated according to Ch 5, Sec 6, [7].

4.1.3 Lightweight

The lightweight of the modelled portion of the hull is to be uniformly distributed over the length of the model in order to obtain the actual longitudinal distribution of the still water bending moment.

4.1.4 Models extended over half ship's breadth

When the ship is symmetrical with respect to her centreline longitudinal plane and the hull structure is modelled over half the ship's breadth, non-symmetrical loads are to be broken down into symmetrical and anti-symmetrical loads and applied separately to the model with symmetry and anti-symmetry boundary conditions in way of the ship's centreline longitudinal plane (see [3.6]).

4.2 Local loads

4.2.1 General

Still water loads include:

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

Wave loads include:

- the wave pressure, defined in [4.2.2] for each load case "a", "b", "c" and "d"
- the inertial loads, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast, and for each load case "a", "b", "c" and "d".

4.2.2 Wave loads

The wave pressure at any point of the model is obtained from the formulae in Tab 2 for upright ship conditions (load cases "a" and "b") and in Tab 3 for inclined ship conditions (load cases "c" and "d").

4.2.3 Distributed loads

Distributed loads are to be applied to the plating panels.

In the analyses carried out on the basis of membrane finite element models or beam models, the loads distributed perpendicularly to the plating panels are to be applied on the ordinary stiffeners proportionally to their areas of influence. When ordinary stiffeners are not modelled or are modelled with rod elements (see [3.4]), the distributed loads are to be applied to the primary supporting members actually supporting the ordinary stiffeners.

4.2.4 Concentrated loads

When the elements directly supporting the concentrated loads are not represented in the structural model, the loads are to be distributed on the adjacent structures according to the actual stiffness of the structures which transmit them.

In the analyses carried out on the basis of coarse mesh finite element models or beam models, concentrated loads applied in 5 or more points almost equally spaced inside the same span may be applied as equivalent linearly distributed loads.

4.2.5 Cargo in sacks, bales and similar packages

The vertical loads are comparable to distributed loads. The loads on vertical walls may be disregarded.

Table 2 : Wave pressure in upright ship conditions (load cases "a" and "b")

Location	Wave pressure p_W, in kN/m²	C_1	
		crest	trough **(1)**
Bottom and sides below the waterline with: $z \le T_1 - h$	$C_1 \rho g h e^{\frac{-2\pi(T_1 - z)}{\alpha L}}$	1,0	-1,0
Sides below the waterline with: $T_1 - h < z \le T_1$	$C_1 \rho g h e^{\frac{-2\pi(T_1 - z)}{\alpha L}}$	1,0	$\frac{z - T_1}{h}$
Sides above the waterline: $z > T_1$	$C_1 \rho g (T_1 + h - z)$	1,0	0,0

(1) The wave pressure for load case "b, trough" is to be used only for the fatigue check of structural details.
Note 1:
$h = \alpha^{1/4} C_{F1} h_1$
C_{F1} : Combination factor, to be taken equal to:
- $C_{F1} = 1{,}0$ for load case "a"
- $C_{F1} = 0{,}5$ for load case "b".

Table 3 : Wave pressure in inclined ship conditions (load cases "c" and "d")

Location	Wave pressure p_W, in kN/m²	C_2 (negative roll angle)	
		$y \ge 0$	$y < 0$
Bottom and sides below the waterline with: $z \le T_1 - h$	$C_2 C_{F2} \alpha^{1/4} \rho g \left[\frac{y}{B_W} h_1 e^{\frac{-2\pi(T_1 - z)}{\alpha L}} + A_R y e^{\frac{-\pi(T_1 - z)}{\alpha L}}\right]$	1,0	1,0
Sides below the waterline with: $T_1 - h < z \le T_1$	$C_2 C_{F2} \alpha^{1/4} \rho g \left[\frac{y}{B_W} h_1 e^{\frac{-2\pi(T_1 - z)}{\alpha L}} + A_R y e^{\frac{-\pi(T_1 - z)}{\alpha L}}\right]$	1,0	$\frac{T_1 - z}{h}$
Sides above the waterline: $z > T_1$	$C_2 \rho g \left[T_1 + C_{F2} \alpha^{1/4} \left(\frac{y}{B_W} h_1 + A_R y\right) - z\right]$	1,0	0,0

Note 1:
$h = \alpha^{1/4} C_{F2} h_2$
C_{F2} : Combination factor, to be taken equal to:
- $C_{F2} = 1{,}0$ for load case "c"
- $C_{F2} = 0{,}5$ for load case "d"

B_W : Moulded breadth, in m, measured at the waterline at draught T_1, at the hull transverse section considered
A_R : Roll amplitude, defined in Ch 5, Sec 3, [2.4.1].

Table 4 : Hull girder loads - Maximal bending moments at the middle of the model

Ship condition	Load case	Vertical bending moments at the middle of the model		Horizontal wave bending moment at the middle of the model	Vertical shear forces at the middle of the model	
		Still water	Wave		Still water	Wave
Upright	"a" crest	$\gamma_{S1} M_{SW}$	$0{,}625\ \gamma_{W1} M_{WV,H}$	0	0	0
	"a" trough	$\gamma_{S1} M_{SW}$	$0{,}625\ \gamma_{W1} M_{WV,S}$	0	0	0
	"b"	$\gamma_{S1} M_{SW}$	$0{,}625\ \gamma_{W1} M_{WV,S}$	0	0	0
Inclined	"c"	$\gamma_{S1} M_{SW}$	$0{,}25\ \gamma_{W1} M_{WV}$	$0{,}625\ \gamma_{W1} M_{WH}$	$\gamma_{S1} Q_{SW}$	$0{,}25\ \gamma_{W1} Q_{WV}$
	"d"	$\gamma_{S1} M_{SW}$	$0{,}25\ \gamma_{W1} M_{WV}$	$0{,}625\ \gamma_{W1} M_{WH}$	$\gamma_{S1} Q_{SW}$	$0{,}25\ \gamma_{W1} Q_{WV}$

Note 1: Hull girder loads are to be calculated at the middle of the model.

4.2.6 Other cargoes

The modelling of cargoes other than those mentioned under [4.2.3] to [4.2.5] will be considered by the Society on a case by case basis.

4.3 Hull girder loads

4.3.1

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

and are to be applied at the model fore end section. The shear forces are to be distributed on the plating according to the theory of bidimensional flow of shear stresses.

These loads are to be applied separately for the following two conditions:

- maximal bending moments at the middle of the central tank/hold: the hull girder loads applied at the fore end section are to be such that the values of the hull girder loads in Tab 4 are obtained
- maximal shear forces in way of the aft transverse bulkhead of the central tank/hold: the hull girder loads applied at the fore end section are to be such that the values of the hull girder loads in Tab 5 are obtained.

Table 5 : Hull girder loads - Maximal shear forces in way of the aft bulkhead of the model

Ship condition	Load case	Vertical bending moments in way of the aft bulkhead of the model		Vertical shear forces in way of the aft bulkhead of the model	
		Still water	Wave	Still water	Wave
Upright	"a" crest	$\gamma_{S1} M_{SW}$	$0,4\ \gamma_{W1} M_{WV}$	$\gamma_{S1} Q_{SW}$	$0,625\ \gamma_{W1} Q_{WV}$
	"a" trough	$\gamma_{S1} M_{SW}$	$0,4\ \gamma_{W1} M_{WV}$	$\gamma_{S1} Q_{SW}$	$0,625\ \gamma_{W1} Q_{WV}$
	"b"	$\gamma_{S1} M_{SW}$	$0,4\ \gamma_{W1} M_{WV}$	$\gamma_{S1} Q_{SW}$	$0,625\ \gamma_{W1} Q_{WV}$
Inclined	"c"	$\gamma_{S1} M_{SW}$	$0,4\ \gamma_{W1} M_{WV}$	$\gamma_{S1} Q_{SW}$	$0,25\ \gamma_{W1} Q_{WV}$
	"d"	$\gamma_{S1} M_{SW}$	$0,4\ \gamma_{W1} M_{WV}$	$\gamma_{S1} Q_{SW}$	$0,25\ \gamma_{W1} Q_{WV}$
Note 1: Hull girder loads are to be calculated in way of the aft bulkhead of the model.					

5 Stress calculation

5.1 Analyses based on finite element models

5.1.1 Stresses induced by local and hull girder loads

Both local and hull girder loads are to be directly applied to the model, as specified in [4.3.1] so that the stresses calculated by the finite element program include the contribution of both local and hull girder loads.

5.1.2 Stress components

Stress components are generally identified with respect to the element co-ordinate system, as shown, by way of example, in Fig 5. The orientation of the element co-ordinate system may or may not coincide with that of the reference co-ordinate system in Ch 1, Sec 2, [10].

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

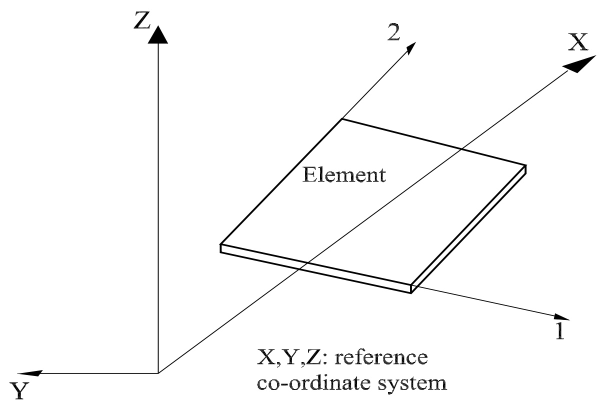
- the normal stresses σ_1 and σ_2 in the directions of the element co-ordinate system axes
- the shear stress τ_{12} with respect to the element co-ordinate system axes
- the Von Mises equivalent stress, obtained from the following formula:

$$\sigma_{VM} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2 + 3\tau_{12}^2}$$

5.1.3 Stress calculation points

Stresses are generally calculated by the computer programs for each element. The values of these stresses are to be used for carrying out the checks required.

Figure 5 : Reference and element co-ordinate systems



5.2 Analyses based on beam models

5.2.1 Stresses induced by local and hull girder loads

Since beam models generally have limited extension compared with the ship's length, only local loads are directly applied to the structural model, as specified in [4.2]. Therefore, the stresses calculated by the beam program include the contribution of local loads only. Hull girder stresses are to be calculated separately and added to the stresses induced by local loads.

5.2.2 Stress components

The following stress components are to be calculated:

- the normal stress σ_1 in the direction of the beam axis
- the shear stress τ_{12} in the direction of the local loads applied to the beam
- the Von Mises equivalent stress, obtained from the following formula:

$$\sigma_{VM} = \sqrt{\sigma_1^{\ 2} + 3\tau_{12}^{\ 2}}$$

5.2.3 Stress calculation points

Stresses are to be calculated at least in the following points of each primary supporting member:

- in the primary supporting member span where the maximum bending moment occurs
- at the connection of the primary supporting member with other structures, assuming as resistant section that formed by the member, the bracket (if any and if represented in the model) and the attached plating
- at the toe of the bracket (if any and if represented in the model) assuming as resistant section that formed by the member and the attached plating.

The values of the stresses are to be used for carrying out the checks required.

6 Fatigue analysis

6.1 Elementary hot spot stress range calculation

6.1.1 General

The requirements of this Article apply for calculating the elementary hot spot stress range for the fatigue check of structural details at the connections of primary supporting members analysed through a three dimensional structural model. The fatigue check of these details is to be carried out in accordance with the general requirements of Sec 4, [1] to Sec 4, [5].

The definitions in Sec 4, [1.3] apply.

6.1.2 Net scantlings

The three dimensional structural model is to be built considering all the structures with their net scantlings according to Ch 4, Sec 2, [1].

6.1.3 Hot spot stresses directly obtained through finite element analyses

Where the structural detail is analysed through a finite element analysis based on a very fine mesh, the elementary hot spot stress range may be obtained as the difference between the maximum and minimum stresses induced by the wave loads in the hot spot considered.

The requirements for:

- the finite element modelling, and
- the calculation of the hot spot stresses and the hot spot stress range

are specified in [6.2].

6.1.4 Hot spot stresses directly obtained through the calculation of nominal stresses

Where the structural detail is analysed through a finite element analysis based on a mesh less fine than that in [6.1.3], the elementary hot spot stress range may be obtained by multiplying the nominal stress range, obtained as the difference between the maximum and minimum nominal stresses induced by the wave loads in the vicinity of the hot spot considered, by the appropriate stress concentration factors.

The requirements for:

- the finite element modelling
- the calculation of the nominal stresses and the nominal stress range
- the stress concentration factors
- the calculation of the hot spot stresses and the hot spot stress range

are specified in [6.3].

6.2 Hot spot stresses directly obtained through finite element analyses

6.2.1 Finite element model

In general, the determination of hot spot stresses necessitates carrying out a very fine mesh finite element analysis, further to a coarser mesh finite element analysis. The boundary nodal displacements or forces obtained from the coarser mesh model are applied to the very fine mesh model as boundary conditions.

The model extension is to be such as to enable a faithful representation of the stress gradient in the vicinity of the hot spot and to avoid it being incorrectly affected by the application of the boundary conditions.

6.2.2 Finite element modelling criteria

The finite element model is to be built according to the following requirements:

- the detail may be considered as being realised with no misalignment
- the size of finite elements located in the vicinity of the hot spot is to be about twice to three times the thickness of the structural member. Where the details is the connection between two or more members of different thickness, the thickness to be considered is that of the thinnest member
- the centre of the first element adjacent to a weld toe is to be located between the weld toe and 0,4 times the thickness of the thinnest structural member connected by the weld
- plating, webs and face plates of primary and secondary members are to be modelled by 4-node thin shell or 8-node solid elements. In the case of a steep stress gradi-

ent, 8-node thin shell elements or 20-node solid elements are recommended

- when thin shell elements are used, the structure is to be modelled at mid-face of the plates
- the aspect ratio of elements is to be not greater than 3

6.2.3 Calculation of hot spot stresses

The hot spot stresses are to be calculated at the centroid of the first element adjacent to the hot spot.

The stress components to be considered are those specified in Sec 4, [3.1.2]. They are to be calculated at the surface of the plate in order to take into account the plate bending moment, where relevant.

Where the detail is the free edge of an opening (e.g. a cut-out for the passage of an ordinary stiffener through a primary supporting member), fictitious truss elements with minimal stiffness may needed to be fitted along the edge to calculate the hot spot stresses.

6.2.4 Calculation of the elementary hot spot stress range

The elementary hot spot stress range is to be obtained, in N/mm², from the following formula:

$$\Delta\sigma_{S,ij} = |\sigma_{S,ij,max} - \sigma_{S,ij,min}|$$

where:

$\sigma_{S,ij,max}$, $\sigma_{S,ij,min}$: Maximum and minimum values of the hot spot stress, induced by the maximum and minimum loads, defined in Sec 4, [2.2] and Sec 4, [2.3]

i : Denotes the load case

j : Denotes the loading condition.

6.3 Hot spot stresses obtained through the calculation of nominal stresses

6.3.1 Finite element model

A finite element is to be adopted, to be built according to the requirements in [3.3] and [3.4]. The areas in the vicinity of the structural details are to be modelled with fine mesh models, as defined in [3.4.3].

6.3.2 Calculation of the elementary nominal stress range

The elementary nominal stress range is to be obtained, in N/mm², from the following formula:

$$\Delta\sigma_{n,ij} = |\sigma_{n,ij,max} - \sigma_{n,ij,min}|$$

where:

$\sigma_{n,ij,max}$, $\sigma_{n,ij,min}$: Maximum and minimum values of the nominal stress, induced by the maximum and minimum loads, defined in Sec 4, [2.2] and Sec 4, [2.3]

i : Denotes the load case

j : Denotes the loading condition.

6.3.3 Calculation of the elementary hot spot stress range

The elementary hot spot stress range is to be obtained, in N/mm², from the following formula:

$$\Delta\sigma_{S,ij} = K_S \Delta\sigma_{n,ij}$$

where:

K_S : Stress concentration factor, defined in Ch 11, Sec 2, [2] for the relevant detail configuration

$\Delta\sigma_{n,ij}$: Elementary nominal stress range, defined in [6.3.2].

APPENDIX 2 ANALYSES OF PRIMARY SUPPORTING MEMBERS SUBJECTED TO WHEELED LOADS

1 General

1.1 Scope

1.1.1 The requirements of this Appendix apply for the analysis criteria, structural modelling, load modelling and stress calculation of primary supporting members subjected to wheeled loads which are to be analysed through three dimensional structural models, according to Sec 3.

1.1.2 The purpose of these structural analyses is to determine:

- the distribution of the forces induced by the vertical acceleration acting on wheeled cargoes, among the various primary supporting members of decks, sides and possible bulkheads
- the behaviour of the above primary supporting members under the racking effects due to the transverse forces induced by the transverse acceleration acting on wheeled cargoes, when the number or location of transverse bulkheads are not sufficient to avoid such effects

and to calculate the stresses in primary supporting members.

The above calculated stresses are to be used in the yielding and buckling checks.

In addition, the results of these analyses may be used, where deemed necessary by the Society, to determine the boundary conditions for finer mesh analyses of the most highly stressed areas.

1.1.3 When the behaviour of primary supporting members under the racking effects, due to the transverse forces induced by the transverse acceleration, is not to be determined, the stresses in deck primary supporting members may be calculated according to the simplified analysis in [6], provided that the conditions for its application are fulfilled (see [6.1]).

1.1.4 The yielding and buckling checks of primary supporting members are to be carried out according to Sec 3.

1.2 Application

1.2.1 The requirements of this Appendix apply to ships whose structural arrangement is such that the following assumptions may be considered as being applicable:

- primary supporting members of side and possible bulkheads may be considered fixed in way of the double bottom (this is generally the case when the stiffness of floors is at least three times that of the side primary supporting members)
- under transverse inertial forces, decks behave as beams loaded in their plane and supported at the ship ends; their effect on the ship transverse rings (side primary supporting members and deck beams) may therefore be simulated by means of elastic supports in the transverse direction or transverse displacements assigned at the central point of each deck beam.

1.2.2 When the assumptions in [1.2.1] are considered by the Society as not being applicable, the analysis criteria are defined on a case by case basis, taking into account the ship's structural arrangement and loading conditions. In such cases, the analysis is generally to be carried out on the basis of a finite element model of the whole ship, built according to the requirements in App 1, as far as applicable.

1.3 Information required

1.3.1 The following information is necessary to perform these structural analyses:

- general arrangement
- structural plans of the areas involved in the analysis
- longitudinal sections and decks
- characteristics of vehicles loaded: load per axles, arrangement of wheels on axles, tyre dimensions.

1.4 Lashing of vehicles

1.4.1 The presence of lashing for vehicles is generally to be disregarded, but may be given consideration by the Society, on a case by case basis, at the request of the interested parties.

2 Analysis criteria

2.1 Finite element model analyses

2.1.1 For ships greater than 200 m in length, finite element models, built according to App 1, [3.4], are generally to be adopted.

The analysis of primary supporting members is to be carried out on fine mesh models, as defined in App 1, [3.4.3].

2.1.2 Areas which appear, from the primary supporting member analysis, to be highly stressed may be required to be further analysed through appropriately meshed structural models, as defined in App 1, [3.4.4].

2.2 Beam model analyses

2.2.1 For ships less than 200 m in length, beam models, built according to App 1, [3.5], may be adopted in lieu of the finite element models in [2.1], provided that:

- primary supporting members are not so stout that the beam theory is deemed inapplicable by the Society
- their behaviour is not substantially influenced by the transmission of shear stresses through the shell plating.

2.2.2 In any case, finite element models may need to be adopted when deemed necessary by the Society on the basis of the ship's structural arrangement.

3 Primary supporting members structural modelling

3.1 Model construction

3.1.1 Elements

The structural model is to represent the primary supporting members with the plating to which they are connected. In particular, the following primary supporting members are to be included in the model:

- deck beams
- side primary supporting members
- primary supporting members of longitudinal and transverse bulkheads, if any
- pillars
- deck beams, deck girders and pillars supporting ramps and deck openings, if any.

3.1.2 Net scantlings

All the elements in [3.1.1] are to be modelled with their net scantlings according to Ch 4, Sec 2, [1].

3.2 Model extension

3.2.1 The structural model is to represent a hull portion which includes the zone under examination and which is repeated along the hull. The non-modelled hull parts are to be considered through boundary conditions as specified in [3.3].

In addition, the longitudinal extension of the structural model is to be such that the results in the areas to be analysed are not influenced by the unavoidable inaccuracy in the modelling of the boundary conditions.

3.2.2 Double bottom structures are not required to be included in the model, based on the assumptions in [1.2.1].

3.3 Boundary conditions of the three dimensional model

3.3.1 Boundary conditions at the lower ends of the model

The lower ends of the model (i.e. the lower ends of primary supporting members of side and possible bulkheads) are to be considered as being clamped in way of the inner bottom.

3.3.2 Boundary conditions at the fore and aft ends of the model

Symmetry conditions are to be applied at the fore and aft ends of the model, as specified in Tab 1.

Table 1 : Symmetry conditions at the model fore and aft ends

DISPLACEMENTS in directions (1):			ROTATION around axes (1):		
X	Y	Z	X	Y	Z
fixed	free	free	free	fixed	fixed
(1) X, Y and Z directions and axes are defined with respect to the reference co-ordinate system in Ch 1, Sec 2, [10].					

3.3.3 Additional boundary conditions at the fore and aft ends of models subjected to transverse loads

When the model is subjected to transverse loads, i.e. when the loads in inclined ship conditions (as defined in Ch 5, Sec 4) are applied to the model, the transverse displacements of the deck beams are to be obtained by means of a racking analysis and applied at the fore and aft ends of the model, in way of each deck beam.

For ships with a traditional arrangement of fore and aft parts, a simplified approximation may be adopted, when deemed acceptable by the Society, defining the boundary conditions without taking into account the racking calculation and introducing springs, acting in the transverse direction, at the fore and aft ends of the model, in way of each deck beam (seecc). Each spring, which simulates the effects of the deck in way of which it is modelled, has a stiffness obtained, in kN/m, from the following formula:

$$R_D = \frac{24EJ_D s_a 10^3}{2x^4 - 4L_D x^3 + L_D^2\left(x^2 + 15{,}6\frac{J_D}{A_D}\right) + L_D^3 x}$$

where:

J_D : Net moment of inertia, in m^4, of the average cross-section of the deck, with the attached side shell plating

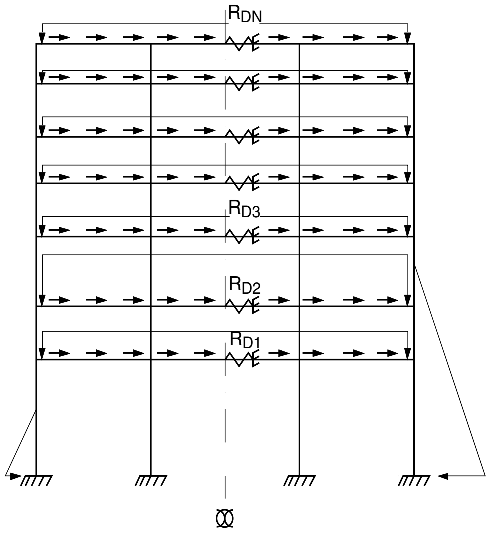
A_D : Net area, in m^2, of the average cross-section of deck plating.

s_a : Spacing of side vertical primary supporting members, in m

x : Longitudinal distance, in m, measured from the transverse section at mid-length of the model to any deck end

L_D : Length of the deck, in m, to be taken equal to the ship's length. Special cases in which such value may be reduced will be considered by the Society on a case by case basis.

Figure 1 : Springs at the fore and aft ends of models subjected to transverse loads



4 Load model

4.1 General

4.1.1 Hull girder and local loads

Only local loads are to be directly applied to the structural model.

The stresses induced by hull girder loads are to be calculated separately and added to the stresses induced by local loads.

4.1.2 Loading conditions and load cases: wheeled cargoes

The still water and wave loads are to be calculated for the most severe loading conditions as given in the loading manual, with a view to maximising the stresses in primary supporting members.

The loads transmitted by vehicles are to be applied taking into account the most severe axle positions for the ship structures.

The wave local loads and hull girder loads are to be calculated in the mutually exclusive load cases "b" and "d" in Ch 5, Sec 4. Load cases "a" and "c" may be disregarded for the purposes of the structural analyses dealt with in this Appendix.

4.1.3 Loading conditions and load cases: dry uniform cargoes

When the ship's decks are also designed to carry dry uniform cargoes, the loading conditions which envisage the transportation of such cargoes are also to be considered. The still water and wave loads induced by these cargoes are to be calculated for the most severe loading conditions, with a view to maximising the stresses in primary supporting members.

The wave local loads and hull girder loads are to be calculated in the mutually exclusive load cases "b" and "d" in Ch 5, Sec 4. Load cases "a" and "c" may be disregarded for the purposes of the structural analyses dealt with in this Appendix.

4.2 Local loads

4.2.1 General

Still water loads include:

- the still water sea pressure, defined in Ch 5, Sec 5, [1]
- the still water forces induced by wheeled cargoes, defined in Ch 5, Sec 6, Tab 5.

Wave induced loads include:

- the wave pressure, defined in Ch 5, Sec 5, [2] for load cases "b" and "d"
- the inertial forces defined in Ch 5, Sec 6, Tab 5 for load cases "b" and "d".

When the ship's decks are also designed to carry dry uniform cargoes, local loads also include the still water and inertial pressures defined in Ch 5, Sec 6, [4]. Inertial pressures are to be calculated for load cases "b" and "d".

4.2.2 Tyred vehicles

For the purpose of primary supporting members analyses, the forces transmitted through the tyres may be considered as concentrated loads in the tyre print centre.

The forces acting on primary supporting members are to be determined taking into account the area of influence of each member and the way ordinary stiffeners transfer the forces transmitted through the tyres.

4.2.3 Non-tyred vehicles

The requirements in [4.2.2] also apply to tracked vehicles. In this case, the print to be considered is that below each wheel or wheelwork.

For vehicles on rails, the loads transmitted are to be applied as concentrated loads.

4.2.4 Distributed loads

In the analyses carried out on the basis of beam models or membrane finite element models, the loads distributed perpendicularly to the plating panels are to be applied on the primary supporting members proportionally to their areas of influence.

4.3 Hull girder loads

4.3.1 The normal stresses induced by the hull girder loads in Tab 2 are to be added to the stresses induced in the primary supporting members by local loads.

Table 2 : Hull girder loads

Ship condition	Load case	Vertical bending moments at the middle of the model		Horizontal wave bending moment at the middle of the model
		Still water	Wave	
Upright	"b"	M_{SW}	0,625 $M_{WV,S}$	0
Inclined	"d"	M_{SW}	0,25 M_{WV}	0,625 M_{WH}

Note 1:

- M_{SW} : Still water bending moment at the middle of the model, for the loading condition considered
- $M_{WV,S}$: Sagging wave bending moments at the middle of the model, defined in Ch 5, Sec 2
- M_{WV} : Wave bending moment at the middle of the model, defined in Ch 5, Sec 2, having the same sign as M_{SW}
- M_{WH} : Horizontal wave bending moment at the middle of the model, defined in Ch 5, Sec 2.

5 Stress calculation

5.1 Stresses induced by local and hull girder loads

5.1.1 Only local loads are directly applied to the structural model, as specified in [4.1.1]. Therefore, the stresses calculated by the program include the contribution of local loads only. Hull girder stresses are to be calculated separately and added to the stresses induced by local loads.

5.2 Analyses based on finite element models

5.2.1 Stress components

Stress components are generally identified with respect to the element co-ordinate system, as shown, by way of example, in Fig 2. The orientation of the element co-ordinate system may or may not coincide with that of the reference co-ordinate system in Ch 1, Sec 2, [10].

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

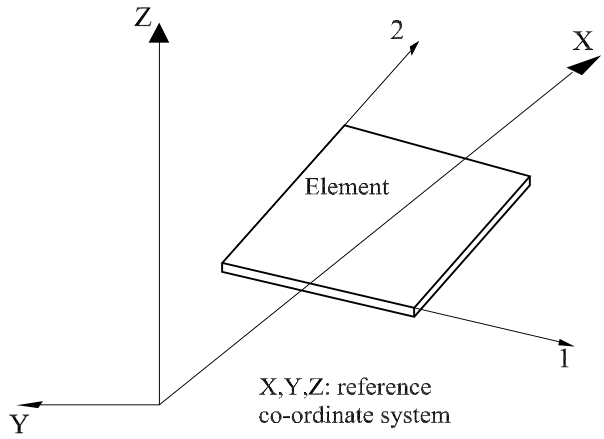
- the normal stresses σ_1 and σ_2 in the directions of element co-ordinate system axes
- the shear stress τ_{12} with respect to the element co-ordinate system axes
- the Von Mises equivalent stress, obtained from the following formula:

$$\sigma_{VM} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2 + 3\tau_{12}^2}$$

5.2.2 Stress calculation points

Stresses are generally calculated by the computer programs for each element. The values of these stresses are to be used for carrying out the checks required.

Figure 2 : Reference and element co-ordinate systems



5.3 Analyses based on beam models

5.3.1 Stress components

The following stress components are to be calculated:

- the normal stress σ_1 in the direction of the beam axis
- the shear stress τ_{12} in the direction of the local loads applied to the beam
- the Von Mises equivalent stress, obtained from the following formula:

$$\sigma_{VM} = \sqrt{\sigma_1^2 + 3\tau_{12}^2}$$

5.3.2 Stress calculation points

Stresses are to be calculated at least in the following points of each primary supporting member:

- in the primary supporting member span where the maximum bending moment occurs
- at the connection of the primary supporting member with other structures, assuming as resistant section that formed by the member, the bracket (if any and if represented in the model) and the attached plating
- at the toe of the bracket (if any and if represented in the model) assuming as resistant section that formed by the member and the attached plating.

The values of the stresses calculated in the above points are to be used for carrying out the checks required.

6 Grillage analysis of primary supporting members of decks

6.1 Application

6.1.1 For the sole purpose of calculating the stresses in deck primary supporting members, due to the forces induced by the vertical accelerations acting on wheeled cargoes, these members may be subjected to the simplified two dimensional analysis described in [6.2].

This analysis is generally considered as being acceptable for usual structural typology, where there are neither pillar lines, nor longitudinal bulkheads.

6.2 Analysis criteria

6.2.1 Structural model

The structural model used to represent the deck primary supporting members is a beam grillage model.

6.2.2 Model extension

The structural model is to represent a hull portion which includes the zone under examination and which is repeated along the hull. The non-modelled hull parts are to be considered through boundary conditions as specified in [3.3].

6.3 Boundary conditions

6.3.1 Boundary conditions at the fore and aft ends of the model

Symmetry conditions are to be applied at the fore and aft ends of the model, as specified in Tab 1.

6.3.2 Boundary conditions at the connections of deck beams with side vertical primary supporting members

Vertical supports are to be fitted at the nodes positioned in way of the connection of deck beams with side primary supporting members.

The contribution of flexural stiffness supplied by the side primary supporting members to the deck beams is to be simulated by springs, applied at their connections, having rotational stiffness, in the plane of the deck beam webs, obtained, in kN.m/rad, from the following formulae:

- for intermediate decks:

$$R_F = \frac{3E(J_1 + J_2)(\ell_1 + \ell_2)}{\ell_1^2 + \ell_2^2 - \ell_1 \ell_2} 10^{-5}$$

- for the uppermost deck:

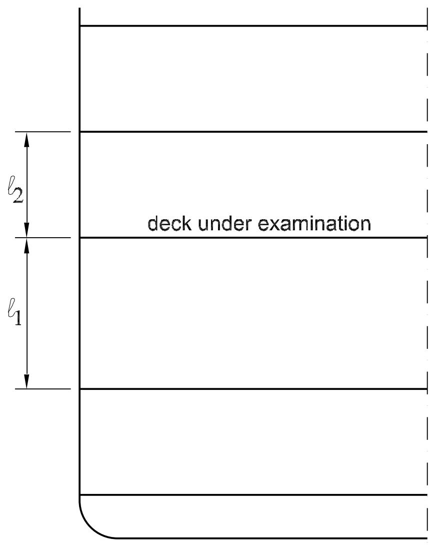
$$R_F = \frac{6EJ_1}{\ell_1} 10^{-5}$$

where:

ℓ_1, ℓ_2 : Height, in m, of the 'tweendecks, respectively below and above the deck under examination (see Fig 3)

J_1, J_2 : Net moments of inertia, in cm^4, of side primary supporting members with attached shell plating, relevant to the 'tweendecks, respectively below and above the deck under examination.

Figure 3 : Heights of tween-decks for grillage analysis of deck primary supporting members



6.4 Load model

6.4.1 Hull girder and local loads are to be calculated and applied to the model according to [4].

Wave loads are to be calculated considering load case "b" only.

6.5 Stress calculation

6.5.1 Stress components are to be calculated according to [5.1] and [5.3].

APPENDIX 3 ANALYSES BASED ON COMPLETE SHIP MODELS

Symbols

$\gamma_{S1}, \gamma_{W1}, \gamma_{S2}, \gamma_{W2}$: Partial safety factors defined in Sec 3

λ : Wave length, in m.

1 General

1.1 Application

1.1.1 The requirements of this Appendix apply for the analysis criteria, structural modelling, load modelling and stress calculation of primary supporting members which are to be analysed through a complete ship model, according to Sec 3.

1.1.2 This Appendix deals with that part of the structural analysis which aims at calculating the stresses in the primary supporting members and more generally in the hull plating, to be used for yielding and buckling checks.

1.1.3 The yielding and buckling checks of primary supporting members are to be carried out according to Sec 3.

1.2 Information required

1.2.1 The following information is necessary to perform these structural analyses:

- general arrangement
- capacity plan
- lines plan
- structural plans
- longitudinal sections and decks
- loading manual.

2 Structural modelling

2.1 Model construction

2.1.1 Elements

The structural model is to represent the primary supporting members with the plating to which they are connected.

Ordinary stiffeners are also to be represented in the model in order to reproduce the stiffness and the inertia of the actual hull girder structure.

2.1.2 Net scantlings

All the elements in [2.1.1] are to be modelled with their net scantlings according to Ch 4, Sec 2. Therefore, also the hull girder stiffness and inertia to be reproduced by the model are those obtained by considering the net scantlings of the hull structures.

2.2 Model extension

2.2.1 Superstructures are to be modelled in order to reproduce the correct lightweight distribution.

Long superstructures are to be modelled in order to also reproduce the correct hull global strength, in particular the contribution of each superstructure deck to the hull girder longitudinal strength.

2.2.2 In the case of structural symmetry with respect to the ship's centreline longitudinal plane, the hull structures may be modelled over half the ship's breadth.

2.3 Finite element modelling criteria

2.3.1 Modelling of primary supporting members

The analyses of primary supporting members are to be based on fine mesh models, as defined in [2.4.2].

Such analyses may be carried out deriving the nodal displacements or forces, to be used as boundary conditions, from analyses of the complete ships based on coarse meshes, as defined in App 1, [3.4.2].

The areas for which analyses based on fine mesh models are to be carried out are the following:

- typical reinforced transverse rings
- typical deck girders
- areas of structural discontinuity (e.g. ramp areas)
- areas in way of typical side and deck openings
- areas of significant discontinuity in primary supporting member arrangements (e.g. in way of large spaces).

Other areas may be required to be analysed through fine mesh models, where deemed necessary by the Society, depending on the ship's structural arrangement and loading conditions as well as the results of the coarse mesh analysis.

2.3.2 Modelling of the most highly stressed areas

The areas which appear from the analyses based on fine mesh models to be highly stressed may be required to be further analysed, using the mesh accuracy specified in App 1, [3.4.4].

2.4 Finite element models

2.4.1 General

Finite element models are generally to be based on linear assumptions. The mesh is to be executed using membrane or shell elements, with or without mid-side nodes.

Meshing is to be carried out following uniformity criteria among the different elements.

In general, for some of the most common elements, the quadrilateral elements are to be such that the ratio between the longer side length and the shorter side length does not exceed 4 and, in any case, is less than 2 for most elements. Their angles are to be greater than 60° and less than 120°. The triangular element angles are to be greater than 30° and less than 120°.

Further modelling criteria depend on the accuracy level of the mesh, as specified in [2.4.2] to [2.4.4].

2.4.2 Coarse mesh

The number of nodes and elements is to be such that the stiffness and the inertia of the model represent properly those of the actual hull girder structure, and the distribution of loads among the various load carrying members is correctly taken into account.

To this end, the structural model is to be built on the basis of the following criteria:

- ordinary stiffeners contributing to the hull girder longitudinal strength and which are not individually represented in the model are to be modelled by rod elements and grouped at regular intervals
- webs of primary supporting members may be modelled with only one element on their height
- face plates may be simulated with bars having the same cross-section
- the plating between two primary supporting members may be modelled with one element stripe
- holes for the passage of ordinary stiffeners or small pipes may be disregarded
- manholes (and similar discontinuities) in the webs of primary supporting members may be disregarded, but the element thickness is to be reduced in proportion to the hole height and the web height ratio.

In some specific cases, some of the above simplifications may not be deemed acceptable by the Society in relation to the type of structural model and the analysis performed.

2.4.3 Fine mesh

The ship's structure may be considered as finely meshed when each longitudinal secondary stiffener is modelled; as a consequence, the standard size of finite elements used is based on the spacing of ordinary stiffeners.

The structural model is to be built on the basis of the following criteria:

- webs of primary members are to be modelled with at least three elements on their height
- the plating between two primary supporting members is to be modelled with at least two element stripes
- the ratio between the longer side and the shorter side of elements is to be less than 3 in the areas expected to be highly stressed
- holes for the passage of ordinary stiffeners may be disregarded.

In some specific cases, some of the above simplifications may not be deemed acceptable by the Society in relation to the type of structural model and the analysis performed.

2.4.4 Mesh for the analysis of structural details

The structural modelling is to be accurate; the mesh dimensions are to be such as to enable a faithful representation of the stress gradients. The use of membrane elements is only allowed when significant bending effects are not present; in other cases, elements with general behaviour are to be used.

2.5 Boundary conditions of the model

2.5.1 In order to prevent rigid body motions of the overall model, the constraints specified in Tab 1 are to be applied.

2.5.2 When the hull structure is modelled over half the ship's breadth (see [2.2.2]), in way of the ship's centreline longitudinal plane, symmetry or anti-symmetry boundary conditions as specified in Tab 2 are to be applied, depending on the loads applied to the model (respectively symmetrical or anti-symmetrical).

Table 1 : Boundary conditions to prevent rigid body motion of the model

Boundary conditions	DISPLACEMENTS in directions **(1)**		
	X	Y	Z
One node on the fore end of the ship	free	fixed	fixed
One node on the port side shell at aft end of the ship **(2)**	fixed	free	fixed
One node on the starboard side shell at aft end of the ship **(2)**	free	fixed	fixed

Boundary conditions	ROTATION around axes **(1)**		
	X	Y	Z
One node on the fore end of the ship	free	free	free
One node on the port side shell at aft end of the ship **(2)**	free	free	free
One node on the starboard side shell at aft end of the ship **(2)**	free	free	free

(1) X, Y and Z directions and axes are defined with respect to the reference co-ordinate system in Ch 1, Sec 2, [10].
(2) The nodes on the port side shell and that on the starboard side shell are to be symmetrical with respect to the ship's longitudinal plane of symmetry.

Table 2 : Symmetry and anti-symmetry conditionsin way of the ship's centreline longitudinal plane

Boundary conditions	DISPLACEMENTS in directions **(1)**		
	X	Y	Z
Symmetry	free	fixed	free
Anti-symmetry	fixed	free	fixed

Boundary conditions	ROTATION around axes **(1)**		
	X	Y	Z
Symmetry	fixed	free	fixed
Anti-symmetry	free	fixed	free

(1) X, Y and Z directions and axes are defined with respect to the reference co-ordinate system in Ch 1, Sec 2, [10].

3 Load model

3.1 General

3.1.1 Local loads

Still water loads include:

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

Wave loads, determined by mean of hydrodynamic calculations according to [3.2], include:

- the wave pressure
- the inertial loads.

3.1.2 Hull girder loads

The hull girder loads are constituted by:

- still water hull girder loads
- wave hull girder loads, to be calculated according to [3.2].

3.1.3 Lightweight

The lightweight of the ship is to be uniformly distributed over the model length, in order to obtain the actual longitudinal distribution of the still water bending moment.

3.1.4 Models extended over half ship's breadth

When the ship is symmetrical with respect to her centreline longitudinal plane and the hull structure is modelled over half the ship's breadth, non-symmetrical loads are to be broken down into symmetrical and anti-symmetrical loads and applied separately to the model with symmetry and anti-symmetry boundary conditions in way of the ship's centreline longitudinal plane (see [2.5.2]).

3.2 Load cases

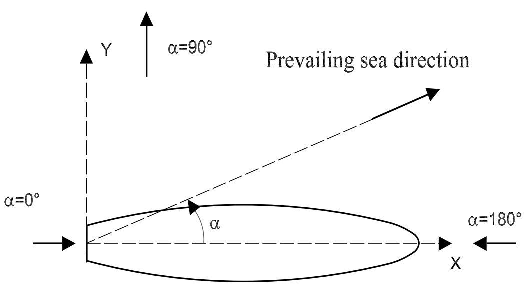
3.2.1 Equivalent waves

Wave loads are to be calculated for different load cases.

For each load case, the ship is considered to encounter a regular wave, defined by its parameters:

- wave length
- heading angle (see Fig 1)
- wave height
- phase.

Figure 1 : Wave heading



3.2.2 Load effects

The parameters listed in [3.2.1] are to be such that they maximise, and make equal to the target values specified in [3.2.3], the following load effects (one for each load case):

- vertical wave bending moment in hogging condition at midship section
- vertical wave bending moment in sagging condition at midship section
- vertical wave shear force on transverse bulkheads
- wave torque for ships with large deck openings at midship section
- transverse acceleration and roll angle
- vertical relative motion at sides in upright ship condition, at midship section.
- vertical relative motion at sides in inclined ship condition, at midship section

3.2.3 Value of loads effects

The wave lengths and headings which maximise each load effect are specified in Tab 3.

The wave amplitudes and phases are to be defined so that the target values in Tab 3 are attained by the maximised load effect, according to the procedure shown in Fig 2.

4 Stress calculation

4.1 Stress components

4.1.1 Stress components are generally identified with respect to the element co-ordinate system, as shown, by way of example, in Fig 3. The orientation of the element co-ordinate system may or may not coincide with that of the reference co-ordinate system in Ch 1, Sec 2, [10].

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 element co-ordinate system axes
- the shear stress τ_{12} with respect to the element co-ordinate system axes
- the Von Mises equivalent stress, obtained from the following formula:

$$\sigma_{VM} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2 + 3\tau_{12}^2}$$

Figure 2 : Wave parameter calculations

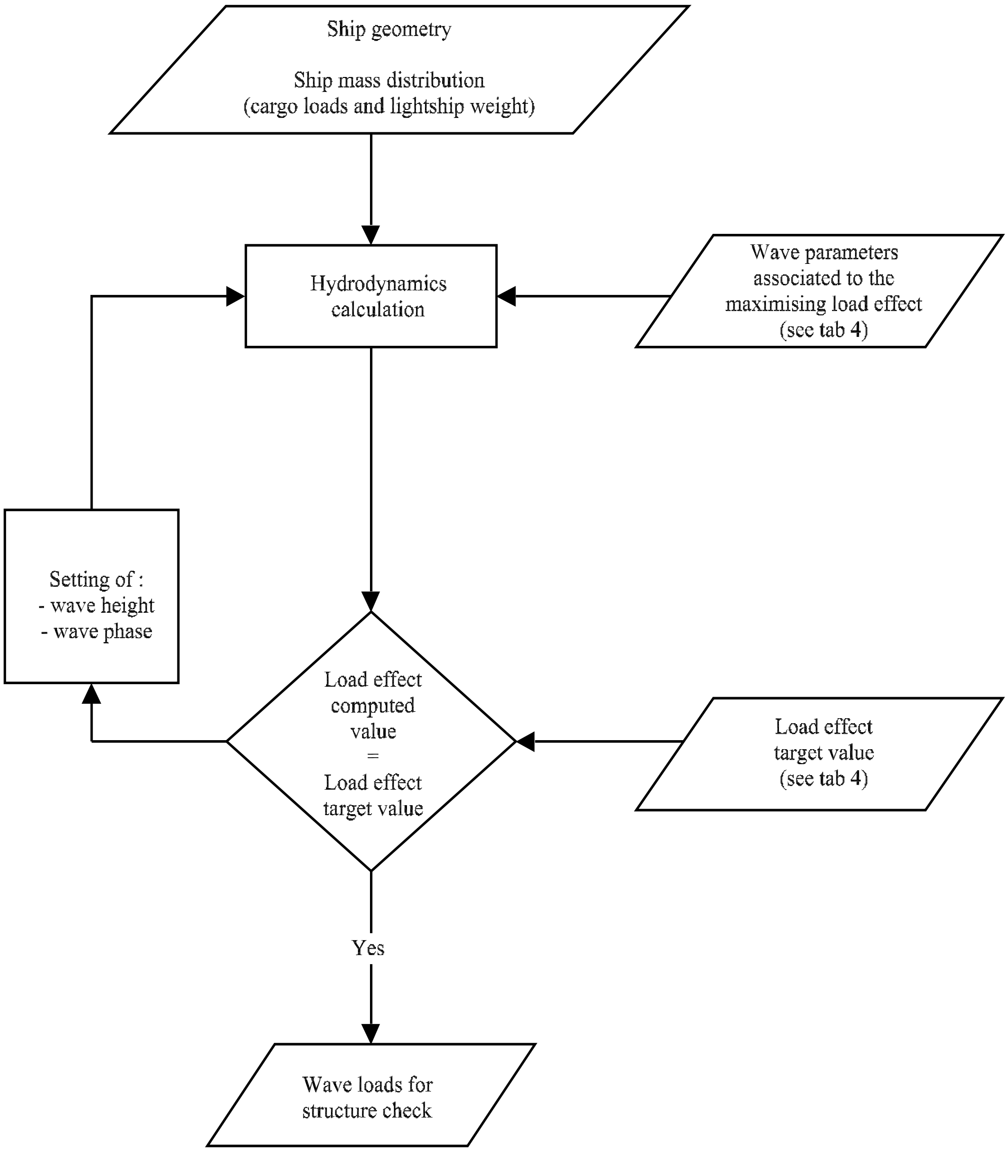


Figure 3 : Reference and element co-ordinate systems

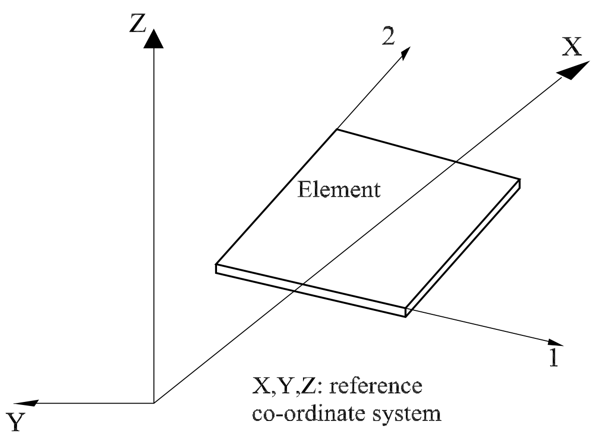


Table 3 : Load cases and load effect values

Load case	Maximised effect	Wave parameters **(2)**		Target		References
		λ/L	Heading angle	Value	Location(s)	
1	Vertical wave bending moment in hogging condition	1,0	180°	$0,625\gamma_{W1}M_{WV,H}$	Midship section	$M_{WV,H}$ defined in Ch 5, Sec 2, [3.1.1]
2	Vertical wave bending moment in sagging condition and vertical acceleration	1,0	180°	$0,625\gamma_{W1}M_{WV,S}$	Midship section	$M_{WV,S}$ defined in Ch 5, Sec 2, [3.1.1]
3	Vertical wave shear force	1,0	0° or 180°	$0,625\gamma_{W1}Q_{WV}$	Each transverse bulkhead	Q_{WV} defined in Ch 5, Sec 2, [3.4]
4	Wave torque **(1)**	0,5	60°	$0,625\gamma_{W1}M_{WT}$	Midship section	M_T defined in Ch 5, Sec 2, [3.3]
5	Transverse acceleration and roll angle	3,0	90°	$\gamma_{W2}A_{TY}$		A_{TY} defined in Ch 5, Sec 6, [1.2.2]
6	Vertical relative motion at sides in upright ship condition, at midship section	1,0	180°	$\gamma_{W2}h_1$	Midship section	h_1 defined in Ch 5, Sec 3, [3.3.1]
7	Vertical relative motion at sides in inclined ship condition, at midship section	0,7	90°	$\gamma_{W2}h_2$	Midship section	h_2 defined in Ch 5, Sec 3, [3.3.2]

(1) This load case is to be considered for ships with large deck openings only.
(2) The forward ship speed is to be taken equal to 0,6V.

APPENDIX 4 SCANTLING CHECKS FOR SHIPS LESS THAN 65 M IN LENGTH

Symbols

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [10]

$F_B = Z_{RB} / Z_{AB}$

$F_D = Z_{RD} / Z_{AD}$

$F_{BH} = Z_{RBH} / Z_{AB}$

$F_{DS} = Z_{RDS} / Z_{AD}$

F_B, F_D, F_{BH} and F_{DS} are to be taken not less than:

- 0,67 when used for the scantling checks of plating
- 0,83 when used for the scantling checks of ordinary stiffeners and primary supporting members

Z_{RB} : Required hull girder section modulus at bottom, in m^3, to be calculated in accordance with Ch 6, Sec 2, [4.2]

Z_{AB} : Actual hull girder section modulus at bottom, in m^3, to be calculated in accordance with Ch 6, Sec 1, [2.3]

Z_{RD} : Required hull girder section modulus at deck, in m^3, to be calculated in accordance with Ch 6, Sec 2, [4.2]

Z_{AD} : Actual hull girder section modulus at deck, in m^3, to be calculated in accordance with Ch 6, Sec 1, [2.3]

Z_{RBH} : Required hull girder section modulus at bottom, in m^3, to be calculated in accordance with Ch 6, Sec 2, [4.2], where the still water and wave bending moments are calculated in hogging condition only

Z_{RDS} : Required hull girder section modulus at deck, in m^3, to be calculated in accordance with Ch 6, Sec 2, [4.2], where the still water and wave bending moments are calculated in sagging condition only

C : Coefficient to be taken equal to:

$$C = \frac{1}{2,29 - 1,29F_B}$$

k : Material factor for steel, defined in Ch 4, Sec 1, [2.3]

p_E : Bottom design pressure, in kN/m², to be obtained from the following formula:

$$p_E = 5L^{1/3}\left[1 - \frac{(T-z)}{2T}\right] + 10(T-z) + p_A \quad \text{for } z \le T$$

$$p_E = (5L^{1/3} + p_A)\frac{10}{10 + (z-T)} \quad \text{for } z > T$$

p_A : Additional pressure, in kN/m², to be obtained from the following formulae:

$$p_A = 0,17L - 1,7x \quad \text{for } 0 \le x < 0,1L$$

$$p_A = 0 \quad \text{for } 0,1L \le x < 0,8L$$

$$p_A = 2,25(x - 0,8L) \quad \text{for } 0,8L \le x \le L$$

p_D : Bottom design pressure, in kN/m², to be obtained from the following formulae:

$$p_D = \max(10T;\ 6,6D) \quad \text{for } T/D \ge 0,5$$

$$p_D = 10T + 2,5L^{1/3} + p_A \quad \text{for } T/D < 0,5$$

p_L : Liquid design pressure, to be taken as the greater of the values obtained, in kN/m² from the following formulae:

$$p_L = 10[(h_a + z_{AP}) - z]P_L$$

$$p_L = 10\left[\frac{2}{3}(z_{TAP} - z)\right]P_L$$

p_{DS} : Single bottom design pressure, in kN/m², to be obtained from the following formulae:

$p_D = 10$ D in general

$p_D = 10$ D + 5 h_T for ships with trunk, where h_T is the trunk height, in m.

h_A : Distance to be taken as the greater of the values obtained, in m, from the following formulae:

$$h_A = [1 + 0,05(L - 50)]\frac{\rho}{\rho_L}$$

without benig taken less than 1,0 m

$$h_A = 10p_{pV}$$

where p_{pV} is the setting pressure, in bar, of safety valves

z_{AP} : Z co-ordinate, in m, of the moulded deck line for the deck to which the air pipes extend

z_{TAP} : Z co-ordinate, in m, of the top of the air pipe of the tank in the z direction

α : Angle, in degrees, between the horizontal plane and the surface of the hull structure to which the calculation point belongs

s : Length, in m, of the shorter side of the plate panel or spacing, in m, of ordinary stiffeners, or spacing, in m, of primary supporting members, as applicable

ℓ : Length, in m, of the longer side of the plate panel or span, in m, of ordinary stiffeners, measured between the supporting members, or span, in m, of primary supporting members, as applicable (to be taken according to Ch 4, Sec 3, [3.2] and Ch 4, Sec 3, [4.1]).

ρ : Sea water density, to be taken equal to 1,025 t/m³

ρ_L : Density, in t/m^3, of the liquid carried, to be taken not less than ρ

1 General

1.1 Application

1.1.1

The requirements of this Appendix may be applied, as an alternative to Sec 1, Sec 2 and Sec 3, for the strength check of plating, ordinary stiffeners and primary supporting members in the central part, as defined in Ch 1, Sec 1, [2.1.3], of ships less than 65 m in length.

1.2 Scantling reduction depending on the navigation notation

1.2.1

The requirements of this Appendix apply for the structural scantling of ships having the unrestricted navigation notation.

For ships with restricted navigation, the required scantling may be reduced by the percentages specified in Tab 1, depending on the navigation notation assigned to the ship.

Table 1 : Scantling reduction percentages depending on the navigation notation

Navigation notation	Reduction
Summer zone	5%
Tropical zone **Coastal area**	10%
Sheltered area	16%
Note 1: For bulkheads and decks, 50% of the reduction applies.	

1.3 Gross scantling

1.3.1

All scantlings referred to in this Appendix are gross, i.e. they include the margins for corrosion.

2 Longitudinally framed single bottom

2.1 Scantlings of plating, ordinary stiffeners and primary supporting members

2.1.1

The scantlings of plating, ordinary stiffeners and primary supporting members are to be not less than both the values obtained from the formulae in Tab 2 and the minimum values in the table.

3 Transversely framed single bottom

3.1 Scantlings of plating, ordinary stiffeners and primary supporting members

3.1.1

The scantlings of plating, ordinary stiffeners and primary supporting members are to be not less than both the values obtained from the formulae in Tab 3 and the minimum values in the table.

4 Bilge

4.1 Bilge plating thickness

4.1.1

The thickness of bilge plating is to be not less than that of the adjacent bottom or side plating, whichever is the greater.

5 Double bottom

5.1 Scantlings of plating, ordinary stiffeners and primary supporting members

5.1.1

The scantlings of plating, ordinary stiffeners and primary supporting members are to be not less than both the values obtained from the formulae in Tab 4 and the minimum values in the table.

5.2 Open floors in transversely framed double bottom

5.2.1 Frames

The section modulus of frames constituting open floors is to be not less than the value obtained, in cm^3, from the following formula:

$$w = 0,8 s \ell^2 p_D$$

where:

ℓ : Span, in m, of transverse ordinary stiffeners constituting the open floor (see Ch 4, Sec 3, [3.2]).

Table 2 : Scantlings of longitudinally framed single bottom structures

Element	Formulae	Minimum value
Plating	Thickness, in mm, the greater of **(1) (2)**: • $t = s(3,12 + 1,12\sqrt{L})\left(\frac{F_{BH}}{k}\right)^{1/2}$ • $t = 9,75s\left(\frac{T \cdot k}{6,76 - 4,37F_B}\right)^{1/2}$	Minimum thickness, in mm **(3)**: $t = (0,033L + 6,5)\left(\frac{sk}{0,46 + 0,0023L}\right)^{1/2} - 1,0$
Ordinary stiffeners	Section modulus, in cm³: $w = 1,2\ s\ \ell^2\ p_{DS}\ Ck$	
Floors	Section modulus, in cm³: $w = s\ \ell^2\ p_D k$	Minimum web plate thickness, in mm: t = 6,0
Girders **(2)**	Web thickness, in mm: • $t = 0,06\ Lk^{1/2} + 5,0$ for centre girders • $t = 0,06\ Lk^{1/2} + 4,0$ for side girders.	
		Minimum face plate area, in cm²: • A = 8,0 for centre girders • A = 5,0 for side girders.
	Where considered as floor supports, section modulus, in cm³: $w = s\ \ell^2\ p_D k$	

(1) s is to be taken, in m, not less than 0,46 + 0,002L.
(2) For ships equal to or greater than 30 m in length, the web thickness and the flange area may be gradually tapered such as to reach, at the collision and after peak bulkheads, 80% of the values obtained from these formulae.
(3) For the purpose of calculation of the minimum thickness t, the actual spacing s is to be taken not less than 0,46 + 0,0023L

Table 3 : Scantlings of transversely framed single bottom structures

Element	Formula	Minimum value
Plating	Thickness, in mm, the greater of **(1)**: • $t = \frac{s}{1 + (s/\ell)^2}(7,82 + 1,45L^{1/2})\left(\frac{F_{BH}}{k}\right)^{1/2}$ • $t = 11,75s\left(\frac{T \cdot k}{6,76 - 4,37F_B}\right)^{1/2}$	Minimum thickness, in mm **(4)**: $t = (0,033L + 6,5)\left(\frac{sk}{0,46 + 0,0023L}\right)^{1/2} - 1,0$
Floors	Section modulus, in cm³ **(2)**: $w = 0,43\ s\ \ell^2\ p_D k$	Minimum web plate thickness, in mm: $t = 10\ h_W + 2,0$
Girders **(3)**	Web thickness, in mm: • $t = 0,06\ Lk^{1/2} + 5,0$ for centre girders • $t = 0,06\ Lk^{1/2} + 4,0$ for side girders.	
		Minimum face plate area, in cm²: • A = 8,0 for centre girders • A = 5,0 for side girders.

Note 1:
h_w : Height, in m, of floors at the centreline to be taken not less than B/16.
(1) s is to be taken, in m, not less than 0,46 + 0,002L.
(2) For ordinary stiffeners located within the engine room area, the required section modulus is to be increased by 40% with respect to that obtained from this formula.
(3) For ships equal to or greater than 30 m in length, the web thickness and the flange area may be gradually tapered such as to reach, at the collision and after peak bulkheads, 80% of the values obtained from these formulae.
(4) For the purpose of calculation of the minimum thickness t, the actual spacing s is to be taken not less than 0,46 + 0,0023L

Table 4 : Scantlings of double bottom structures

Element	Formula	Minimum value
Bottom plating	As specified in: • [2] for longitudinally framed structure • [3] for transversely framed structure	Minimum thickness, in mm **(6)**: $t = (0,033L + 6,5)\left(\frac{sk}{0,46 + 0,0023L}\right)^{1/2} - 1,0$
Bottom ordinary stiffeners	Section modulus, in cm^3, the greater of: • $w = 1,2\, s\, \ell^2\, p_D\, C\, k$ • the value required in [5.5] for tank bulkheads, where the pressure is reduced by an amount, in kN/m^2, not greater than 0,3T, for ordinary stiffeners of bottoms that constitute boundary of compartments intended to carry liquids.	
Inner bottom plating	Thickness, in mm, the greater of: **(1) (2) (3)** • $t = 0,04\, L\, k^{1/2} + 5\, s + 2$ • $t = 4,25\, s\, (p_B\, k)^{1/2}$ for inner bottoms that constitute boundary of compartments intended to carry dry bulk cargoes • $t = 4,25\, s\, (p_L\, k)^{1/2}$ for inner bottoms that constitute boundary of compartments intended to carry liquids	Minimum thickness, in mm: t = 5,0
Inner bottom ordinary stiffeners	Section modulus, in cm^3, the greater of: • $w = s\, \ell^2\, p_D\, C\, k$ • the value required in [5.5] for tank bulkheads, for ordinary stiffeners of inner bottoms that constitute boundary of compartments intended to carry liquids.	
Centre girder	Web thickness, in mm **(4)** $t = \frac{22B + 25(T + 10)}{100}k^{1/2} + 4$	Minimum web thickness, in mm: t = 6,0
Side girders	Web thickness, in mm **(4)** • For longitudinally framed structure: $t = 0,054\, L\, k^{1/2} + 4,5$ • For transversely framed structure: $t = \frac{22B + 25(T + 10)}{100}k^{1/2} + 3$	Minimum web thickness, in mm: t = 6,0
Floors	Web thickness, in mm **(5)** $t = f_S\left[\frac{22B + 25(T + 10)}{100}k^{1/2} + 1\right]$	Minimum web thickness, in mm: t = 6,0

Note 1:

f_S : Coefficient to be taken equal to:
- 1,1 for longitudinally framed structure
- 1,0 for transversely framed structure

$C' = 1 + (C - 1)(1 - z/N)$

N : Z co-ordinate, in m, of the centre of gravity of the hull transverse section, with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [4].

(1) For ships equal to or greater than 30 m in length, this thickness may be gradually tapered such as to reach, at the collision and after peak bulkheads, 90% of the value obtained from this formula.

(2) For plating located within the engine room area, this thickness is to be increased by 10% with respect to that obtained from this formula.

(3) For margin plates inclined downward with respect to the inner bottom plating, this thickness is to be increased by 20% with respect to that obtained from this formula.

(4) For ships equal to or greater than 30 m in length, this thickness may be gradually tapered such as to reach, at the collision and after peak bulkheads, a thickness reduced by 2 $k^{1/2}$ mm with respect to that obtained from this formula.

(5) For floors located within the engine room with transversely framed structure, this thickness is to be increased by 1 mm with respect to that obtained from this formula.

(6) For the purpose of calculation of the minimum thickness t, the actual spacing s is to be taken not less than 0,46 + 0,0023L

Table 5 : Scantlings of side structures

Element	Formula	Minimum value
Plating	Thickness, in mm **(1)** **(2)**: • for longitudinally framed structure: $t = 6,1\ s\ (Tk)^{1/2}$ • for transversely framed structure: $t = 7,2\ s\ (Tk)^{1/2}$	Minimum thickness, in mm: t = 4,0
Ordinary stiffeners	Section modulus, in cm^3, the greater of: • for longitudinal ordinary stiffeners: $w = 0,675\ s\ \ell^2\ p_E k$ • for transverse frames **(3)**: $w = 0,75 s \ell^2 p_H f_c R k$	Minimum section modulus, in cm^3: w = 20
Primary supporting members	Section modulus, in cm^3, the greater of: • for longitudinal and vertical primary supporting members: $w = K_{CR} s \ell^2 p_H k$ • for vertical primary supporting members not associated with side girders, in ships with a transversely framed side: $w = 0,75 s \ell^2 \left(p_E + \frac{n_S h_2 B}{12}\right) k$	Minimum thickness, in mm: t = 4,0

Note 1:

p_H : Design pressure, in kN/m^2, to be obtained from the following formula:
$p_H = p_E + 0,083 h_2 B$
For transverse frames of 'tweendecks:
- p_H is to be taken not less than 0,37L where the upper end is located below the full load waterline
- p_H is to be taken not less than 0,23L - $2d_P$ where the upper end is located above the full load waterline and aft of the collision bulkhead
- p_H is to be taken not less than 0,3L where the upper end is located above the full load waterline and forward of the collision bulkhead.

d_p : Vertical distance, in m, measured between the design deck (first deck above the full load waterline extending for at least 0,6L) and the deck above the frame

h_2 : Sum of the heights, in m, of all 'tweendecks above the deck located at the top of the frame without being taken less than 2,5m; for 'tweendecks intended as accommodation decks and located above the design deck (first deck above the full load waterline extending for at least 0,6L), half of the height may be taken; for 'tweendecks above a deck which is longitudinally framed and supported by deck transverses, a height equal to 0 may be taken

f_c : Coefficient depending on the type of connection and the type of frame as defined in Tab 6

R : Coefficient depending on the location of the ordinary stiffeners:
- R = 0,8 for ordinary stiffeners in hold and engine room
- R = 1,4 for ordinary stiffeners in 'tweendecks.

K_{CR} : Coefficient to be taken equal to:
- K_{CR} = 0,4 for vertical primary supporting members located outside machinery spaces and not associated with side girders, in ships with a transversely framed side
- K_{CR} = 0,5 for vertical primary supporting members located inside machinery spaces and not associated with side girders, in ships with a transversely framed side
- K_{CR} = 0,9 in other cases.

n_S : Number of transverse ordinary stiffener spaces between vertical primary supporting members.

(1) For ships equal to or greater than 30 m in length, this thickness may be gradually tapered such as to reach, at the collision and fore peak bulkheads, 80% of the value obtained from this formula, without being less than 5 mm.

(2) s is to be taken, in m, not less than 0,46 + 0,002L.

(3) Where the span is the same, it is not necessary to assume a section modulus of 'tweendeck frame greater than that of the frame below.

5.2.2 Reverse frames

The section modulus of reverse frame constituting open floors is to be not less than the value obtained, in cm^3, from the following formula:

$w = 0{,}7 s \ell^2 p_D$

where:

ℓ : as indicated in [5.2.1].

5.3 Side

5.3.1 Sheerstrake width

For ships greater than 20 m in length, the width of the sheerstrake is to be not less than the value obtained, in mm, from the following formula:

$$b = 0{,}715 + 0{,}425\frac{L}{100}$$

Table 6 : Coefficient f_C

Type of connection	Type of frame	f_C
Brackets at both ends	Hold frames	0,62
	'Tweendeck frames	0,80
Bracket at one end and without bracket at the other	Hold or 'tweendeck frames	1,20
Without brackets at both ends	Hold or 'tweendeck frames	1,20

5.3.2 Plating, ordinary stiffeners and primary supporting members

The scantlings of plating, ordinary stiffeners and primary supporting members are to be not less than both the values obtained from the formulae in Tab 5 and the minimum values in the table.

In addition, the scantlings of plating, ordinary stiffeners and primary supporting members of sides that constitute boundary of compartments intended to carry liquids are to be not less than the values required in [5.5] for tank bulkheads.

5.3.3 Sheerstrake thickness

For ship greater than 20 m in length, the thickness of the sheerstrake is to be increased by 1 mm with respect to that obtained from the formulae in [5.3.2]. In any case, it is to be not less than that of the stringer plate.

5.4 Decks

5.4.1 Stringer plate width

The width of the stringer plate is to be not less than the value obtained, in mm, from the following formula:

$$b = 0{,}35 + 0{,}5\frac{L}{100}$$

5.4.2 Minimum scantlings of pillars

The thickness, in mm, of hollow (tubular or rectangular) pillars is to be not less than the greater of 5 mm and d / 35, where d is the nominal diameter, in mm, for tubular pillar cross-sections or the larger side, in mm, for rectangular pillar cross-sections.

The thickness, in mm, of the face plate of built-up pillars is to be not less than b_f / 36, where b_f is the face plate width, in mm.

5.4.3 Scantlings of plating, ordinary stiffeners and primary supporting members

The scantlings of plating, ordinary stiffeners and primary supporting members are to be not less than both the values obtained from the formulae in Tab 7 and the minimum values in the table.

In the case of decks subjected to wheeled loads, their scantlings are also to comply with the relevant requirements in Sec 1, Sec 2 and Sec 3.

In addition, the scantlings of plating, ordinary stiffeners and primary supporting members of decks that constitute boundary of compartments intended to carry liquids are to be not less than the values required in [5.5] for tank bulkheads.

5.4.4 Scantlings of pillars subjected to compressive axial load

The area of solid, tubular or prismatic pillars made of steel, having ultimate minimum tensile strength within the range 400-490 N/mm^2, and of pillars consisting of hollow profiles made of steel, having ultimate minimum tensile strength within the range 400-540 N/mm^2, subjected to compression axial load is to be not less than the value obtained, in cm^2, from the following formula:

$$A = \frac{0{,}7 A_D p_2 + Q_N}{12{,}5 - 0{,}045\lambda}$$

where:

p_2 : Design pressure, in kN/m^2, to be taken equal to:

- the greater of:
  $p_2 = 3{,}0$
  $p_2 = 1{,}3\ p_1$
  for pillars located below exposed deck areas
- $p_2 = 0{,}6\ p_0$, for pillars located below unexposed accommodation areas and above the strength deck
- $p_2 = p_0$ in other cases

p_0, p_1 : Design pressures, in kN/m^2, defined in Tab 8

λ : Slenderness of the pillar, to be obtained from the following formula:
$\lambda = 100\ \ell / \rho$

ρ : Minimum radius of gyration, in cm, of the pillar cross-section

A_D : Area, in m^2, of the portion of the deck supported by the pillar considered

Q_N : Load from pillar above, in kN, if any, or any other concentrated load

d : Nominal diameter, in mm, for tubular pillar cross-sections or the larger side, in mm, for rectangular pillar cross-sections

b_f : face plate width, in mm

Scantlings of pillars other than those above are to be considered by the Society on a case-by-case basis.

Table 7 : Scantlings of deck structures

Element	Formula	Minimum value
Strength deck plating **(1)** **(2)**	Thickness, in mm **(1)**: • for longitudinally framed structure - $t = s(1,4L^{1/2} - 1,1)(F_{DS}/k)^{1/2}$ - $t = 1,05s(L \cdot k)^{1/2}$ • for transversely framed structure, the greater of: - $t = \frac{s}{1 + (s/\ell)^2}(1,98L^{1/2} - 1,5)(F_{DS}/k)^{1/2}$ - $t = 1,3s(Lk)^{1/2}$	Minimum thickness, in mm: $t = (5s + 0,022L + 1,0)\,k^{1/2}$
Lower deck and platform plating	Thickness, in mm **(2)**: • for longitudinally framed structure, the greater of: - $t = (5\,s + 0,022\,L + 1,0)\,k^{1/2}$ - $t = 10\,s$ • for transversely framed structure, the greater of: - $t = (6\,s + 0,026\,L + 1,0)\,k^{1/2}$ - $t = 10\,s$	
Ordinary stiffeners	Section modulus, in cm^3: $w = 0,75\,C_1\,C_2\,s\,\ell^2\,(p_0 + p_1)\,k$	
Primary supporting members	Section modulus, in cm^3: $w = 0,1\,C_3\,C_4\,s\,\ell^2\,(p_0 + p_1)\,k$ Moment of inertia, in cm^4: $I = 2,5\,w\,\ell$	Minimum thickness, in mm: $t = 4,0$

Note 1:

p_0, p_1 : Design pressure, in kN/m^2, defined in Tab 8
C_1 : Coefficient equal to $(L/110)^{0,5}$, to be taken not less than 0,6
C_2 : Coefficient, defined in Tab 9
C_3 : Coefficient, defined in Tab 10
C_4 : Coefficient equal to:
- C_4= 0,50 for weather deck area aft of 0,075 L from the FE and for accomodation decks above the design deck, as defined in Tab 8
- C_4 = 0,10 in other cases.

(1) s is to be taken, in m, not less than 0,46 + 0,002 L
(2) For ships equal to or greater than 30 m in length, this thickness may be gradually tapered such as to reach, at the collision bulkhead, 80% of the value obtained from this formula.

Table 8 : Deck design pressure

Type of deck **(1)**	Location	p_0, in kN/m²	p_1, in kN/m²
Decks located below the design deck **(2)**	Any location	• $10h_{TD}$ in general • 9 for accommodation decks	0
Design deck	Exposed area, forward of 0,075L from the FE	15	• 23 for ordinary stiffeners • $37-d_p$ for primary supporting members
	Exposed area, aft of 0,075L from the FE	11	Girders and longitudinal ordinary stiffeners: • 14 for single deck ships • 10 for other ships Other structures: • 18 for single deck ships • 12 for other ships
	Unexposed area	• $10h_{TD}$ in general • 9 for accommodation decks	Girders and longitudinal ordinary stiffeners: • 0 Other structures: • 4 for single deck ships • 0 for other ships
Decks located above the design deck and to which side plating extends	Exposed area, forward of 0,075L from the FE	15	• $37-d_p$ for primary supporting members • $23-d_p$ for ordinary stiffeners
	Exposed area, aft of 0,075L	• 10 in general • 3 for shelter decks	• $15,4(T/D_0)-d_p$ with $0,7 \leq T/D_0 \leq 0,85$ in general • 0 for higher decks
	Unexposed area	• $10h_{TD}$ in general • 9 for accommodation decks	0
Decks located above the design deck and to which side plating does not extend	Exposed area, aft of 0,075L from the FE	• 5 in general • 3 for shelter decks	• $15,4(T/D_0)-d_p$ with $0,7 \leq T/D_0 \leq 0,85$ in general • 0 for higher decks
	Unexposed area	• $10h_{TD}$ in general • 9 for accommodation decks	0

Note 1:

d_p : Vertical distance, in m, measured from the deck under consideration to the design deck

h_{TD} : 'Tweendeck height, in m

D_0 : Vertical distance, in m, measured from the design deck to the base line.

(1) Design deck: first deck above the full load waterline extending for at least 0,6L.

(2) For platforms and flats located in the machinery space, p_0+p_1 is to be not less than 25 kN/m².

Table 9 : Coefficient C_2

Type of ordinary stiffener	Location	C_1
Longitudinal	Strength deck and decks below, within 0,4 L amidships	$1,44C_{HG}$
	Strength deck, forward of 0,12 L from the fore end	1,00
	Other	0,63
Transverse	Single span or end span	0,56
	Intermediate span	0,63

Note 1:

C_{HG} : Coefficient to be obtained from the following formulae:

$$C_{HG} = \frac{1}{2,29 - 1,29F'} \quad \text{for } F' < 0,73$$

$$C_{HG} = 0,74 \quad \text{for } 0,73 \le F' \le 0,84$$

$$C_{HG} = \frac{1}{3,25 - 2,25F'} \quad \text{for } F' > 0,84$$

F' : Coefficient equal to:

$$F' = F_D\frac{z - N}{z_D - N} \quad \text{for } z \ge N$$

$$F' = F_B\frac{N - z}{N} \quad \text{for } z < N$$

N : Z co-ordinate, in m, of the centre of gravity of the hull transverse section, with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [4]

z_D : Z co-ordinate, in m, of the strength deck, defined in Ch 6, Sec 1, [2.2], with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [10].

5.4.5 Scantlings of pillars subjected to compressive axial load and bending moments

The scantlings of pillars subjected to compression axial load and bending moments are to be considered by the Society on a case-by-case basis.

5.4.6 Stringer plate thickness

The thickness of the stringer plate is to be increased by 1 mm with respect to that obtained from the formulae in [5.4.3]. In any case, it is to be not less than that of the sheerstrake.

Table 10 : Coefficient C_3

Type of primary supporting member	Location	C_2
Longitudinal (deck girder)	Constituting longitudinal coamings of hatchways on the strength deck	7,25
	Deck girders of strength deck and decks below, extending more than 0,15 L amidship	$10,88\ C_{HG}$
	Other	4,75
Transverse (deck beam)	Constituting front beams of hatchways on the strength deck	5,60
	Other	4,75

Note 1:

C_{HG} : Coefficient, defined in Tab 9

5.5 Tank bulkheads

5.5.1

The scantlings of plating, ordinary stiffeners and primary supporting members are to be not less than both the values obtained from the formulae in Tab 11 and the minimum values in the table.

5.6 Watertight bulkheads

5.6.1 Scantlings of plating, ordinary stiffeners and primary supporting members

The scantlings of plating, ordinary stiffeners and primary supporting members are to be not less than both the values obtained from the formulae in Tab 12 and the minimum values in the table.

5.7 Non-tight bulkheads

5.7.1 Scantlings of plating, ordinary stiffeners and primary supporting members

The scantlings of plating, ordinary stiffeners and primary supporting members are to be not less than both the values obtained from the formulae in Tab 13 and the minimum values in the table.

Table 11 : Scantlings of tank bulkheads

Element	Formula	Minimum value
Plating	Thickness, in mm: $t=1,35s(p_Lk)^{1/2}$	Minimum thickness, in mm: t = 5,0
Ordinary stiffeners	Section modulus, in cm^3 **(1)**: $w = 0,465s\ell^2p_Lk$	Minimum section modulus, in cm^3 w=20,0
Primary supporting members	Section modulus, in cm^3 $w = s\ell^2p_Lk$	
(1) For ordinary stiffeners without brackets at both ends, this modulus is to be increased by 90% with respect to that obtained from this formula.		

Table 12 : Scantlings of watertight bulkheads

Element	Formula	Minimum value
Plating	Thickness, in mm **(1)**: • $t = 3,8\ s\ (hk)^{1/2}$ in general • $t = 4,35\ s\ (hk)^{1/2}$ for the collision bulkhead	Minimum thickness, in mm: t = 4,5
Ordinary stiffeners	Section modulus, in cm^3 **(2)**: • $w = 3\ s\ \ell^2\ h_Bk$ in general • $w = 3,7\ s\ \ell^2\ h_Bk$ for the collision bulkhead	Minimum section modulus, in cm^3: w = 10,0
Primary supporting members	Section modulus, in cm^3: • $w = 6\ s\ \ell^2\ h_Bk$ in general • $w = 6,75\ s\ \ell^2\ h_Bk$ for the collision bulkhead	

Note 1:
h : Vertical distance, in m, between the lowest point of the plating and the highest point of the bulkhead.
h_B : Vertical distance, in m, between the mid-span point of the ordinary stiffener and the highest point of the bulkhead.
(1) For the lower strake, this thickness is to be increased by 1 mm with respect to that obtained from this formula.
(2) For ordinary stiffeners without brackets at both ends, this modulus is to be increased by 90% with respect to that obtained from this formula.

Table 13 : Scantlings of non-tight bulkheads

Element	Formula
Plating	Minimum thickness, in mm: • t = 4,0 for bulkhead acting as pillar • t = 3,0 for bulkhead not acting as pillar.
Vertical ordinary stiffeners	Net section modulus, in cm^3: • $w = 2,65\ s\ \ell^2k$ for bulkhead acting as pillar • $w = 2,00\ s\ \ell^2\ k$ for bulkhead not acting as pillar.

Part B
Hull and Stability

Chapter 8
OTHER STRUCTURES

SECTION 1 FORE PART

Symbols

L_1, L_2 : Lengths, in m, defined in Ch 1, Sec 2, [2.1.1]

n : Navigation coefficient, defined in Ch 5, Sec 1, [2.6]

h_1 : Reference value of the ship relative motion, defined in Ch 5, Sec 3, [3.3]

a_{Z1} : Reference value of the vertical acceleration, defined in Ch 5, Sec 3, [3.4]

ρ_L : Density, in t/m^3, of the liquid carried

g : Gravity acceleration, in m/s^2:

$g = 9,81$ m/s^2

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [10]

p_S, p_W : Still water pressure and wave pressure defined in [2.3]

p_{BI} : Bottom impact pressure, defined in [3.2]

p_{FI} : Bow impact pressure, defined in [4.2]

k : Material factor, defined in Ch 4, Sec 1, [2.3]

R_y : Minimum yield stress, in N/mm^2, of the material, to be taken equal to 235/k, unless otherwise specified

s : Spacing, in m, of ordinary stiffeners or primary supporting members, as applicable

ℓ : Span, in m, of ordinary stiffeners or primary supporting members, as applicable

c_a : Aspect ratio of the plate panel, equal to:

$$c_a = 1,21\sqrt{1 + 0,33\left(\frac{s}{\ell}\right)^2} - 0,69\frac{s}{\ell}$$

to be taken not greater than 1,0

c_r : Coefficient of curvature of the panel, equal to:

$$c_r = 1 - 0,5s/r$$

to be taken not less than 0,75

r : Radius of curvature, in m

β_b, β_s : Coefficients defined in Ch 7, Sec 2, [3.7.3]

λ_{bS}, λ_{bW}, λ_{sS}, λ_{sW}: Coefficients defined in Ch 7, Sec 2, [3.4.5]

c_E : Coefficient to be taken equal to:

$c_E = 1$ for $L \le 65$ m

$c_E = 3 - L / 32,5$ for $65 \text{ m} < L < 90$ m

$c_E = 0$ for $L \ge 90$ m

c_F : Coefficient to be taken equal to:

$c_F = 0,9$ for forecastle sides

$c_F = 1,0$ in other cases.

1 General

1.1 Application

1.1.1 The requirements of this Section apply for the scantling of structures located forward of the collision bulkhead, i.e.:

- fore peak structures
- reinforcements of the flat bottom forward area
- reinforcements of the bow flare area
- stems.

1.1.2 Fore peak structures which form the boundary of spaces not intended to carry liquids, and which do not belong to the outer shell, are to be subjected to lateral pressure in flooding conditions. Their scantlings are to be determined according to the relevant criteria in Chapter 6 or Chapter 7, as applicable.

1.2 Connections of the fore part with structures located aft of the collision bulkhead

1.2.1 Tapering

Adequate tapering is to be ensured between the scantlings in the fore part and those aft of the collision bulkhead. The tapering is to be such that the scantling requirements for both areas are fulfilled.

1.2.2 Supports of fore peak structures

Aft of the collision bulkhead, side girders are to be fitted as specified in Ch 4, Sec 5, [2.2] or Ch 4, Sec 5, [3.2], as applicable.

1.3 Net scantlings

1.3.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

Gross scantlings are obtained as specified in Ch 4, Sec 2.

2 Fore peak

2.1 Partial safety factors

2.1.1 The partial safety factors to be considered for checking fore peak structures are specified in Tab 1.

Table 1 : Fore peak structures - Partial safety factors

Partial safety factors covering uncertainties regarding:	Partial safety factors			
	Symbol	Plating	Ordinary stiffeners	Primary supporting members
Still water pressure	γ_{S2}	1,00	1,00	1,00
Wave induced pressure	γ_{W2}	1,20	1,20	1,20
Material	γ_m	1,02	1,02	1,02
Resistance	γ_R	1,20	1,40	1,60

2.2 Load point

2.2.1 Unless otherwise specified, lateral pressure is to be calculated at:

- the lower edge of the elementary plate panel considered, for plating
- mid-span, for stiffeners.

2.3 Load model

2.3.1 General

The still water and wave lateral pressures in intact conditions are to be considered. They are to be calculated as specified in [2.3.2] for the elements of the outer shell and in [2.3.3] for the other elements.

Still water pressure (p_S) includes:

- the still water sea pressure, defined in Tab 2
- the still water internal pressure due to liquids or ballast, defined in Tab 4
- for decks, the still water internal pressure due to uniform loads, defined in Tab 5.

Wave pressure (p_W) includes:

- the wave pressure, defined in Tab 2
- the inertial internal pressure due to liquids or ballast, defined in Tab 4
- for decks, the inertial internal pressure due to uniform loads, defined in Tab 5.

2.3.2 Lateral pressures for the elements of the outer shell

The still water and wave lateral pressures are to be calculated considering separately:

- the still water and wave external sea pressures
- the still water and wave internal pressures, considering the compartment adjacent to the outer shell as being loaded.

If the compartment adjacent to the outer shell is not intended to carry liquids, only the external sea pressures are to be considered.

Table 2 : Still water and wave pressures

Location	Still water sea pressure p_S, in kN/m²	Wave pressure p_W, in kN/m²
Bottom and side below the waterline: $z \le T$	$\rho g(T-z)$	$\rho g h_1 e^{\frac{-2\pi(T-z)}{L}}$
Side above the waterline: $z > T$	0	$\rho g(T+h_1-z)$ without being taken less than 0,15L
Exposed deck	Pressure due to the load carried **(1)**	$19{,}6 n \varphi \sqrt{H}$

(1) The pressure due to the load carried is to be defined by the Designer and, in any case, it may not be taken less than 10φ kN/m², where φ is here defined. The Society may accept pressure values lower than 10φ kN/m² when considered appropriate on the basis of the intended use of the deck.

Note 1:

φ : Coefficient defined in Tab 3.

$$H = \left[2{,}66\left(\frac{x}{L}-0{,}7\right)^2 + 0{,}14\right]\sqrt{\frac{VL}{C_B}} - (z-T)$$

without being taken less than 0,8

V : Maximum ahead service speed, in knots, to be taken not less than 13 knots.

Table 3 : Coefficient for pressure on exposed deck

Exposed deck location	φ
Freeboard deck	1
Superstructure deck	0,75
1st tier of deckhouse	0,56
2nd tier of deckhouse	0,42
3rd tier of deckhouse	0,32
4th tier of deckhouse and above	0,25

Table 4 : Still water and inertial internal pressures due to liquids

Still water pressure p_S in kN/m²	Inertial pressure p_W in kN/m²
$\rho_L g(z_L - z)$	$\rho_L a_{Z1}(z_{TOP} - z)$

Note 1:

z_{TOP} : Z co-ordinate, in m, of the highest point of the tank

z_L : Z co-ordinate, in m, of the highest point of the liquid:
$z_L = z_{TOP} + 0{,}5\,(z_{AP} - z_{TOP})$

z_{AP} : Z co-ordinate, in m, of the moulded deck line of the deck to which the air pipes extend, to be taken not less than z_{TOP}.

Table 5 : Still water and inertial internal pressures due to uniform loads

Still water pressure p_S, in kN/m^2	Inertial pressure p_W, in kN/m^2
The value of p_S is, in general, defined by the Designer; in any case it may not be taken less than 10 kN/m^2. When the value of p_S is not defined by the Designer, it may be taken, in kN/m^2, equal to 6,9 h_{TD}, where h_{TD} is the compartment 'tweendeck height at side, in m	$p_S \frac{a_{Z1}}{g}$

2.3.3 Lateral pressures for elements other than those of the outer shell

The still water and wave lateral pressures to be considered as acting on an element which separates two adjacent compartments are those obtained considering the two compartments individually loaded.

2.4 Longitudinally framed bottom

2.4.1 Plating and ordinary stiffeners

The net scantlings of plating and ordinary stiffeners are to be not less than the values obtained from the formulae in Tab 6 and the minimum values in the same Table.

2.4.2 Floors

Floors are to be fitted at every four frame spacings and generally spaced no more than 2,5 m apart.

The floor dimensions and scantlings are to be not less than those specified in Tab 7.

In no case may the above scantlings be lower than those of the corresponding side transverses, as defined in [2.6.2].

2.4.3 Centre girder

Where no centreline bulkhead is to be fitted (see [2.10]), a centre bottom girder having the same dimensions and scantlings required in [2.4.2] for floors is to be provided.

The centre bottom girder is to be connected to the collision bulkhead by means of a large end bracket.

2.4.4 Side girders

Side girders, having the same dimensions and scantlings required in [2.4.2] for floors, are generally to be fitted every two longitudinals, in line with bottom longitudinals located aft of the collision bulkhead. Their extension is to be compatible in each case with the shape of the bottom.

2.5 Transversely framed bottom

2.5.1 Plating

The net scantling of plating is to be not less than the value obtained from the formulae in Tab 6 and the minimum values in the same table.

2.5.2 Floors

Solid floors are to be fitted at every frame spacing.

The solid floor dimensions and scantlings are to be not less than those specified in Tab 8.

2.5.3 Centre girder

Where no centreline bulkhead is to be fitted (see [2.10]), a centre bottom girder is to be fitted according to [2.4.3].

2.6 Longitudinally framed side

2.6.1 Plating and ordinary stiffeners

The net scantlings of plating and ordinary stiffeners are to be not less than the values obtained from the formulae in Tab 9 and the minimum values in the same table.

2.6.2 Side transverses

Side transverses are to be located in way of bottom transverse and are to extend to the upper deck. Their ends are to be amply faired in way of bottom and deck transverses.

Their net section modulus w, in cm^3, and net shear sectional area A_{Sh}, in cm^2, are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} \lambda_{bS} p_S + \gamma_{W2} \lambda_{bW} p_W}{8 R_y} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} \lambda_{sS} p_S + \gamma_{W2} \lambda_{sW} p_W}{R_y} s \ell$$

Table 6 : Scantling of bottom plating and ordinary stiffeners

Element	Formula	Minimum value
Plating	Net thickness, in mm: $t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}}$	Net minimum thickness, in mm: • in general: $t = c_F (0{,}038L + 7{,}0)(sk)^{1/2} - c_E$ • for inner bottom: unchanged
Ordinary stiffeners	Net section modulus, in cm^3: $w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{8 R_y} \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$	Web net minimum thickness, in mm, to be not less than the lesser of: • $t = 1{,}5 L_2^{1/3} k^{1/6}$ • the thickness of the attached plating.
	Net shear sectional area, in cm^2: $A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} \left(1 - \frac{s}{2\ell}\right) s \ell$	

Table 7 : Longitudinally framed bottom Floor dimensions and scantlings

Dimension or scantling	Specified value
Web height, in m	h_M = 0,085 D + 0,15
Web net thickness, in mm	To be not less than that required for double bottom floors aft of the collision bulkhead; in any case, it may be taken not greater than 10 mm.
Floor face plate net sectional area, in cm²	A_P = 3,15 D
Floor face plate net thickness, in mm	t_P = 0,4 D + 5 May be assumed not greater than 14 mm.

Table 8 : Transversely framed bottom Floor dimensions and scantlings

Dimension or scantling	Specified value
Web height, in m	h_M = 0,085 D + 0,15
Web net thickness, in mm	To be not less than that required for double bottom floors aft of the collision bulkhead; in any case, it may be taken not greater than 10 mm.
Floor face plate net sectional area, in cm²	A_P = 1,67 D

2.7 Transversely framed side

2.7.1 Plating and ordinary stiffeners (side frames)

Side frames fitted at every frame space are to have the same vertical extension as the collision bulkhead.

The net scantlings of plating and side frames are to be not less than the values obtained from the formulae in Tab 9 and the minimum values in the table.

The value of the side frame section modulus is generally to be maintained for the full extension of the side frame.

2.7.2 Side girders

Depending on the hull body shape and structure aft of the collision bulkhead, one or more adequately spaced side girders per side are to be fitted.

Their net section modulus w, in cm³, and net shear sectional area A_{Sh}, in cm², are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{8 R_y} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} s \ell$$

Moreover, the depth b_A, in mm, and the net thickness t_A, in mm, of the side girder web are generally to be not less than the values obtained from the following formulae:

$b_A = 2,5\ (180 + L)$

$t_A = (6 + 0,018L)k^{1/2}$

2.7.3 Panting structures

In order to withstand the panting loads, horizontal structures are to be provided. These structures are to be fitted at a spacing generally not exceeding 2 m and consist of side girders supported by panting beams or side transverses whose ends are connected to deck transverses, located under the tank top, so as to form a strengthened ring structure.

Panting beams, which generally consist of sections having the greater side vertically arranged, are to be fitted every two frames.

2.7.4 Connection between panting beams, side frames and side girders

Each panting beam is to be connected to the side transverses by means of brackets whose arms are generally to be not less than twice the panting beam depth.

2.7.5 Connection between side frames and side girders

Side transverses not supporting panting beams are to be connected to side girders by means of brackets having the same thickness as that of the side girder and arms which are to be not less than one half of the depth of the side girder.

Table 9 : Scantling of side plating and ordinary stiffeners

Element	Formula	Minimum value
Plating	Net thickness, in mm: $t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}}$	Net minimum thickness, in mm: $t = c_F (0{,}038L + 7{,}0)(sk)^{1/2} - c_E$
Ordinary stiffeners	Net section modulus, in cm³: $w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{8 R_y} \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$	Web net minimum thickness, in mm, to be not less than the lesser of: • $t = 1{,}5 L_2^{1/3} k^{1/6}$ • the thickness of the attached plating
	Net shear sectional area, in cm²: $A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} \left(1 - \frac{s}{2\ell}\right) s \ell$	

Table 10 : Scantling of deck plating and ordinary stiffeners

Element	Formula	Minimum value
Plating	Net thickness, in mm: $t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \dfrac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}}$	Net minimum thickness, in mm: $t = 2{,}1 + 0{,}013 L k^{1/2} + 4{,}5 s$
Ordinary stiffeners	Net section modulus, in cm³: $w = \gamma_R \gamma_m \beta_b \dfrac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m R_y} \left(1 - \dfrac{s}{2\ell}\right) s \ell^2 10^3$	Web net minimum thickness, in mm, to be not less than the lesser of: • $t = 1{,}5 L_2^{1/3} k^{1/6}$ • the thickness of the attached plating.
	Net shear sectional area, in cm²: $A_{Sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} \left(1 - \dfrac{s}{2\ell}\right) s \ell$	
Note 1: m : Boundary coefficient, to be taken equal to: • m = 12 for longitudinally framed decks • m = 8 for transversely framed decks.		

2.7.6 Panting beam scantlings

The net area A_B, in cm², and the net inertia J_B, in cm⁴, of the panting beam section are to be not less than the values obtained from the following formulae:

$A_B = 0{,}5\ L - 18$

$J_B = 0{,}34\ (0{,}5\ L - 18)\ b_B^2$

where:

b_B : Beam length, in m, measured between the internal edges of side girders or the internal edge of the side girder and any effective central or lateral support.

Where side girder spacing is other than 2 m, the values A_B and J_B are to be modified according to the relation between the actual spacing and 2 m.

2.7.7 Panting beams of considerable length

Panting beams of considerable length are generally to be supported at the centreline by a wash bulkhead or pillars arranged both horizontally and vertically.

2.7.8 Non-tight platforms

Non-tight platforms may be fitted in lieu of side girders and panting beams. Their openings and scantlings are to be in accordance with [2.9.1].

Their spacing is to be not greater than 2,5 m.

If the peak exceeds 10 m in depth, a non-tight platform is to be arranged at approximately mid-depth.

2.7.9 Additional transverse bulkheads

Where the peak exceeds 10 m in length and the frames are supported by panting beams or non-tight platforms, additional transverse wash bulkheads or side transverses are to be fitted.

2.8 Decks

2.8.1 Plating and ordinary stiffeners

The net scantlings of plating and ordinary stiffeners are to be not less than the values obtained from the formulae in Tab 10 and the minimum values in the same table.

2.8.2 Primary supporting members

Scantlings of primary supporting members are to be in accordance with Ch 7, Sec 3, considering the loads in [2.3].

The partial safety factors to be used are those defined in Ch 7, Sec 3, [1.3].

2.9 Platforms

2.9.1 Non-tight platforms

Non-tight platforms located inside the peak are to be provided with openings having a total area not less than 10% of that of the platforms. Moreover, the thickness of the plating and the section modulus of ordinary stiffeners are to be not less than those required in [2.10] for the non-tight central longitudinal bulkhead.

The number and depth of non-tight platforms within the peak is considered by the Society on a case by case basis.

The platforms may be replaced by equivalent horizontal structures whose scantlings are to be supported by direct calculations.

2.9.2 Platform transverses

The net sectional area of platform transverses, calculated considering a width of attached plating whose net sectional area is equal to that of the transverse flange, is to be not less than the value obtained, in cm², from the following formula:

$$A = 10 \gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{C_P R_y} d_S h_S$$

where:

p_S, p_W : Still water pressure and wave pressure, defined in [2.9.1], acting at the ends of the platform transverse in the direction of its axis

d_S : Half of the longitudinal distance, in m, between the two transverses longitudinally adjacent to that under consideration

h_S : Half of the vertical distance, in m, between the two transverses vertically adjacent to that under consideration

C_P : Coefficient, to be taken equal to:

$$C_P = 1 \quad \text{for} \quad \frac{d_P}{r_P} \le 70$$

$$C_P = 1{,}7 - 0{,}01\frac{d_P}{r_P} \quad \text{for} \quad 70 < \frac{d_P}{r_P} \le 140$$

When d_P / r_P > 140, the scantlings of the struts are considered by the Society on a case by case basis

d_P : Distance, in cm, from the face plate of the side transverse and that of the bulkhead vertical web, connected by the strut, measured at the level of the platform transverse

r_P : Radius of gyration of the strut, to be obtained, in cm, from the following formula:

$$r_P = \sqrt{\frac{J}{A_E}}$$

J : Minimum net moment of inertia, in cm^4, of the strut considered

A_E : Actual net sectional area, in cm^2, of the transverse section of the strut considered.

2.9.3 Breasthooks

Breasthooks are to have the same thickness of that required for platforms. They are to be arranged on the stem, in way of every side longitudinal, or at equivalent spacing in the case of transverse framing, extending aft for a length equal to approximately twice the breasthook spacing.

2.10 Central longitudinal bulkhead

2.10.1 General

Unless otherwise agreed by the Society on a case by case basis, a centreline non-tight longitudinal bulkhead is not to be fitted. In case such a bulkhead is fitted, the following requirements apply.

2.10.2 Extension

In the case of a bulbous bow, such bulkhead is generally to extend for the whole length and depth of the fore peak.

Where hull structures are flared, such as those situated above the bulb and in the fore part of the peak, the bulkhead may be locally omitted.

Similarly, the extension of the bulkhead may be limited for bows without a bulb, depending on the shape of the hull. However, the bulkhead is to be fitted in the higher part of the peak.

2.10.3 Plating thickness

The net plating thickness of the lower part of the longitudinal bulkhead over a height at least equal to h_M defined in [2.4.2] is to be not less than that required for the centre girder in [2.4.3].

Elsewhere, the net thickness of the longitudinal bulkhead plating is to be not less than the value obtained, in mm, from the following formula:

$$t = 6{,}5 + 0{,}013\, L_1$$

2.10.4 Ordinary stiffeners

The net section modulus of ordinary stiffeners is to be not less than the value obtained, in cm^3, from the following formula:

$$w = 3{,}5 s \ell^2 k (z_{TOP} - z_M)$$

where:

z_{TOP} : Z co-ordinate, in m, of the highest point of the tank

z_M : Z co-ordinate, in m, of the stiffener mid-span.

2.10.5 Primary supporting members

Vertical and longitudinal primary supporting members, to be made preferably with symmetrical type sections, are to have a section modulus not less than 50% of that required for the corresponding side or longitudinal webs.

The vertical and longitudinal webs are to be provided with adequate fairing end brackets and to be securely connected to the struts, if any.

2.10.6 Openings

Bulkhead openings are to be limited in the zone corresponding to the centre girder to approximately 2% of the area, and, in the zone above, to not less than 10% of the area. Openings are to be located such as to affect as little as possible the plating sections adjacent to primary supporting members.

2.11 Bulbous bow

2.11.1 General

Where a bulbous bow is fitted, fore peak structures are to effectively support the bulb and are to be adequately connected to its structures.

When the bulbous bow is intended to contain a sonar device, the requirements in [2.11.7] apply.

2.11.2 Shell plating

The thickness of the shell plating of the fore end of the bulb and the first strake above the keel is generally to be not less than that required in [5.2.1] for plate stems. This thickness is to be extended to the bulbous zone, which, depending on its shape, may be damaged by anchors and chains during handling.

2.11.3 Connection with the fore peak

Fore peak structures are to be extended inside the bulb as far as permitted by the size and shape of the latter.

2.11.4 Floors

Solid floors are to be part of reinforced transverse rings generally arranged not more than 3 frame spaces apart.

2.11.5 Longitudinal centreline wash bulkhead

For a bulb of considerable width, a longitudinal centreline wash bulkhead may be required by the Society in certain cases.

2.11.6 Transverse wash bulkhead

In way of a long bulb, transverse wash bulkheads or side transverses of adequate strength arranged not more than 5 frame spaces apart may be required by the Society in certain cases.

2.11.7 Bulbous bow intended to contain a sonar device

The fore part of the bulbous bow is generally constituted by a GRP dome boltd to the fore strcutures. The aft part of the bulbous bow, of metallic construction, is to be connected with the fore structures according to [2.11.3] to [2.11.6] as far as practicable.

The sonar space is generally filled with water and is provided with a system for filling and emptying it. The hull watertightness is to be ensured by means of an horizontal flat and a transverse watertight floor, which contour teh sonar dome. The scantlings of these watertight elements are to be checked considering them as being part of the outer shell.

If the access, in floating condition, to the sonar dome is to be ensured, for inspection and maintenance, two watertight hatches are, in general, to be fitted. For small domes, one hatch only may be accepted provided that its clear opening is such to allow contemporary easy access and ventilation. For the scantlings of these hatches, the sea pressures acting on the outer shell are to be considered.

3 Reinforcements of the flat bottom forward area

3.1 Area to be reinforced

3.1.1 In addition to the requirements in [2], the structures of the flat bottom forward area are to be able to sustain the dynamic pressures due to the bottom impact. The flat bottom forward area is:

- longitudinally, over the bottom located between ξL and 0,05L aft of the fore end, where the coefficient ξ is obtained from the following formula:

$$\xi = 0,25(1,6 - C_B)$$

  without being taken less than 0,2 or greater than 0,25

- transversely, over the whole flat bottom and the adjacent zones up to a height, from the base line, not less than 2L, in mm. In any case, it is not necessary that such height is greater than 300 mm.

3.1.2 The bottom dynamic impact pressure is to be considered if:

$T_F < \min(0,04L; 8,6\text{ m})$

where T_F is the minimum forward draught, in m, among those foreseen in operation in ballast conditions or conditions of partial loading.

3.1.3 The value of the minimum forward draught T_F adopted for the calculations is to be specified in the loading manual.

3.1.4 An alternative arrangement and extension of strengthening with respect to the above may also be required where the minimum forward draught exceeds 0,04 L, depending on the shape of the forward hull body and the ship's length and service speed.

3.2 Bottom impact pressure

3.2.1 The bottom impact pressure p_{BI} is to be obtained, in kN/m^2, from the following formula:

$$p_{BI} = 25n\left[0,004 - \left(\frac{T_F}{L}\right)^2\right]\frac{L_1 L}{T_F}$$

where T_F is the draught defined in [3.1.2].

3.3 Partial safety factors

3.3.1 The partial safety factors to be considered for checking the reinforcements of the flat bottom forward area are specified in Tab 11.

Table 11 : Reinforcements of the flat bottom forward area - Partial safety factors

Partial safety factors covering uncertainties regarding:	Partial safety factors		
	Symbol	Plating	Ordinary stiffeners
Still water pressure	γ_{S2}	1,00	1,00
Wave pressure	γ_{W2}	1,10	1,10
Material	γ_m	1,02	1,02
Resistance	γ_R	1,30	1,15

3.4 Scantlings

3.4.1 Plating and ordinary stiffeners

In addition to the requirements in [2.4.1] and [2.5.1], the net scantlings of plating and ordinary stiffeners of the flat bottom forward area, defined in [3.1], are to be not less than the values obtained from the formulae in Tab 12 and the minimum values in the same Table.

The span of ordinary stiffeners to be considered for the calculation of net section modulus and net shear sectional area is to be taken as the distance between the adjacent primary supporting members; the effect of local supports (e.g. additional vertical brackets located between primary supporting members) is considered by the Society on a case-by-case basis.

3.4.2 Tapering

Outside the flat bottom forward area, scantlings are to be gradually tapered so as to reach the values required for the areas considered.

Table 12 : Reinforcements of plating and ordinary stiffeners of the flat bottom forward area

Element	Formula	Minimum value
Plating	Net thickness, in mm: $t = 13{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{W2} p_{BI}}{R_y}}$	Net minimum thickness, in mm: $t = c_F (0{,}038L + 7{,}0)(sk)^{1/2} - c_E$
Ordinary stiffeners	Net section modulus, in cm³: $w = \gamma_R \gamma_m \beta_b \frac{\gamma_{W2} p_{BI}}{16 c_P R_y}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$	Web net minimum thickness, in mm, to be not less than the lesser of: • $t = 1{,}5 L_2^{1/3} k^{1/6}$ • the thickness of the attached plating
	Net shear sectional area, in cm²: $A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{W2} p_{BI}}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$	

Note 1:
c_P : Ratio of the plastic section modulus to the elastic section modulus of the ordinary stiffeners with attached shell plating, to be taken equal to 1,16 in the absence of more precise evaluation.

3.5 Arrangement of primary supporting members and ordinary stiffeners: longitudinally framed bottom

3.5.1 The requirements in [3.5.2] to [3.5.4] apply to the structures of the flat bottom forward area, defined in [3.1], in addition to the requirements of [2.4].

3.5.2 Bottom longitudinals and side girders, if any, are to extend as far forward as practicable, and their spacing may not exceed that adopted aft of the collision bulkhead.

3.5.3 The spacing of solid floors in a single or double bottom is to be not greater than either that required for the midship section in Ch 4, Sec 4 or (1,35 + 0,007 L) m, whichever is the lesser.

However, where the minimum forward draught T_F is less than 0,02 L, the spacing of floors forward of 0,2 L from the stem is to be not greater than (0,9 + 0,0045 L) m.

3.5.4 The Society may require adequately spaced side girders having a depth equal to that of the floors. As an alternative to the above, girders with increased scantlings may be fitted.

3.6 Arrangement of primary supporting members and ordinary stiffeners: transversely framed double bottom

3.6.1 The requirements in [3.6.2] to [3.6.4] apply to the structures of the flat bottom forward area, defined in [3.1], in addition to the requirements of [2.5].

3.6.2 Solid floors are to be fitted:

- at every second frame between 0,75L and 0,8L from the aft end
- at every frame space forward of 0,8L from the aft end.

3.6.3 Side girders with a depth equal to that of the floors are to be fitted at a spacing generally not exceeding 2,4 m. In addition, the Society may require intermediate half height girders, half the depth of the side girders, or other equivalent stiffeners.

3.6.4 Intercostal longitudinal ordinary stiffeners are to be fitted at a spacing generally not exceeding 1,2 m. Their section modulus is to be not less than 250 cm³.

4 Reinforcements of the bow flare area

4.1 Area to be reinforced

4.1.1 In addition to the requirements in [2], the structures of the bow flare area are to be able to sustain the dynamic pressures due to the bow impact pressure.

4.1.2 The bow area is that extending forward of 0,9 L from the aft end of L and above the summer load waterline.

4.2 Bow impact pressure

4.2.1 The bow impact pressure p_{FI} is to be obtained, in kN/m², from the following formula:

$$p_{FI} = n C_S C_L C_Z (0{,}22 + 0{,}15 \tan\alpha)(0{,}4 V \sin\beta + 0{,}6\sqrt{L})^2$$

where:

C_S : Coefficient depending on the type of structures on which the bow impact pressure is considered to be acting:
- $C_S = 1{,}8$ for plating and ordinary stiffeners
- $C_S = 0{,}5$ for primary supporting members

C_L : Coefficient depending on the ship's length:
- $C_L = 0{,}0125\ L$ for $L < 80$ m
- $C_L = 1{,}0$ for $L \geq 80$ m

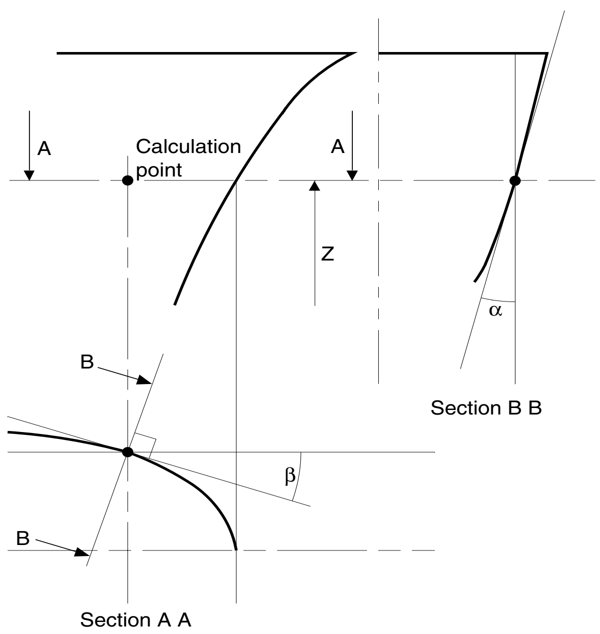
C_Z : Coefficient depending on the distance between the summer load waterline and the calculation point:
- $C_Z = C - 0{,}5\,(z - T)$ for $z \geq 2\,C + T - 11$
- $C_Z = 5{,}5$ for $z < 2\,C + T - 11$

C : Wave parameter, defined in Ch 5, Sec 2

α : Flare angle at the calculation point, defined as the angle between a vertical line and the tangent to the side plating, measured in a vertical plane normal to the horizontal tangent to the shell plating (see Fig 1)

β : Entry angle at the calculation point, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane (see Fig 1).

Figure 1 : Definition of angles α and β



4.3 Partial safety factors

4.3.1 The partial safety factors to be considered for checking the reinforcements of the bow flare area are specified in Tab 13.

Table 13 : Reinforcements of the bow flare area Partial safety factors

Partial safety factors covering uncertainties regarding:	Partial safety factors		
	Symbol	Plating	Ordinary stiffeners
Still water pressure	γ_{S2}	1,00	1,00
Wave pressure	γ_{W2}	1,10	1,10
Material	γ_m	1,02	1,02
Resistance	γ_R	1,30	1,02

4.4 Scantlings

4.4.1 Plating and ordinary stiffeners *(1/1/2017)*

In addition to the requirements in [2.6.1] and [2.7.1], the net scantlings of plating and ordinary stiffeners of the bow flare area, defined in [4.1], are to be not less than the values obtained from the formulae in Tab 14 and the minimum values in the same table.

The span of ordinary stiffeners to be considered for the calculation of net section modulus and net shear sectional area is to be taken as the distance between the adjacent primary supporting members measured along the chord of the curve defined by the intersection between the ordinary stiffener and the side shell; the effect of local supports (e.g. additional vertical brackets located between primary supporting members) is considered by the Society on a case-by-case basis.

4.4.2 Tapering

Outside the bow flare area, scantlings are to be gradually tapered so as to reach the values required for the areas considered.

4.4.3 Intercostal stiffeners

Intercostal stiffeners are to be fitted at mid-span where the angle between the stiffener web and the attached plating is less than 70°.

4.4.4 Primary supporting members

In addition to the requirements in [2.6] and [2.7], primary supporting members are generally to be verified through direct calculations carried out according to Ch 7, Sec 3, considering the bow impact pressures defined in [4.2] and the partial safety factors in Tab 13.

5 Stems

5.1 General

5.1.1 Arrangement

Adequate continuity of strength is to be ensured at the connection of stems to the surrounding structure.

Abrupt changes in sections are to be avoided.

Table 14 : Reinforcements of plating and ordinary stiffeners of the bow flare area

Element	Formula	Minimum value
Plating	Net thickness, in mm: $t = 11 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{W2} p_{FI}}{R_y}}$	Net minimum thickness, in mm: $t = c_F (0,038L + 7,0)(sk)^{1/2} - c_E$
Ordinary stiffeners	Net section modulus, in cm³: $w = \gamma_R \gamma_m \beta_b \frac{\gamma_{W2} p_{FI}}{18 c_P R_y}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$	Web net minimum thickness, in mm, to be not less than the lesser of: • $t = 1,5 L_2^{1/3} k^{1/6}$ • the thickness of the attached plating.
	Net shear sectional area, in cm²: $A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{W2} p_{FI}}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$	

Note 1:
c_P : Ratio of the plastic section modulus to the elastic section modulus of the ordinary stiffeners with attached shell plating, to be taken equal to 1,16 in the absence of more precise evaluation.

5.1.2 Gross scantlings

With reference to Ch 4, Sec 2, [1], all scantlings and dimensions referred to in [5.2] and [5.3] are gross, i.e. they include the margins for corrosion.

5.2 Plate stems

5.2.1 Where the stem is constructed of shaped plates, the gross thickness of the plates below the load waterline is to be not less than the value obtained, in mm, from the following formula:

$$t_S = 1,37(0,95 + \sqrt{L_3})\sqrt{k}$$

where:

L_3 : Ship's length L, in m, but to be taken not greater than 300.

Above the load waterline this thickness may be gradually tapered towards the stem head, where it is to be not less than that required for side plating at ends.

5.2.2 The plating forming the stems is to be supported by horizontal diaphragms spaced not more than 1200 mm apart and connected, as far as practicable, to the adjacent frames and side stringers.

5.2.3 If considered necessary, and particularly where the stem radius is large, a centreline stiffener or web of suitable scantlings is to be fitted.

5.3 Bar stems

5.3.1 The gross area of bar stems constructed of forged or rolled steel is to be not less than the value obtained, in cm², from the following formulae:

$$A_P = \left(0,40 + \frac{10T}{L}\right)(0,009L^2 + 20)\sqrt{k} \quad \text{for } L \le 90$$

$$A_P = \left(0,40 + \frac{10T}{L}\right)(1,8L - 69)\sqrt{k} \quad \text{for } 90 < L \le 200$$

where the ratio T/L in the above formulae is to be taken not less than 0,05 or greater than 0,075.

5.3.2 The gross thickness t_B of the bar stem is to be not less than the value obtained, in mm, from the following formula:

$$t_B = (0,4L + 13)\sqrt{k}$$

5.3.3 The cross-sectional area of the stem may be gradually tapered from the load waterline to the upper end, where it may be equal to the two thirds of the value as calculated above.

5.3.4 The lower part of the stem may be constructed of cast steel subject to the examination by the Society; where necessary, a vertical web is to be fitted for welding of the centre keelson.

5.3.5 Welding of the bar stem with the bar keel and the shell plating is to be in accordance with Ch 11, Sec 1, [3.4].

6 Transverse thrusters

6.1 Scantlings of the thruster tunnel and connection with the hull

6.1.1 The thickness of the tunnel is to be not less than that of the adjacent hull plating.

6.1.2 When the tunnel is not welded to the hull, the connection devices are examined by the Society on a case by case basis.

SECTION 2 AFT PART

Symbols

L_1, L_2 : Lengths, in m, defined in Ch 1, Sec 2, [2.1.1]

h_1 : Reference value of the ship relative motion, defined in Ch 5, Sec 3, [3.3]

a_{Z1} : Reference value of the vertical acceleration, defined in Ch 5, Sec 3, [3.4]

ρ : Sea water density, in t/m^3

g : Gravity acceleration, in m/s^2:

$g = 9,81$ m/s^2

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [10]

p_S, p_W : Still water pressure and wave pressure defined in [2.3]

k : Material factor, defined in Ch 4, Sec 1, [2.3]

R_y : Minimum yield stress, in N/mm^2, of the material, to be taken equal to 235/k, unless otherwise specified

s : Spacing, in m, of ordinary stiffeners or primary supporting members, as applicable

ℓ : Span, in m, of ordinary stiffeners or primary supporting members, as applicable

c_a : Aspect ratio of the plate panel, equal to:

$$c_a = 1,21\sqrt{1 + 0,33\left(\frac{s}{\ell}\right)^2} - 0,69\frac{s}{\ell}$$

to be taken not greater than 1,0

c_r : Coefficient of curvature of the panel, equal to:

$c_r = 1 - 0,5\ s/r$

to be taken not less than 0,75

r : Radius of curvature, in m

β_b, β_s : Coefficients defined in Ch 7, Sec 2, [3.7.3]

λ_{bS}, λ_{bW}, λ_{sS}, λ_{sW}: Coefficients defined in Ch 7, Sec 2, [3.4.5]

c_E : Coefficient to be taken equal to:

$c_E = 1$ for $L \leq 65$ m

$c_E = 3 - L/30$ for $65\ m < L < 90$ m

$c_E = 0$ for $L \geq 90$ m

c_F : Coefficient:

$c_F = 0,8$ for poop sides

$c_F = 1,0$ in other cases.

1 General

1.1 Application

1.1.1 The requirements of this Section apply for the scantlings of structures located aft of the after peak bulkhead and for the reinforcements of the flat bottom aft area.

1.1.2 Aft peak structures which form the boundary of spaces not intended to carry liquids, and which do not belong to the outer shell, are to be subjected to lateral pressure in flooding conditions. Their scantlings are to be determined according to the relevant criteria in Chapter 7, as applicable.

1.2 Connections of the aft part with structures located fore of the after peak bulkhead

1.2.1 Tapering

Adequate tapering is to be ensured between the scantlings in the aft part and those fore of the after peak bulkhead. The tapering is to be such that the scantling requirements for both areas are fulfilled.

1.3 Net scantlings

1.3.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

Gross scantlings are obtained as specified in Ch 4, Sec 2.

2 Aft peak

2.1 Partial safety factors

2.1.1 The partial safety factors to be considered for checking aft peak structures are specified in Tab 1.

2.2 Load point

2.2.1 Unless otherwise specified, lateral pressure is to be calculated at:

- the lower edge of the elementary load panel considered, for plating
- mid-span, for stiffeners.

Table 1 : Aft peak structures - Partial safety factors

Partial safety factors covering uncertainties regarding:	Partial safety factors			
	Symbol	Plating	Ordinary stiffeners	Primary supporting members
Still water pressure	γ_{S2}	1,00	1,00	1,00
Wave pressure	γ_{W2}	1,20	1,20	1,20
Material	γ_m	1,02	1,02	1,02
Resistance	γ_R	1,20	1,40	1,60

2.3 Load model

2.3.1 General *(1/1/2017)*

The still water and wave lateral pressures in intact conditions are to be considered. They are to be calculated as specified in [2.3.2] for the elements of the outer shell and in [2.3.3] for the other elements.

Still water pressure (p_S) includes:

- the still water sea pressure, defined in Tab 2
- the still water internal pressure due to liquid or ballast, defined in Tab 4
- for decks, the still water internal pressure due to dry uniform weights, defined in Tab 5.

Wave pressure (p_W) includes:

- the wave pressure, defined in Tab 2
- the inertial pressure due to liquids or ballast, defined in Tab 4
- for decks, the inertial pressure due to uniform loads, defined in Tab 5.

2.3.2 Lateral pressures for the elements of the outer shell

The still water and wave lateral pressures are to be calculated considering separately:

- the still water and wave external sea pressures
- the still water and wave internal pressure, considering the compartment adjacent to the outer shell as being loaded

If the compartment adjacent to the outer shell is not intended to carry liquids, only the external sea pressures are to be considered.

2.3.3 Lateral pressures for elements other than those of the outer shell

The still water and wave lateral pressures to be considered as acting on an element which separates two adjacent compartments are those obtained considering the two compartments individually loaded.

3 After peak

3.1 Arrangement

3.1.1 General *(1/1/2017)*

The after peak is, in general, to be transversely framed.

3.1.2 Floors *(1/1/2017)*

Solid floors are to be fitted at every frame spacing.

The floor height is to be adequate in relation to the shape of the hull. Where a sterntube is fitted, the floor height is to extend at least above the sterntube. Where the hull lines do not allow such extension, plates of suitable height with upper and lower edges stiffened and securely fastened to the frames are to be fitted above the sterntube.

Table 2 : Still water and wave pressures *(1/1/2017)*

Location	Still water sea pressure p, in kN/m²	Wave pressure p_W, in kN/m²
Bottom and side below the waterline: $z \le T$	$\rho g(T-z)$	$\rho g h_1 e^{\frac{-2\pi(T-z)}{L}}$
Side above the waterline: $z > T$	0	$\rho g(T+h_1-z)$ without being taken less than 0,15L
Exposed deck	Pressure due to the load carried **(1)**	$17{,}5n\varphi$

(1) The pressure due to the load carried is to be defined by the Designer and, in any case, it may not be taken less than 10φ kN/m², where φ is defined in Tab 3.
The Society may accept pressure values lower than 10φ kN/m² when considered appropriate on the basis of the intended use of the deck.

Note 1:

φ : Coefficient defined in Tab 3.

Table 3 : Coefficient for pressure on exposed deck *(1/1/2017)*

Exposed deck location	φ
Bulkhead deck	1
Superstructure deck	0,75
1st tier of deckhouse	0,56
2nd tier of deckhouse	0,42
3rd tier of deckhouse	0,32
4th tier of deckhouse and above	0,25

Table 4 : Still water and wave internal pressures due to liquids *(1/1/2017)*

Still water pressure p_S, in kN/m²	Inertial pressure p_W, in kN/m²
$\rho g(z_L - z)$	$\rho a_{Z1}(z_{TOP} - z)$

Note 1:

z_{TOP} : Z co-ordinate, in m, of the highest point of the tank

z_L : Z co-ordinate, in m, of the highest point of the liquid:

$$z_L = z_{TOP} + 0{,}5(z_{AP} - z_{TOP})$$

z_{AP} : Z co-ordinate, in m, of the moulded deck line of the deck to which the air pipes extend, to be taken not less than z_{TOP}.

Table 5 : Still water and inertial internal pressures due to uniform loads *(1/1/2017)*

Still water pressure p_S, in kN/m²	Inertial pressure p_W, in kN/m²
The value of p_S is, in general, defined by the Designer: in any case it may not be taken less than 10 kN/m². When the value of p_S is not defined by the Designer, it may be taken, in kN/m², equal to 6,9 h_{TD}, where h_{TD} is the compartment 'tweendeck height at side, in m	$p_S \frac{a_{Z1}}{g}$

In way of and near the rudder post, propeller post and rudder horn, floors are to be extended up to the peak tank top and are to be increased in thickness; the increase will be considered by the Society on a case by case basis, depending on the arrangement proposed.

Floors are to be fitted with stiffeners having spacing not greater than 800 mm.

3.1.3 Side frames *(1/1/2017)*

Side frames are to be extended up to a deck located above the full load waterline.

Side frames are to be supported by one of the following types of structure:

- non-tight platforms, to be fitted with openings having a total area not less than 10% of the area of the platforms
- side girders supported by side primary supporting members connected to deck transverses.

The distance between the above side frame supports is to be not greater than 2,5 m.

3.1.4 Platforms and side girders *(1/1/2017)*

Platforms and side girders within the peak are to be arranged in line with those located in the area immediately forward.

Where this arrangement is not possible due to the shape of the hull and access needs, structural continuity between the peak and the structures of the area immediately forward is to be ensured by adopting wide tapering brackets.

Where the after peak is adjacent to a machinery space whose side is longitudinally framed, the side girders in the after peak are to be fitted with tapering brackets.

3.1.5 Longitudinal bulkheads *(1/1/2017)*

A longitudinal non-tight bulkhead is to be fitted on the centreline of the ship, in general in the upper part of the peak, and stiffened at each frame spacing.

Where either the stern overhang is very large or the maximum breadth of the peak is greater than 20 m, additional longitudinal wash bulkheads may be required.

3.2 Scantlings

3.2.1 Plating and ordinary stiffeners (side frames) *(1/1/2017)*

The net scantlings of plating and ordinary stiffeners are to be not less than those obtained from the formulae in:

- Tab 6 for plating
- Tab 7 for ordinary stiffeners

and not less than the minimum values in the same tables.

3.2.2 Floors *(1/1/2017)*

The net thickness of floors is to be not less than that obtained, in mm, from the following formula:

$t_M = 6{,}5 + 0{,}023\ L_1\ k^{1/2}$

3.2.3 Side transverses *(1/1/2017)*

The net section modulus w, in cm³, and the net shear sectional area A_{SH}, in cm², of side transverses are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2}\lambda_{bS} p_S + \gamma_{W2}\lambda_{bW} p_W}{8R_y} s \ell^2 10^3$$

$$A_{Sh} = 10\gamma_R \gamma_m \beta_s \frac{\gamma_{S2}\lambda_{sS} p_S + \gamma_{W2}\lambda_{sW} p_W}{R_y} s \ell$$

3.2.4 Side girders *(1/1/2017)*

The net section modulus w, in cm³, and the net shear sectional area A_{Sh}, in cm², of side girders are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{8R_y} s \ell^2 10^3$$

$$A_{Sh} = 10\gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} s \ell$$

3.2.5 Deck primary supporting members *(1/1/2017)*

Scantlings of deck primary supporting members are to be in accordance with Ch 7, Sec 3, considering the loads in [2.3].

The partial safety factors to be used are those defined in Ch 7, Sec 3, [1.3].

Table 6 : Net thickness of plating *(1/1/2017)*

Plating location	Net thickness, in mm	Net minimum thickness, in mm
Bottom, side and transom	$14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}}$	$t = c_F(0{,}038L + 7{,}0)(sk)^{1/2} - c_E$
Inner bottom		$2 + 0{,}017\ L\ k^{1/2} + 4{,}5\ s$
Deck		For strength deck: $2{,}1 + 0{,}013\ L\ k^{1/2} + 4{,}5\ s$
Platform and wash bulkhead		$1{,}3 + 0{,}004\ L\ k^{1/2} + 4{,}5\ s$ for $L < 120$ m $2{,}1 + 2{,}2\ k^{1/2} + s$ for $L \geq 120$ m

Table 7 : Net scantlings of ordinary stiffeners *(1/1/2017)*

Ordinary stiffener location	Formulae	Minimum value
Bottom and side	Net section modulus, in cm³: $w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{8 R_y}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$	Web net minimum thickness, in mm, to be not less than the lesser of: • $t = 1{,}5 L_2^{1/3} k^{1/6}$ • the thickness of the attached plating.
	Net shear sectional area, in cm²: $A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$	
Deck	Net section modulus, in cm³: $w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m R_y}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$	
	Net shear sectional area, in cm²: $A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$	
Platform and wash bulkhead	Net section modulus, in cm³: $w = 3{,}5 s \ell^2 k (z_{TOP} - z_M)$	
Note 1: m : Boundary coefficient, to be taken equal to: • m = 12 for longitudinally framed decks • m = 8 for transversely framed decks Z_{TOP} : Z co-ordinate, in m, of the highest point of the peak tank Z_M : Z co-ordinate, in m, of the stiffener mid-span.		

4 Reinforcements of the flat area of the bottom aft

4.1 General

4.1.1 In the flat area of the bottom aft, if any, increased bottom plating thickness as well as additional bottom stiffeners may be considered by the Society on a case by case basis.

5 Connection of hull structures with the rudder horn

5.1 Connection of after peak structures with the rudder horn

5.1.1 General

The requirement of this sub-article apply to the connection between peak structure and rudder horn where the sternframe is of an open type and is fitted with the rudder horn.

5.1.2 Rudder horn

Horn design is to be such as to enable sufficient access for welding and inspection.

The scantlings of the rudder horn, which are to comply with Ch 9, Sec 1, [9.2], may be gradually tapered inside the hull.

Connections by slot welds are not acceptable.

5.1.3 Hull structures

Between the horn intersection with the shell and the peak tank top, the vertical extension of the hull structures is to be not less than the horn height, defined as the distance from the horn intersection with the shell to the mid-point of the lower horn gudgeon.

The thickness of the structures adjacent to the rudder horn, such as shell plating, floors, platforms and side girders, the centreline bulkhead and any other structures, is to be adequately increased in relation to the horn scantlings.

5.2 Structural arrangement above the after peak

5.2.1 Side transverses *(1/1/2017)*

Where a rudder horn is fitted, side transverses, connected to deck beams, are to be arranged between the platform forming the peak tank top and the weather deck.

The side transverse spacing is to be not greater than:

- 2 frame spacings in way of the horn
- 4 frame spacings for and aft of the rudder horn
- 6 frame spacings in the area close to the after peak bulkhead.

The side transverses are to be fitted with end brackets and located within the poop. Where there is no poop, the scantlings of side transverses below the weather deck are to be adequately increased with respect to those obtained from the formulae in [3.2.3].

5.2.2 Side girders

Where the depth from the peak tank top to the weather deck is greater than 2,6 m and the side is transversely framed, one or more side girders are to be fitted, preferably in line with similar structures existing forward.

6 Sternframes

6.1 General

6.1.1 Sternframes may be made of cast or forged steel, with a hollow section, or fabricated from plate.

6.1.2 Cast steel and fabricated sternframes are to be strengthened by adequately spaced horizontal plates.

Abrupt changes of section are to be avoided in castings; all sections are to have adequate tapering radius.

6.2 Connections

6.2.1 Connection with hull structure

Sternframes are to be effectively attached to the aft structure and the lower part of the sternframe is to be extended forward of the propeller post to a length not less than 1500 + 6L mm, in order to provide an effective connection with the keel. However, the sternframe need not extend beyond the after peak bulkhead.

The net thickness of shell plating connected with the sternframe is to be not less than that obtained, in mm, from the following formula:

$t = 0,045\ L\ k^{1/2} + 8,5$

6.2.2 Connection with the keel

The thickness of the lower part of the sternframes is to be gradually tapered to that of the solid bar keel or keel plate.

Where a keel plate is fitted, the lower part of the sternframe is to be so designed as to ensure an effective connection with the keel.

6.2.3 Connection with transom floors

Rudder posts and, in the case of ships greater than 90 m in length, propeller posts are to be connected with transom floors having height not less than that of the double bottom and net thickness not less than that obtained, in mm, from the following formula:

$t = 9 + 0,023\ L_1\ k^{1/2}$

6.2.4 Connection with centre keelson

Where the sternframe is made of cast steel, the lower part of the sternframe is to be fitted, as far as practicable, with a longitudinal web for connection with the centre keelson.

6.3 Propeller posts

6.3.1 Gross scantlings

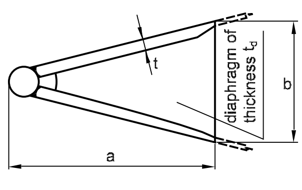
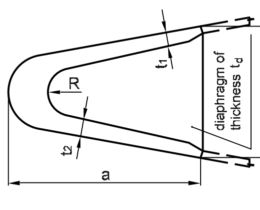
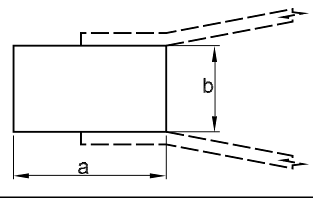
With reference to Ch 4, Sec 2, [1], all scantlings and dimensions referred to in [6.3.2] to [6.3.4] are gross, i.e. they include the margins for corrosion.

6.3.2 Gross scantlings of propeller posts

The gross scantlings of propeller posts are to be not less than those obtained from the formulae in Tab 1 for single screw ships and Tab 9 for twin screw ships.

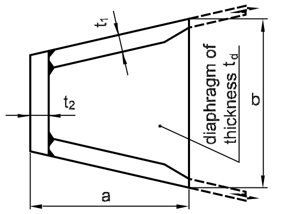
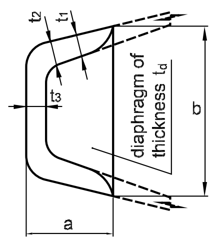
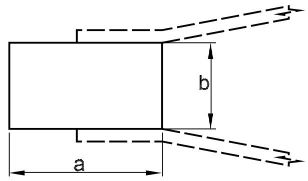
Scantlings and proportions of the propeller post which differ from those above may be considered acceptable provided that the section modulus of the propeller post section about its longitudinal axis is not less than that calculated with the propeller post scantlings in Tab 1 or Tab 9, as applicable.

Table 8 : Single screw ships - Gross scantlings of propeller posts

Gross scantlings of propellerposts, in mm	**Fabricated propeller post** 	**Cast propeller post** 	**Bar propeller post, cast or forged, having rectangular section** 
a	$50\ L^{1/2}$	$33\ L^{1/2}$	$10 \cdot \sqrt{2,5(L+10)}$ for $L \le 60$ $10 \cdot \sqrt{7,2L-256}$ for $L > 60$
b	$35\ L^{1/2}$	$23\ L^{1/2}$	$10 \cdot \sqrt{1,6(L+10)}$ for $L \le 60$ $10 \cdot \sqrt{4,6L-164}$ for $L > 60$
t_1 **(1)**	$2,5\ L^{1/2}$	$3,2\ L^{1/2}$ to be taken not less than 19 mm	ϕ
t_2 **(1)**	ϕ	$4,4\ L^{1/2}$ to be taken not less than 19 mm	ϕ
t_D	$1,3\ L^{1/2}$	$2,0\ L^{1/2}$	ϕ
R	ϕ	$50\ L^{1/2}$	ϕ

(1) Propeller post thicknesses t_1 and t_2 are, in any case, to be not less than (0,05 L + 9,5) mm.
Note 1: ϕ = not applicable.

Table 9 : Twin screw ships - Gross scantlings of propeller posts

Gross scantlings of propellerposts, in mm	**Fabricated propeller post** 	**Cast propeller post** 	**Bar propeller post, cast or forged, having rectangular section** 
a	25 $L^{1/2}$	12,5 $L^{1/2}$	0,72 L + 90 for $L \leq 50$ 2,40 L + 6 for $L > 50$
b	25 $L^{1/2}$	25 $L^{1/2}$	0,24 L + 30 for $L \leq 50$ 0,80 L + 2 for $L > 50$
t_1 **(1)**	2,5 $L^{1/2}$	2,5 $L^{1/2}$	ϕ
t_2 **(1)**	3,2 $L^{1/2}$	3,2 $L^{1/2}$	ϕ
t_3 **(1)**	ϕ	4,4 $L^{1/2}$	ϕ
t_D	1,3 $L^{1/2}$	2 $L^{1/2}$	ϕ

(1) Propeller post thicknesses t_1, t_2 and t_3 are, in any case, to be not less than (0,05 L + 9,5) mm.
Note 1:ϕ = not applicable.

6.3.3 Section modulus below the propeller shaft bossing

In the case of a propeller post without a sole piece, the section modulus of the propeller post may be gradually reduced below the propeller shaft bossing down to 85% of the value calculated with the scantlings in Tab 1 or Tab 9, as applicable.

In any case, the thicknesses of the propeller posts are to be not less than those obtained from the formulae in the tables.

6.3.4 Welding of fabricated propeller post with the propeller shaft bossing

Welding of a fabricated propeller post with the propeller shaft bossing is to be in accordance with Ch 11, Sec 1, [3.3].

6.4 Integral rudder posts

6.4.1 Net section modulus of integral rudder post

The net section modulus around the horizontal axis X (see Fig 1) of an integral rudder post is to be not less than that obtained, in cm³, from the following formula:

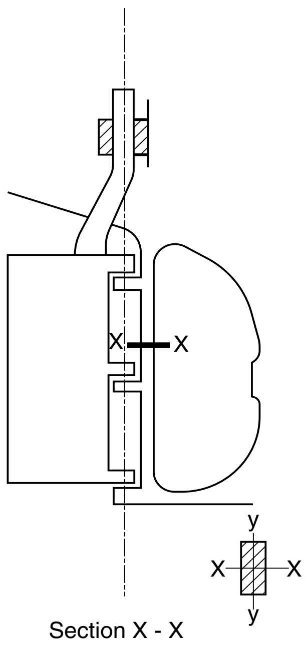
$w_{RP} = 14,4\ C_R\ L_D\ 10^{-6}$

where:

C_R : Rudder force, in N, acting on the rudder blade, defined in Ch 9, Sec 1, [2.1.2] and Ch 9, Sec 1, [2.2.2], as the case may be

L_D : Length of rudder post, in m.

Figure 1 : Integral rudder post



6.5 Propeller shaft bossing

6.5.1 In single screw ships, the thickness of the propeller shaft bossing, included in the propeller post, is to be not less than 60% of the dimension "b" required in [6.3.2] for bar propeller posts with a rectangular section.

6.6 Rudder gudgeon

6.6.1 Rudder gudgeons

In general, gudgeons are to be solidly forged or cast with the sternframe.

The height of the gudgeon is to be not greater than 1,2 times the pintle diameter. In any case, the height and diameter of the gudgeons are to be suitable to house the rudder pintle.

The thickness of the metal around the finished bore of the gudgeons is to be not less than half the diameter of the pintle.

6.7 Sterntubes

6.7.1 The sterntube thickness is considered by the Society on a case by case basis. In no case, however, may it be less than the thickness of the side plating adjacent to the sternframe.

Where the materials adopted for the sterntube and the plating adjacent to the sternframe are different, the sterntube thickness is to be at least equivalent to that of the plating.

SECTION 3 MACHINERY SPACE

Symbols

L_2 : Length, in m, defined in Ch 1, Sec 2, [2.1.1]

k : Material factor, defined in Ch 4, Sec 1, [2.3]

s : Spacing, in m, of ordinary stiffeners

P : Maximum power, in kW, of the engine

n_r : Number of revolutions per minute of the engine shaft at power equal to P

L_E : Effective length, in m, of the engine foundation plate required for bolting the engine to the seating, as specified by the engine manufacturer.

1 General

1.1 Application

1.1.1 The requirements of this Section apply for the arrangement and scantling of machinery space structures as regards general strength. It is no substitute to machinery manufacturer's requirements which have to be dealt with at Shipyard diligence.

1.2 Scantlings

1.2.1 Net scantlings

As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 4, Sec 2.

1.2.2 General

Unless otherwise specified in this Section, the scantlings of plating, ordinary stiffeners and primary supporting members in the machinery space are to be determined according to the relevant criteria in Chapter 7as applicable. In addition, the minimum thickness requirements specified in this Section apply.

1.2.3 Primary supporting members

The Designer may propose arrangements and scantlings alternative to the requirements of this Section, on the basis of direct calculations which are to be submitted to the Society for examination on a case by case basis.

The Society may also require such direct calculations to be carried out whenever deemed necessary.

1.3 Connections of the machinery space with structures located aft and forward

1.3.1 Tapering

Adequate tapering is to be ensured between the scantlings in the machinery space and those aft and forward. The tapering is to be such that the scantling requirements for all areas are fulfilled.

1.3.2 Deck discontinuities

Decks which are interrupted in the machinery space are to be tapered on the side by means of horizontal brackets.

2 Double bottom

2.1 Arrangement

2.1.1 General

Where the machinery space is immediately forward of the after peak, the double bottom is to be transversely framed. In all other cases it may be transversely or longitudinally framed.

2.1.2 Double bottom height

The double bottom height at the centreline, irrespective of the location of the machinery space, is to be not less than the value defined in Ch 4, Sec 4, [4.2.1]. This depth may need to be considerably increased in relation to the type and depth of main machinery seatings.

The above height is to be increased by the Shipyard where the machinery space is very large and where there is a considerable variation in draught between light ballast and full load conditions.

Where the double bottom height in the machinery space differs from that in adjacent spaces, structural continuity of longitudinal members is to be ensured by sloping the inner bottom over an adequate longitudinal extent. The knuckles in the sloped inner bottom are to be located in way of floors.

2.1.3 Centre bottom girder

In general, the centre bottom girder may not be provided with holes. In any case, in way of any openings for manholes on the centre girder, permitted only where absolutely necessary for double bottom access and maintenance, local strengthening is to be arranged.

2.1.4 Side bottom girders

In the machinery space the number of side bottom girders is to be adequately increased, with respect to the adjacent areas, to ensure adequate rigidity of the structure.

The side bottom girders are to be a continuation of any bottom longitudinals in the areas adjacent to the machinery space and are generally to have a spacing not greater than 3 times that of longitudinals and in no case greater than 3 m.

2.1.5 Side bottom girders in way of machinery seatings

Additional side bottom girders are to be fitted in way of machinery seatings.

Side bottom girders arranged in way of main machinery seatings are to extend for the full length of the machinery space.

Where the machinery space is situated amidships, the bottom girders are to extend aft of the after bulkhead of such space for at least three frame spaces, and beyond to be connected to the hull structure by tapering.

Where the machinery space is situated aft, the bottom girders are to extend as far aft as practicable in relation to the shape of the bottom and to be supported by floors and side primary supporting members at the ends.

Forward of the machinery space forward bulkhead, the bottom girders are to be tapered for at least three frame spaces and are to be effectively connected to the hull structure.

2.1.6 Floors in longitudinally framed double bottom

Where the double bottom is longitudinally framed, the floor spacing is to be not greater than:

- 1 frame spacing in way of the main engine and thrust bearing
- 2 frame spacings in other areas of the machinery space.

Additional floors are to be fitted in way of other important machinery.

2.1.7 Floors in transversely framed double bottom

Where the double bottom in the machinery space is transversely framed, floors are to be arranged at every frame.

Furthermore, additional floors are to be fitted in way of boiler foundations or other important machinery.

2.1.8 Floors stiffeners

In addition to the requirements in Ch 4, Sec 3, [4.7], floors are to have web stiffeners sniped at the ends and spaced not more than approximately 1 m apart.

The section modulus of web stiffeners is to be not less than 1,2 times that required in Ch 4, Sec 3, [4.7].

2.1.9 Manholes and wells

The number and size of manholes in floors located in way of seatings and adjacent areas are to be kept to the minimum necessary for double bottom access and maintenance.

The depth of manholes is generally to be not greater than 40% of the floor local depth, and in no case greater than 750 mm, and their width is to be equal to approximately 400 mm.

In general, manhole edges are to be stiffened with flanges; failing this, the floor plate is to be adequately stiffened with flat bars at manhole sides.

Manholes with perforated portable plates are to be fitted in the inner bottom in the vicinity of wells arranged close to the aft bulkhead of the engine room.

Drainage of the tunnel is to be arranged through a well located at the aft end of the tunnel.

2.2 Minimum thicknesses

2.2.1 The net thicknesses of inner bottom, floor and girder webs are to be not less than the values given in Tab 1.

3 Single bottom

3.1 Arrangement

3.1.1 Bottom girder

For single bottom girder arrangement, the requirements of Ch 4, Sec 4, [2] and Ch 4, Sec 4, [4] for double bottom apply.

3.1.2 Floors in longitudinally framed single bottom

Where the single bottom is longitudinally framed, the floor spacing is to be not greater than:

- 1 frame spacing in way of the main engine and thrust bearing
- 2 frame spacings in other areas of the machinery spaces.

Additional floors are to be fitted in way of other important machinery.

Table 1 : Double bottom - Minimum net thicknesses of inner bottom, floor and girder webs

Element	Minimum net thickness, in mm	
	Machinery space within 0,4L amidships	Machinery space outside 0,4L amidships
Inner bottom	$[0,75L^{1/2} + 1,35 + 4,5(s - 0,23L^{1/4})]k^{1/2}$ The Society may require the thickness of the inner bottom in way of the main machinery seatings and on the main thrust blocks to be increased, on a case by case basis.	
Margin plate	$L^{1/2} k^{1/4} + 1$	$0,9 L^{1/2} k^{1/4} + 1$
Centre girder	$1,8 L^{1/3} k^{1/6} + 4$	$1,55 L^{1/3} k^{1/6} + 3,5$
Floors and side girders	$1,7 L^{1/3} k^{1/6} + 1$	
Girder bounding a duct keel	$0,8 L^{1/2} k^{1/4} + 2,5$ to be taken not less than that required for the centre girder	

3.1.3 Floors in transversely framed single bottom

Where the single bottom is transversely framed, the floors are to be arranged at every frame.

Furthermore, additional floors are to be fitted in way of boiler foundations or other important machinery.

3.1.4 Floor height

The height of floors in way of machinery spaces located amidships is to be not less than B/14,5. Where the top of the floors is recessed in way of main machinery, the height of the floors in way of this recess is generally to be not less than B/16. Lower values will be considered by the Society on a case by case basis.

Where the machinery space is situated aft or where there is considerable rise of floor, the depth of the floors will be considered by the Society on a case by case basis.

3.1.5 Floor flanging

Floors are to be fitted with welded face plates in way of:

- engine bed plates
- thrust blocks
- auxiliary seatings.

3.2 Minimum thicknesses

3.2.1 The net thicknesses of inner bottom, floor and girder webs are to be not less than the values given in Tab 2.

Table 2 : Single bottom - Minimum net thicknesses of inner bottom, floor and girder webs

Element	Minimum net thickness, in mm	
	Machinery space within 0,4L amidships	Machinery space outside 0,4L amidships
Centre girder	$7 + 0,05\ L_2\ k^{1/2}$	$6 + 0,05\ L_2\ k^{1/2}$
Floors and side girder	$6,5 + 0,05\ L_2\ k^{1/2}$	$5 + 0,05\ L_2\ k^{1/2}$

4 Side

4.1 Arrangement

4.1.1 General

The type of side framing in machinery spaces is generally to be the same as that adopted in the adjacent areas.

4.1.2 Extension of the hull longitudinal structure within the machinery space

In ships where the machinery space is located aft and where the side is longitudinally framed, the longitudinal structure is preferably to extend for the full length of the machinery space.

In any event, the longitudinal structure is to be maintained for at least 0,3 times the length of the machinery space, calculated from the forward bulkhead of the latter, and abrupt structural discontinuities between longitudinally and transversely framed structures are to be avoided.

4.1.3 Side transverses

Side transverses are to be aligned with floors. One is preferably to be located in way of the forward end and another in way of the after end of the machinery casing.

For a longitudinally framed side, the side transverse spacing is to be not greater than 4 frame spacings.

For a transversely framed side, the side transverse spacing is to be not greater than 5 frame spaces. The web height is to be not less than twice that of adjacent frames and the section modulus is to be not less than four times that of adjacent frames.

Side transverse spacing greater than that above may be accepted provided that the scantlings of ordinary frames are increased, according to the Society's requirements to be defined on a case by case basis.

5 Platforms

5.1 Arrangement

5.1.1 General

The location and extension of platforms in machinery spaces are to be arranged so as to be a continuation of the structure of side longitudinals, as well as of platforms and side girders located in the adjacent hull areas.

5.1.2 Platform transverses

In general, platform transverses are to be arranged in way of side or longitudinal bulkhead transverses.

For longitudinally framed platforms, the spacing of platform transverses is to be not greater than 4 frame spacings.

5.2 Minimum thicknesses

5.2.1 The net thickness of platforms is to be not less than that obtained, in mm, from the following formula:

$$t = 0,018 L_2 k^{1/2} + 4,5$$

6 Pillaring

6.1 Arrangement

6.1.1 General

The pillaring arrangement in machinery spaces is to account both for the concentrated loads transmitted by machinery and superstructures and for the position of main machinery and auxiliary engines.

6.1.2 Pillars

Pillars are generally to be arranged in the following positions:

- in way of machinery casing corners and corners of large openings on platforms; alternatively, two pillars may be fitted on the centreline (one at each end of the opening)
- in way of the intersection of platform transverses and girders
- in way of transverse and longitudinal bulkheads of the superstructure.

In general, pillars are to be fitted with brackets at their ends.

6.1.3 Pillar bulkheads

In general, pillar bulkheads, fitted 'tweendecks below the upper deck, are to be located in way of load-bearing bulkheads in the superstructures.

Longitudinal pillar bulkheads are to be a continuation of main longitudinal hull structures in the adjacent spaces forward and aft of the machinery space.

Pillar bulkhead scantlings are to be not less than those required in [7.3] for machinery casing bulkheads.

7 Machinery casing

7.1 Arrangement

7.1.1 Ordinary stiffener spacing

Ordinary stiffeners are to be located:

- at each frame, in longitudinal bulkheads
- at a distance of about 750 mm, in transverse bulkheads.

The ordinary stiffener spacing in portions of casings which are particularly exposed to wave action is considered by the Society on a case by case basis.

7.2 Openings

7.2.1 General

All machinery space openings, which are to comply with the requirements in [5], are to be enclosed in a steel casing leading to the highest open deck. Casings are to be reinforced at the ends by deck beams and girders associated to pillars.

In the case of large openings, the arrangement of cross-ties as a continuation of deck beams may be required.

Skylights, where fitted with openings for light and air, are to have coamings of a height not less than:

- 900 mm, if in position 1
- 760 mm, if in position 2.

7.2.2 Access doors

Access doors to casings are to comply with Sec 9, [6].

7.3 Scantlings

7.3.1 Plating and ordinary stiffeners

The net scantlings of plating and ordinary stiffeners are to be not less than those obtained according to the applicable requirements in Sec 4.

7.3.2 Minimum thicknesses

The net thickness of bulkheads is to be not less than:

- 5,5 mm for bulkheads in way of cargo holds
- 4 mm for bulkheads in way of accommodation spaces.

8 Main machinery seatings

8.1 Arrangement

8.1.1 General

The scantlings of main machinery seatings and thrust bearings are to be adequate in relation to the weight and power of engines and the static and dynamic forces transmitted by the propulsive installation.

8.1.2 Seating supporting structure

Transverse and longitudinal members supporting the seatings are to be located in line with floors and double or single bottom girders, respectively.

They are to be so arranged as to avoid discontinuity and ensure sufficient accessibility for welding of joints and for surveys and maintenance.

8.1.3 Seatings included in the double bottom structure

Where high-power internal combustion engines or turbines are fitted, seatings are to be integral with the double bottom structure. Girders supporting the bedplates in way of seatings are to be aligned with double bottom girders and are to be extended aft in order to form girders for thrust blocks.

The girders in way of seatings are to be continuous from the bedplates to the bottom shell.

8.1.4 Seatings above the double bottom plating

Where the seatings are situated above the double bottom plating, the girders in way of seatings are to be fitted with flanged brackets, generally located at each frame and extending towards both the centre of the ship and the sides.

The extension of the seatings above the double bottom plating is to be limited as far as practicable while ensuring adequate spaces for the fitting of bedplate bolts. Bolt holes are to be located such that they do not interfere with seating structures.

8.1.5 Seatings in a single bottom structure

For ships having a single bottom structure within the machinery space, seatings are to be located above the floors and to be adequately connected to the latter and to the girders located below.

8.1.6 Number of girders in way of machinery seatings

In general, at least two girders are to be fitted in way of main machinery seatings.

One girder may be fitted only where the following three formulae are complied with:

$$L < 150 m$$

$$P < 7100 kW$$

$$P < 2{,}3\, n_R L_E$$

8.2 Minimum scantlings

8.2.1

As a guidance, the net scantlings of the structural elements in way of the internal combustion engine seatings may be obtained from the formulae in Tab 3.

Table 3 : Minimum scantlings of the structural elements in way of machinery seatings

Scantling	Minimum value
Net cross-sectional area, in cm², of each bedplate of the seatings	$40 + 70\frac{P}{n_r L_E}$
Bedplate net thickness, in mm	• Bedplates supported by two or more girders: $\sqrt{240 + 175\frac{P}{n_r L_E}}$ • Bedplates supported by one girder: $5 + \sqrt{240 + 175\frac{P}{n_r L_E}}$
Total web net thickness, in mm, of girders fitted in way of machinery seatings	• Bedplates supported by two or more girders: $\sqrt{320 + 215\frac{P}{n_r L_E}}$ • Bedplates supported by one girder: $\sqrt{95 + 65\frac{P}{n_r L_E}}$
Web net thickness, in mm, of floors fitted in way of machinery seatings	$\sqrt{55 + 40\frac{P}{n_r L_E}}$

SECTION 4 SUPERSTRUCTURES AND DECKHOUSES

Symbols

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [10]

s : Spacing, in m, of ordinary stiffeners

k : Material factor, defined in:
- Ch 4, Sec 1, [2.3], for steel
- Ch 4, Sec 1, [4.4], for aluminium alloys

t_c : Corrosion addition, in mm, defined in Ch 4, Sec 2, Tab 2.

1 General

1.1 Application

1.1.1 The requirements of this Section apply for the scantling of plating and associated structures of front, side and aft bulkheads and decks of superstructures and deckhouses, which may or may not contribute to the longitudinal strength.

1.1.2 The requirements of this Section comply with the applicable regulations of the 1966 International Convention on Load Lines, with regard to the strength of enclosed superstructures.

1.2 Net scantlings

1.2.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 4, Sec 2.

1.3 Definitions

1.3.1 Superstructures and deckhouses contributing to the longitudinal strength

Superstructures and deckhouses contributing to the longitudinal strength are defined in Ch 6, Sec 1, [2.2].

1.3.2 Tiers of superstructures and deckhouses

The lowest tier is normally that which is directly situated above the main watertigth deck.

Where the freeboard exceeds the value given, in m, by the following formula:

$$1,80 + 0,01(L - 75)$$

to be taken neither less than 1,80 m, nor greater than 2,30 m, the lowest tier may be considered as an upper tier when calculating the scantlings of superstructures and deckhouses

The second tier is that located immediately above the lowest tier, and so on.

1.4 Connections of superstructures and deckhouses with the hull structure

1.4.1 Superstructure and deckhouse frames are to be fitted as far as practicable as extensions of those underlying and are to be effectively connected to both the latter and the deck beams above.

Ends of superstructures and deckhouses are to be efficiently supported by bulkheads, diaphragms, webs or pillars.

Where hatchways are fitted close to the ends of superstructures, additional strengthening may be required.

1.4.2 Connection to the deck of corners of superstructures and deckhouses is considered by the Society on a case by case basis. Where necessary, doublers or reinforced welding may be required.

1.4.3 As a rule, the frames of sides of superstructures and deckhouses are to have the same spacing as the beams of the supporting deck.

Web frames are to be arranged to support the sides and ends of superstructures and deckhouses.

1.4.4 The side plating at ends of superstructures is to be tapered into the bulwark or sheerstrake of the strength deck.

Where a raised deck is fitted, this arrangement is to extend over at least 3 frame spacings.

1.5 Structural arrangement of superstructures and deckhouses

1.5.1 Strengthening in way of superstructures and deckhouses

Web frames, transverse partial bulkheads or other equivalent strengthening are to be fitted inside deckhouses of at least 0,5B in breadth extending more than 0,15L in length within 0,4L amidships. These transverse strengthening reinforcements are to be spaced approximately 9 m apart and are to be arranged, where practicable, in line with the transverse bulkheads below.

Web frames are also to be arranged in way of large openings, boats davits and other areas subjected to point loads.

Web frames, pillars, partial bulkheads and similar strengthening are to be arranged, in conjunction with deck transverses, at ends of superstructures and deckhouses.

1.5.2 Strenghtening of the raised quarter deck stringer plate

When a superstructure is located above a raised quarter deck, the thickness of the raised quarter deck stringer plate is to be increased by 30% and is to be extended within the superstructure.

The increase above may be reduced when the raised quarter deck terminates outside 0,5 L amidships.

1.5.3 Openings

Openings are to be in accordance with Sec 9.

Continuous coamings are to be fitted above and below doors or similar openings.

1.5.4 Access and doors

Access openings cut in sides of enclosed superstructures are to be fitted with doors made of steel or other equivalent material, and permanently attached.

Special consideration is to be given to the connection of doors to the surrounding structure.

Securing devices which ensure watertightness are to include tight gaskets, clamping dogs or other similar appliances, and are to be permanently attached to the bulkheads and doors. These doors are to be operable from both sides.

Doors are to open outwards, to provide additional security against the impact of the sea, unless otherwise permitted by the Society.

1.5.5 Strengthening of deckhouses in way of lifeboats and rescue boats

Sides of deckhouses are to be strengthened in way of lifeboats and rescue boats and the top plating is to be reinforced in way of their lifting appliances.

1.5.6 Constructional details

Lower tier stiffeners are to be welded to the decks at their ends.

Brackets are to be fitted at the upper and preferably also the lower ends of vertical stiffeners of exposed front bulkheads of engine casings and superstructures or deckhouses protecting pump room openings.

1.5.7 Use of aluminium alloys

Use of aluminium alloys for unprotected front bulkheads of first tier superstructures or deckhouses is to be specially agreed with the Society.

2 Design loads

2.1 Sides contributing to the longitudinal strength

2.1.1 Load point

Lateral pressure is to be calculated at:

- the lower edge of the elementary plate panel, for plating
- mid-span, for stiffeners.

2.1.2 Lateral pressure

The lateral pressure is constituted by the still water sea pressure (p_S) and the wave pressure (p_W), defined in Ch 5, Sec 5.

Moreover, when the side is a tank boundary, the lateral pressure constituted by the still water internal pressure (p_S) and the inertial pressure (p_W), defined in Ch 5, Sec 6, [1] is also to be considered.

2.2 Front, side and aft bulkheads not contributing to the longitudinal strength

2.2.1 Load point

Lateral pressure is to be calculated at:

- mid-height of the bulkhead, for plating
- mid-span, for stiffeners.

2.2.2 Lateral pressure

The lateral pressure to be used for the determination of scantlings of the structure of front, side and aft bulkheads of superstructures and deckhouses is to be obtained, in kN/m², from the following formula:

$$p = 10ac[bf - (z - T)]$$

without being less than p_{min}

where:

a : Coefficient defined in Tab 1

c : Coefficient taken equal to:

$$c = 0{,}3 + 0{,}7\frac{b_1}{B_1}$$

For exposed parts of machinery casings, c is to be taken equal to 1

b_1 : Breadth of deckhouse, in m, at the position considered, to be taken not less than $0{,}25B_1$

B_1 : Actual maximum breadth of ship on the exposed weather deck, in m, at the position considered

b : Coefficient defined in Tab 2

f : Coefficient defined in Tab 3

p_{min} : Minimum lateral pressure defined in Tab 4.

2.3 Decks

2.3.1 The lateral pressure for decks which may or may not contribute to the longitudinal strength is constituted by the still water internal pressure (p_S) and the inertial pressure (p_W), defined in Ch 5, Sec 6, [6].

Moreover, when the deck is a tank boundary, the lateral pressure constituted by the still water internal pressure (p_S) and the inertial pressure (p_W), defined in Ch 5, Sec 6, [1] is also to be considered.

Table 1 : Lateral pressure for superstructures and deckhouses - Coefficient a

Type of bulkhead	Location	a	a maximum
Unprotected front	Lowest tier	$2 + \frac{L}{120}$	4,5
	Second tier	$1 + \frac{L}{120}$	3,5
	Third tier	$0,5 + \frac{L}{150}$	2,5
	Fourth tier	$0,9\left(0,5 + \frac{L}{150}\right)$	2,25
	Fifth tier and above	$0,8\left(0,5 + \frac{L}{150}\right)$	2,0
Protected front	Lowest, second and third tiers	$0,5 + \frac{L}{150}$	2,5
	Fourth tier	$0,9\left(0,5 + \frac{L}{150}\right)$	2,25
	Fifth tier and above	$0,8\left(0,5 + \frac{L}{150}\right)$	2,0
Side	Lowest, second and third tiers	$0,5 + \frac{L}{150}$	2,5
	Fourth tier	$0,9\left(0,5 + \frac{L}{150}\right)$	2,25
	Fifth tier and above	$0,8\left(0,5 + \frac{L}{150}\right)$	2,0
Aft end	All tiers, when: x/L ≤ 0,5	$0,7 + \frac{L}{1000} - 0,8\frac{x}{L}$	$1 - 0,8\frac{x}{L}$
	All tiers, when: x/L > 0,5	$0,5 + \frac{L}{1000} - 0,4\frac{x}{L}$	$0,8 - 0,4\frac{x}{L}$

Table 2 : Lateral pressure for superstructures and deckhouses - Coefficient b

Location of bulkhead **(1)**	b
$\frac{x}{L} \le 0,45$	$1 + \left(\frac{\frac{x}{L} - 0,45}{C_B + 0,2}\right)^2$
$\frac{x}{L} > 0,45$	$1 + 1,5\left(\frac{\frac{x}{L} - 0,45}{C_B + 0,2}\right)^2$
(1) For deckhouse sides, the deckhouse is to be subdivided into parts of approximately equal length, not exceeding 0,15L each, and x is to be taken as the co-ordinate of the centre of each part considered. **Note 1:** C_B : Block coefficient, with $0,6 \le C_B \le 0,8$	

Table 3 : Lateral pressure for superstructures and deckhouses - Coefficient f

Length L of ship, in m	f
L < 150	$\frac{L}{10}e^{-L/300} - \left[1 - \left(\frac{L}{150}\right)^2\right]$
150 ≤ L < 300	$\frac{L}{10}e^{-L/300}$
L ≥ 300	11,03

Table 4 : Lateral minimum pressure for superstructures and deckhouses

Type of bulkhead	Location	p_{min}, in kN/m²
Unprotected front	Lowest tier	$30 \le 25,0 + 0,10L \le 50$
	Second and third tiers	$15 \le 12,5 + 0,05L \le 25$
	Fourth tier and above	$12 \le 10,0 + 0,04L \le 20$
Protected front, side and aft end	Lowest, second and third tiers	$15 \le 12,5 + 0,05L \le 25$
	Fourth tier and above	$12 \le 10,0 + 0,04L \le 20$

3 Plating

3.1 Front, side and aft bulkheads

3.1.1 Plating contributing to the longitudinal strength

The net thickness of side plate panels contributing to the longitudinal strength is to be determined in accordance with the applicable requirements of Ch 7, Sec 1, as applicable, considering the lateral pressure defined in [2.1.2].

3.1.2 Plating not contributing to the longitudinal strength

The net thickness of plating of front, side and aft bulkheads not contributing to the longitudinal strength is to be not less than the value obtained, in mm, from the following formula:

$$t = 0,95 s \sqrt{kp} - t_c$$

without being less than the values indicated in Tab 5, where p is the lateral pressure, in kN/m², defined in [2.2].

For plating which forms tank boundaries, the net thickness is to be determined in accordance with [3.1.1], considering the hull girder stress equal to 0.

Table 5 : Superstructures and deckhouses Minimum thicknesses

Location	Minimum thickness, in mm
Lowest tier	$(5 + 0{,}01\ L)\ k^{1/2} - t_C$
Second tier and above	$(4 + 0{,}01\ L)\ k^{1/2} - t_C$
Note 1: L is to be taken not less than 100m and not greater than 300m.	

3.2 Decks

3.2.1 The net thickness of plate panels of decks which may or may not contribute to the longitudinal strength is to be determined in accordance with the applicable requirements of Ch 7, Sec 1 or Sec 3, as applicable.

3.2.2 For decks sheathed with wood, the net thickness obtained from [3.2.1] may be reduced by 10 percent.

4 Ordinary stiffeners

4.1 Front, side and aft bulkheads

4.1.1 Ordinary stiffeners of plating contributing to the longitudinal strength

The net scantlings of ordinary stiffeners of plating contributing to the longitudinal strength are to be determined in accordance with the applicable requirements of Ch 7, Sec 2 or Sec 4, as applicable.

4.1.2 Ordinary stiffeners of plating not contributing to the longitudinal strength

The net section modulus w of ordinary stiffeners of plating not contributing to the longitudinal strength is to be not less than the value obtained, in cm³, from the following formula:

$$w = 0{,}35\varphi k s \ell^2 p(1 - \alpha t_c) - \beta t_c$$

where:

ℓ : Span of the ordinary stiffener, in m, equal to the 'tweendeck height and to be taken not less than 2 m

p : Lateral pressure, in kN/m², defined in [2.2.2]

φ : Coefficient depending on the stiffener end connections, and taken equal to:

- 1 for lower tier stiffeners
- value defined in Tab 6 for stiffeners of upper tiers

α, β : Parameters defined in Ch 4, Sec 2, Tab 1.

The section modulus of side ordinary stiffeners need not be greater than that of the side ordinary stiffeners of the tier situated directly below taking account of spacing and span.

For ordinary stiffeners of plating forming tank boundaries, the net scantlings are to be determined in accordance with [4.1.1], considering the hull girder stress equal to 0.

Table 6 : Stiffeners of superstructures and deckhouses - Coefficient φ for end connections

Coefficient φ	Upper end welded to deck	Bracketed upper end	Sniped upper end
Lower end welded to deck	1,00	0,85	1,15
Bracketed lower end	0,85	0,85	1,00
Sniped lower end	1,15	1,00	1,15

4.2 Decks

4.2.1 The net scantlings of ordinary stiffeners of decks which may or may not contribute to the longitudinal strength are to be determined in accordance with the applicable requirements of Ch 7, Sec 2.

5 Primary supporting members

5.1 Front, side and aft bulkheads

5.1.1 Primary supporting members of plating contributing to the longitudinal strength

The net scantlings of side primary supporting members of plating contributing to the longitudinal strength are to be determined in accordance with the applicable requirements of Ch 7, Sec 3, as applicable.

5.1.2 Primary supporting members of plating not contributing to the longitudinal strength

The net scantlings of side primary supporting members of plating not contributing to the longitudinal strength are to be determined in accordance with the applicable requirements of Ch 7, Sec 3, as applicable, using the lateral pressure defined in [2.2.2].

5.2 Decks

5.2.1 The net scantlings of primary supporting members of decks which may or may not contribute to the longitudinal strength are to be determined in accordance with the applicable requirements of Ch 7, Sec 3.

SECTION 5 BOW DOORS AND INNER DOORS

Symbols

L_1 : Length, in m, defined in Ch 1, Sec 2, [2.1.1].

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the arrangement, strength and securing of bow doors and inner doors leading to a complete or long forward enclosed superstructure.

1.1.2 Two types of bow door are provided for:

- visor doors opened by rotating upwards and outwards about a horizontal axis through two or more hinges located near the top of the door and connected to the primary supporting members of the door by longitudinally arranged lifting arms
- side-opening doors opened either by rotating outwards about a vertical axis through two or more hinges located near the outboard edges or by horizontal translation by means of linking arms arranged with pivoted attachments to the door and the ship. It is anticipated that side-opening bow doors are arranged in pairs.

Other types of bow door are considered by the Society on a case by case basis in association with the applicable requirements of this Section.

1.2 Gross scantlings

1.2.1 With reference to Ch 4, Sec 2, [1], all scantlings and dimensions referred to in this Section are gross, i.e. they include the margins for corrosion.

1.3 Arrangement

1.3.1

Bow doors are to be situated above the main deck. A watertight recess in the main deck located forward of the collision bulkhead and above the deepest waterline fitted for arrangement of ramps or other related mechanical devices may be regarded as a part of the main deck for the purpose of this requirement.

1.3.2 An inner door is to be fitted as part of the collision bulkhead. The inner door need not be fitted directly above the bulkhead below, provided it is located within the limits specified for the position of the collision bulkhead, as per Ch 2, Sec 1, [3.1].

A vehicle ramp may be arranged for this purpose, provided its position complies with Ch 2, Sec 1, [3.1].

If this is not possible, a separate inner weathertight door is to be installed, as far as practicable within the limits specified for the position of the collision bulkhead.

1.3.3 Bow doors are to be so fitted as to ensure tightness consistent with operational conditions and to give effective protection to inner doors.

Inner doors forming part of the collision bulkhead are to be weathertight over the full height of the cargo space and arranged with fixed sealing supports on the aft side of the doors.

1.3.4 Bow doors and inner doors are to be arranged so as to preclude the possibility of the bow door causing structural damage to the inner door or to the collision bulkhead in the case of damage to or detachment of the bow door. If this is not possible, a separate inner weathertight door is to be installed, as indicated in [1.3.2].

1.3.5 The requirements for inner doors are based on the assumption that vehicles are effectively lashed and secured against movement in stowed position.

1.4 Definitions

1.4.1 Securing device

A securing device is a device used to keep the door closed by preventing it from rotating about its hinges.

1.4.2 Supporting device

A supporting device is a device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, which transmits loads from the door to the ship's structure.

1.4.3 Locking device

A locking device is a device that locks a securing device in the closed position.

2 Design loads

2.1 Bow doors

2.1.1 Design external pressure

The design external pressure to be considered for the scantlings of primary supporting members and securing and supporting devices of bow doors is to be not less than that obtained, in kN/m², from the following formula:

$$p_E = 0,5 n_D C_L C_Z (0,22 + 0,15 \tan\alpha)(0,4 V \sin\beta + 0,6\sqrt{L_1})^2$$

where:

n_D : Navigation coefficient, defined in Tab 1

V : Maximum ahead service speed, in knots

C_L : Coefficient depending on the ship's length:

$C_L = 0,0125\ L$ for $L < 80$ m

$C_L = 1,0$ for $L \geq 80$ m

C_Z : Coefficient defined in Sec 1, [4.2.1], to be taken equal to 5,5

α : Flare angle at the calculation point, defined as the angle between a vertical line and the tangent to the side plating, measured in a vertical plane normal to the horizontal tangent to the shell plating (see Fig 1)

β : Entry angle at the calculation point, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane (see Fig 1).

Table 1 : Navigation coefficient *(1/1/2017)*

Navigation notation	Navigation coefficient n	Navigation coefficient n_D
Unrestricted navigation	1,00	1,00
Summer zone	0,90	0,95
Tropical zone	0,80	0,90
Offshore navigation	0,90	0,95
Coastal area	0,80	0,90
Sheltered area	0,65	0,80

2.1.2 Design external forces

The design external forces F_X, F_Y, F_Z to be considered for the scantlings of securing and supporting devices of bow doors are to be not less than those obtained, in kN, from the following formulae:

$F_X = p_E A_X$

$F_Y = p_E A_Y$

$F_Z = p_E A_Z$

where:

p_E : External pressure, in kN/m², to be calculated according to [2.1.1], assuming the angles α and β measured at the point on the bow door located $\ell/2$ aft of the stem line on the plane h/2 above the bottom of the door, as shown in Fig 1

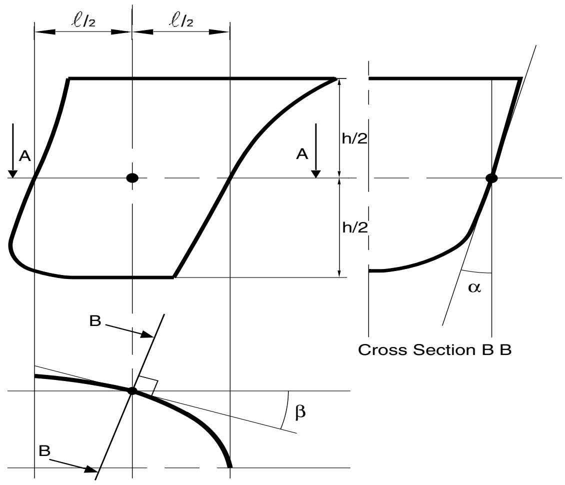
h : Height, in m, to be taken as the lesser of h_1 and h_2

h_1 : Height, in m, of the door between the levels of its bottom and the upper deck

h_2 : Height, in m, of the door between its bottom and top

ℓ : Length, in m, of the door at a height h/2 above the bottom of the door

Figure 1 : Definition of angles α and β



A_X : Area, in m², of the transverse vertical projection of the door between the levels of the bottom of the door and the top of the upper deck bulwark, or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is lesser. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser. In determining the height from the bottom of the door to the upper deck or to the top of the door, the bulwark is to be excluded

A_Y : Area, in m², of the longitudinal vertical projection of the door between the levels of the bottom of the door and the top of the upper deck bulwark, or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is lesser. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser

A_Z : Area, in m², of the horizontal projection of the door between the bottom of the door and the top of the upper deck bulwark, or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is the lesser. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser.

For bow doors, including bulwark, of unusual form or proportions, e.g. ships with a rounded nose and large stem angles, the areas and angles used for determination of the design values of external forces will be considered on a case by case basis.

2.1.3 Closing moment

For visor doors, the closing moment under external loads is to be obtained, in kN.m, from the following formula:

$M_Y = F_X a + 10 W c - F_Z b$

where:

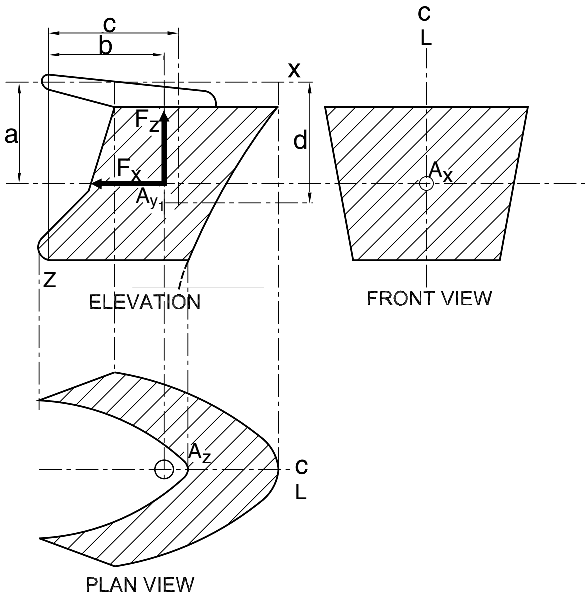
W : Mass of the visor door, in t

a : Vertical distance, in m, from visor pivot to the centroid of the transverse vertical projected area of the visor door, as shown in Fig 2

b : Horizontal distance, in m, from visor pivot to the centroid of the horizontal projected area of the visor door, as shown in Fig 2

c : Horizontal distance, in m, from visor pivot to the centre of gravity of visor mass, as shown in Fig 2.

Figure 2 : Bow doors of visor type



2.1.4 Forces acting on the lifting arms

The lifting arms of a visor door and its supports are to be dimensioned for the static and dynamic forces applied during the lifting and lowering operations, and a minimum wind pressure of 1,5 kN/m² is to be taken into account.

2.2 Inner doors

2.2.1 Design external pressure

The design external pressure to be considered for the scantlings of primary supporting members, securing and supporting devices and surrounding structure of inner doors is to be taken as the greater of the values obtained, in kN/m², from the following formulae:

$p_E = 0{,}45 L_1$

$p_E = 10 h$

where:

h : Distance, in m, from the calculation point to the top of the cargo space.

2.2.2 Design internal pressure

The design internal pressure p_I to be considered for the scantlings of securing devices of inner doors is to be not less than 25 kN/m².

3 Scantlings of bow doors

3.1 General

3.1.1 The strength of bow doors is to be commensurate with that of the surrounding structure.

3.1.2 Bow doors are to be adequately stiffened and means are to be provided to prevent lateral or vertical movement of the doors when closed.

For visor doors, adequate strength for opening and closing operations is to be provided in the connections of the lifting arms to the door structure and to the ship's structure.

3.2 Plating and ordinary stiffeners

3.2.1 Plating

The thickness of the bow door plating is to be not less than that obtained according to the requirements in Sec 1 for the fore part, using the bow door stiffener spacing. In no case may it be less than the minimum required thickness of fore part shell plating.

3.2.2 Ordinary stiffeners

The section modulus of bow door ordinary stiffeners is to be not less than that obtained according to the requirements in Sec 1 for the fore part, using the bow door stiffener spacing.

Consideration is to be given, where necessary, to differences in conditions of fixity between the ends of ordinary stiffeners of bow doors and those of the fore part shell.

3.3 Primary supporting members

3.3.1 Bow door ordinary stiffeners are to be supported by primary supporting members constituting the main stiffening of the door.

3.3.2 The primary supporting members of the bow door and the hull structure in way are to have sufficient stiffness to ensure integrity of the boundary support of the door.

3.3.3

Scantlings of primary supporting members are generally to be verified through direct calculations on the basis of the external pressure p_E in [2.1.1] and the strength criteria in [6.1.1] and [6.1.2].

In general, isolated beam models may be used to calculate the loads and stresses in primary supporting members, which are to be considered as having simply supported end connections.

4 Scantlings of inner doors

4.1 General

4.1.1 The gross scantlings of the primary supporting members are generally to be verified through direct calculations on the basis of the external pressure p_E in [2.1.1] and the strength criteria in [6.1.1] and [6.1.2].

In general, isolated beam models may be used to calculate the loads and stresses in primary supporting members.

4.1.2 Where inner doors also serve as vehicle ramps, their scantlings are to be not less than those obtained according to Sec 8.

4.1.3 The distribution of the forces acting on the securing and supporting devices is generally to be supported by direct calculations taking into account the flexibility of the structure and the actual position and stiffness of the supports.

5 Securing and supporting of bow doors

5.1 General

5.1.1 Bow doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure.

The hull supporting structure in way of the bow doors is to be suitable for the same design loads and design stresses as the securing and supporting devices.

Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered by the Society on a case by case basis.

The maximum design clearance between securing and supporting devices is generally not to exceed 3 mm.

A means is to be provided for mechanically fixing the door in the open position.

5.1.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide local compression of the packing material may generally not be included in the calculation in [5.2.5].

The number of securing and supporting devices is generally to be the minimum practical while taking into account the requirements for redundant provision given in [5.2.6] and [5.2.7]and the available space for adequate support in the hull structure.

5.1.3 For visor doors which open outwards, the pivot arrangement is generally to be such that the visor is self-closing under external loads, i.e. it is to be checked that the closing moment M_Y, defined in [2.1.3], is in compliance with the following formula:

$$M_Y > 0$$

Moreover, the closing moment M_Y is to be not less than the value M_{Y0} , in kN.m, obtained from the following formula:

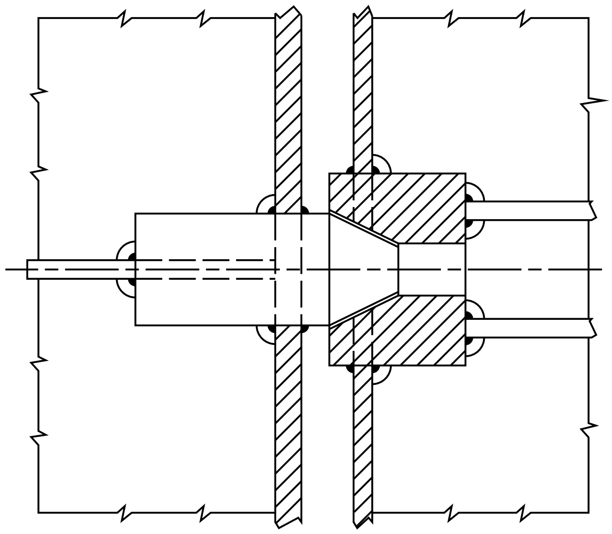
$$M_{Y0} = 10Wc + 0{,}1\sqrt{a^2 + b^2}\sqrt{F_X^2 + F_Z^2}$$

5.1.4 For side-opening doors, a thrust bearing is to be provided in way of girder ends at the closing of the two leaves to prevent one leaf from shifting towards the other under the effect of unsymmetrical pressure (see example in Fig 3).

The parts of the thrust bearing are to be kept secured to each other by means of securing devices.

The Society may consider any other arrangement serving the same purpose.

Figure 3 : Thrust bearing



5.2 Scantlings

5.2.1 Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the allowable stresses defined in [6.1.1].

5.2.2 For visor doors, the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door:

- Case 1: F_X and F_Z
- Case 2: $0{,}7F_Y$ acting on each side separately together with $0{,}7F_X$ and $0{,}7F_Z$

where F_X, F_Y and F_Z are to be calculated as indicated in [2.1.2] and applied at the centroid of projected areas.

5.2.3 For side-opening doors, the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door:

- Case 1: F_X , F_Y and F_Z acting on both doors
- Case 2: 0,7F_X and 0,7F_Z acting on both doors and 0,7F_Y acting on each door separately

where F_X, F_Y and F_Z are to be calculated as indicated in [2.1.2] and applied at the centroid of projected areas.

5.2.4 The support forces as calculated according to Case 1 in [5.2.2]and Case 1 in [5.2.3] are to generally give rise to a zero moment about the transverse axis through the centroid of the area A_X.

For visor doors, longitudinal reaction forces of pin and/or wedge supports at the door base contributing to this moment are not to be in the forward direction.

5.2.5 The distribution of the reaction forces acting on the securing and supporting devices may need to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports.

5.2.6 The arrangement of securing and supporting devices in way of these securing devices is to be designed with redundancy so that, in the event of failure of any single securing or supporting device, the remaining devices are capable of withstanding the reaction forces without exceeding by more than 20% the allowable stresses defined in [6.1.1].

5.2.7 For visor doors, two securing devices are to be provided at the lower part of the door, each capable of providing the full reaction force required to prevent opening of the door within the allowable stresses defined in [6.1.1].

The opening moment M_0 to be balanced by this reaction force is to be taken not less than that obtained, in kN.m, from the following formula:

$$M_0 = 10\,W\,d + 5\,A_X\,a$$

where:

d : Vertical distance, in m, from the hinge axis to the centre of gravity of the door, as shown in Fig 2

a : Vertical distance, in m, defined in [2.1.3].

5.2.8 For visor doors, the securing and supporting devices excluding the hinges are to be capable of resisting the vertical design force (F_Z-10W), in kN, within the allowable stresses defined in [6.1.1].

5.2.9

All load transmitting elements in the design load path, from the door through securing and supporting devices into the ship's structure, including welded connections, are to be of the same strength standard as required for the securing and supporting devices. These elements include pins, supporting brackets and back-up brackets.

6 Strength Criteria

6.1 Primary supporting members and securing and supporting devices

6.1.1 Yielding check

It is to be checked that the normal stresses σ, the shear stress τ and the equivalent stress σ_{VM}, induced in the primary supporting members and in the securing and supporting devices of bow doors by the design load defined in [2], are in compliance with the following formulae:

$$\sigma \le \sigma_{ALL}$$

$$\tau \le \tau_{ALL}$$

$$\sigma_{VM} = (\sigma^2 + \tau^2)^{0,5} \le \sigma_{VM,ALL}$$

where:

σ_{ALL} : Allowable normal stress, in N/mm², equal to: $\sigma_{ALL} = 120 / k$

τ_{ALL} : Allowable shear stress, in N/mm², equal to: $\tau_{ALL} = 80 / k$

$\sigma_{VM,ALL}$: Allowable equivalent stress, in N/mm², equal to: $\sigma_{VM,ALL} = 150 / k$

k : Material factor, defined in Ch 4, Sec 1, [2.3], but to be taken not less than 0,72 unless a fatigue analysis is carried out.

6.1.2 Buckling check

The buckling check of primary supporting members is to be carried out according to Ch 7, Sec 3, [6].

6.1.3 Bearings

For steel to steel bearings in securing and supporting devices, it is to be checked that the nominal bearing pressure σ_B, in N/mm², is in compliance with the following formula:

$$\sigma_B \le 0,8\,R_{e,HB}$$

where:

$$\sigma_B = 10\frac{F}{A_B}$$

F : Design force, in kN, defined in [2.1.2]

A_B : Projected bearing area, in cm²

$R_{e,HB}$: Yield stress, in N/mm², of the bearing material.

For other bearing materials, the allowable bearing pressure is to be determined according to the manufacturer's specification.

6.1.4 Bolts

The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces.

It is to be checked that the tension σ_T in way of threads of bolts not carrying support forces is in compliance with the following formula:

$$\sigma_T \le \sigma_{T,ALL}$$

where:

$\sigma_{T,ALL}$: Allowable tension in way of threads of bolts, in N/mm², equal to: $\sigma_{T,ALL} = 125 / k$

k : Material coefficient defined in [6.1.1].

7 Securing and locking arrangement

7.1 Systems for operation

7.1.1 Securing devices are to be simple to operate and easily accessible.

Securing devices are to be equipped with mechanical locking arrangement (self-locking or separate arrangement), or to be of the gravity type.

The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

7.1.2

Bow doors and inner doors giving access to vehicle decks are to be provided with an arrangement for remote control, from a position above the main deck, of:

- the closing and opening of the doors, and
- associated securing and locking devices for every door.

Indication of the open/closed position of every door and every securing and locking device is to be provided at the remote control stations.

The operating panels for operation of doors are to be inaccessible to unauthorised persons.

A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

7.1.3 Where hydraulic securing devices are applied, the system is to be mechanically lockable in closed position. This means that, in the event of loss of hydraulic fluid, the securing devices remain locked.

The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits, when in closed position.

7.2 Systems for indication/monitoring

7.2.1 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on the operating panel to show that the bow door and inner door are closed and that their securing and locking devices are properly positioned.

The indication panel is to be provided with a lamp test function. It is not to be possible to turn off the indicator light.

7.2.2

The indicator system is to be designed on the fail safe principle and is to show by visual alarms if the door is not fully closed and not fully locked and by audible alarms if securing devices become open or locking devices become unsecured.

The power supply for the indicator system is to be independent of the power supply for operating and closing the doors and is to be provided with a back-up power supply from the emergency source of power or other secure power supply e.g. UPS.

The sensors of the indicator system are to be protected from water, ice formation and mechanical damage.

Note 1: The indicator system is considered designed on the fail-safe principle when the following conditions occur.

- The indication panel is provided with:
  - a power failure alarm
  - an earth failure alarm
  - a lamp test
  - separate indication for door closed, door locked, door not closed and door unlocked.
- Limit switches are electrically closed when the door is closed (when several limit switches are provided they may be connected in series).
- Limit switches are electrically closed when securing arrangements are in place (when several limit switches are provided they may be connected in series).
- Two electrical circuits (also in one multicore cable) are fitted, one for the indication of door closed / not closed and the other for door locked / unlocked.
- In the case of dislocation of limit switches, indication to show: not closed / unlocked / securing arrangement not in place - as appropriate.

7.2.3

The indication panel on the navigation bridge is to be equipped with a mode selection function “harbour/sea voyage”, so arranged that an audible alarm is given on the navigation bridge if the ship leaves harbour with the bow door or inner door not closed and with any of the securing devices not in the correct position.

7.2.4 A water leakage detection system with an audible alarm and television surveillance is to be arranged to provide an indication to the navigation bridge and to the engine control room of leakage through the inner door.

7.2.5 Between the bow door and the inner door a television surveillance system is to be fitted with a monitor on the navigation bridge and in the engine control room.

The system is to monitor the position of doors and a sufficient number of their securing devices.

Special consideration is to be given to the lighting and contrasting colour of the objects under surveillance.

7.2.6 The indicator system for the closure of the doors and the television surveillance systems for the doors and water leakage detection, and for special category and ro-ro spaces are to be suitable to operate correctly in the ambient conditions on board and to be type approved on the basis of the applicable tests.

7.2.7

A drainage system is to be arranged in the area between bow door and ramp, or, where no ramp is fitted, between bow door and inner door.

The system is to be equipped with an audible alarm providing an indication on the navigation bridge when the water level in these areas exceeds 0,5 m or the high water level alarm, whichever is the lesser.

8 Operating and maintenance manual

8.1 General

8.1.1

An operating and maintenance manual (OMM) for the bow door and inner door is to be provided on board and contain necessary information on:

a) main particulars and design drawings
   - special safety precautions
   - details of vessel, class, statutory certificates
   - equipment and design loading (for ramps)
   - key plan of equipment (doors and ramps)
   - Manufacturer's recommended testing for equipment
   - description of equipment (bow doors, inner bow doors, bow ramp/doors, side doors, stern doors, central power pack, bridge panel, engine control room panel)

b) service conditions
   - limiting heel and trim of ship for loading/unloading
   - limiting heel and trim for door operations
   - door/ramp operating instructions
   - door/ramp emergency operating instructions

c) maintenance
   - schedule and extent of maintenance
   - trouble-shooting and acceptable clearances
   - Manufacturer's maintenance procedures

d) register of inspections, including inspection of locking, securing and supporting devices, repairs and renewals.

This manual is to be submitted in duplicate to the Society for approvalthat the above-mentioned items are contained in the OMM and that the maintenance part includes the necessary information with regard to inspections, trouble-shooting and acceptance / rejection criteria.

Note 1: It is recommended that inspections of the doors and supporting and securing devices be carried out by ship's personnel at monthly intervals or following any incidents which could result in damage, including heavy weather or contact in the region of the shell doors. A record is to be kept and any damage found during such inspections is to be reported to the Society.

8.1.2 Documented operating procedures for closing and securing the bow door and inner door are to be kept on board and posted at an appropriate place.

SECTION 6 SIDE DOORS AND STERN DOORS

Symbols

L_1 : Length, in m, defined in Ch 1, Sec 2, [2.1.1].

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the arrangement, strength and securing of side doors, abaft the collision bulkhead, and stern doors leading into enclosed spaces.

1.2 Gross scantlings

1.2.1 With reference to Ch 4, Sec 2, [1], all scantlings and dimensions referred to in this Section are gross, i.e. they include the margins for corrosion.

1.3 Arrangement

1.3.1 Side doors and stern doors are to be so fitted as to ensure tightness and structural integrity commensurate with their location and the surrounding structure.

1.3.2 Where the sill of any side door is below the uppermost load line, the arrangement is considered by the Society on a case by case basis.

1.3.3 Doors are preferably to open outwards.

1.4 Definitions

1.4.1 Securing device

A securing device is a device used to keep the door closed by preventing it from rotating about its hinges or about pivoted attachments to the ship.

1.4.2 Supporting device

A supporting device is a device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, which transmits loads from the door to the ship's structure.

1.4.3 Locking device

A locking device is a device that locks a securing device in the closed position.

2 Design loads

2.1 Side and stern doors

2.1.1 Design forces

The design external forces F_E and the design internal forces F_I to be considered for the scantlings of primary supporting members and securing and supporting devices of side doors and stern doors are to be obtained, in kN, from the formulae in Tab 1.

3 Scantlings of side doors and stern doors

3.1 General

3.1.1 The strength of side doors and stern doors is to be commensurate with that of the surrounding structure.

3.1.2 Side doors and stern doors are to be adequately stiffened and means are to be provided to prevent any lateral or vertical movement of the doors when closed.

Adequate strength is to be provided in the connections of the lifting/manoeuvring arms and hinges to the door structure and to the ship's structure.

3.1.3 Where doors also serve as vehicle ramps, the design of the hinges is to take into account the ship angle of trim and heel which may result in uneven loading on the hinges.

3.1.4 Shell door openings are to have well rounded corners and adequate compensation is to be arranged with web frames at sides and stringers or equivalent above and below.

3.2 Plating and ordinary stiffeners

3.2.1 Plating

The thickness of the door plating is to be not less than that obtained according to the requirements in Ch 7, Sec 1 for side plating, using the door stiffener spacing. In no case may it be less than the minimum required thickness of side plating.

Where doors also serve as vehicle ramps, the thickness of the door plating is to be not less than that obtained according to Sec 8.

3.2.2 Ordinary stiffeners

The scantling of door ordinary stiffeners is to be not less than that obtained according to the requirements in Ch 7, Sec 2 for the side, using the door stiffener spacing.

Table 1 : Design forces

Structural elements	External force F_E, in kN	Internal force F_I, in kN
Securing and supporting devices of doors opening inwards	$A\ p_E + F_P$	$F_0 + 10\ W$
Securing and supporting devices of doors opening outwards	$A\ p_E$	$F_0 + 10\ W + F_P$
Primary supporting members **(1)**	$A\ p_E$	$F_0 + 10\ W$

(1) The design force to be considered for the scantlings of the primary supporting members is the greater of F_E and F_I.

Note 1:

- A : Area, in m², of the door opening
- W : Mass of the door, in t
- F_P : Total packing force, in kN; the packing line pressure is normally to be taken not less than 5 N/mm
- F_0 : the greater of F_C and 5A, in kN
- F_C : Accidental force, in kN, due to loose cargoes etc., to be uniformly distributed over the area A and to be taken not less than 300 kN. For small doors such as bunker doors and pilot doors, the value of F_C may be appropriately reduced. However, the value of F_C may be taken as zero, provided an additional structure such as an inner ramp is fitted, which is capable of protecting the door from accidental forces due to loose cargoes.
- p_E : External design pressure determined at the centre of gravity of the door opening and to be taken not less than that obtained, in kN/m², from the following formulae:

  $p_E = 10\ (T - Z_G) + 25$ for $Z_G < T$

  $p_E = 25$ for $Z_G \geq T$

  Moreover, for stern doors of ships fitted with bow doors, p_E is to be taken not less than that obtained, in kN/m², from the following formula:

  $$p_E = 0{,}6 n_D C_L (0{,}8 + 0{,}6\sqrt{L_1})^2$$

- T : Draught, in m, at the highest subdivision load line
- Z_G : Height of the centre of the area of the door, in m, above the baseline
- n_D : Navigation coefficient, defined in Tab 2
- C_L : Coefficient depending on the ship's length:

  $C_L = 0{,}0125\ L$ for $L < 80$ m

  $C_L = 1{,}0$ for $L \geq 80$ m.

Consideration is to be given, where necessary, to differences in conditions of fixity between the ends of ordinary stiffeners of doors and those of the side.

Where doors also serve as vehicle ramps, the scantling of ordinary stiffeners is to be not less than that obtained according to Sec 8.

3.3 Primary supporting members

3.3.1 The door ordinary stiffeners are to be supported by primary supporting members constituting the main stiffening of the door.

3.3.2 The primary supporting members and the hull structure in way are to have sufficient stiffness to ensure structural integrity of the boundary of the door.

3.3.3

Scantlings of primary supporting members are generally to be verified through direct calculations on the basis of the design forces in [2.1.1] and the strength criteria in Sec 5, [6.1.1] and Sec 5, [6.1.2].

In general, isolated beam models may be used to calculate the loads and stresses in primary supporting members, which are to be considered as having simply supported end connections.

Table 2 : Navigation coefficient *(1/1/2017)*

Navigation notation	Navigation coefficient n	Navigation coefficient n_D
Unrestricted navigation	1,00	1,00
Summer zone	0,90	0,95
Tropical zone	0,80	0,90
Offshore navigation	0,90	0,95
Coastal area	0,80	0,90
Sheltered area	0,65	0,80

4 Securing and supporting of doors

4.1 General

4.1.1 Side doors and stern doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure.

The hull supporting structure in way of the doors is to be suitable for the same design loads and design stresses as the securing and supporting devices.

Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered by the Society on a case by case basis.

The maximum design clearance between securing and supporting devices is generally not to exceed 3 mm.

A means is to be provided for mechanically fixing the door in the open position.

4.1.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide local compression of the packing material may generally not be included in the calculation in [4.2.2].

The number of securing and supporting devices is generally to be the minimum practical while taking into account the requirements for redundant provision given in [4.2.3] and the available space for adequate support in the hull structure.

4.2 Scantlings

4.2.1 Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the allowable stresses defined in Sec 5, [6.1.1].

4.2.2 The distribution of the reaction forces acting on the securing and supporting devices may need to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position of the supports.

4.2.3 The arrangement of securing and supporting devices in way of these securing devices is to be designed with redundancy so that, in the event of failure of any single securing or supporting device, the remaining devices are capable of withstanding the reaction forces without exceeding by more than 20% the allowable stresses defined in Sec 5, [6.1.1].

4.2.4

All load transmitting elements in the design load path, from the door through securing and supporting devices into the ship's structure, including welded connections, are to be of the same strength standard as required for the securing and supporting devices. These elements include pins, supporting brackets and back-up brackets.

5 Strength criteria

5.1 Primary supporting members and securing and supporting devices

5.1.1 Yielding check

It is to be checked that the normal stress σ, the shear stress τ and the equivalent stress σ_{VM}, induced in the primary supporting members and in the securing and supporting devices of doors by the design load defined in [2], are in compliance with the following formulae:

$\sigma \leq \sigma_{ALL}$

$\tau \leq \tau_{ALL}$

$\sigma_{VM} = (\sigma^2 + \tau^2)^{0,5} \leq \sigma_{VM,ALL}$

where:

σ_{ALL} : Allowable normal stress, in N/mm²:

$\sigma_{ALL} = 120 / k$

τ_{ALL} : Allowable shear stress, in N/mm²:

$\tau_{ALL} = 80 / k$

$\sigma_{VM,ALL}$: Allowable equivalent stress, in N/mm²:

$\sigma_{VM,ALL} = 150 / k$

k : Material factor, defined in Ch 4, Sec 1, [2.3], but to be taken not less than 0,72 unless a fatigue analysis is carried out.

5.1.2 Buckling check

The buckling check of primary supporting members is to be carried out according to Ch 7, Sec 3, [6].

5.1.3 Bearings

For steel to steel bearings in securing and supporting devices, it is to be checked that the nominal bearing pressure σ_B, in N/mm², is in compliance with the following formula:

$\sigma_B \leq 0,8\ R_{eH,B}$

where:

$$\sigma_B = 10\frac{F}{A_B}$$

with:

F : Design force, in KN, defined in [2.1.1]

A_B : Projected bearing area, in cm²

$R_{eH,B}$: Yield stress, in N/mm², of the bearing material.

For other bearing materials, the allowable bearing pressure is to be determined according to the manufacturer's specification.

5.1.4 Bolts

The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces.

It is to be checked that the tension σ_T in way of threads of bolts not carrying support forces is in compliance with the following formula:

$\sigma_T \leq \sigma_{T,ALL}$

where:

$\sigma_{T,ALL}$: Allowable tension in way of threads of bolts, in N/mm²:

$\sigma_{T,ALL} = 125 / k$

k : Material factor, defined in Sec 5, [6.1.1].

6 Securing and locking arrangement

6.1 Systems for operation

6.1.1 Securing devices are to be simple to operate and easily accessible.

Securing devices are to be equipped with mechanical locking arrangement (self-locking or separate arrangement), or to be of the gravity type.

The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

6.1.2

Doors which are located partly or totally below the main deck with a clear opening area greater than 6 m^2 are to be provided with an arrangement for remote control, from a position above the main deck, of:

- the closing and opening of the doors
- associated securing and locking devices.

For doors which are required to be equipped with a remote control arrangement, indication of the open/closed position of the door and the securing and locking device is to be provided at the remote control stations.

The operating panels for operation of doors are to be inaccessible to unauthorised persons.

A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

6.1.3 Where hydraulic securing devices are applied, the system is to be mechanically lockable in closed position. This means that, in the event of loss of hydraulic fluid, the securing devices remain locked.

The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits, when in closed position.

7 Operating and Maintenance Manual

7.1 General

7.1.1 *(1/1/2017)*

An operating and maintenance manual (OMM) for the side and stern doors is to be provided on board and contain necessary information on:

a) main particulars and design drawings
   - special safety precautions
   - details of vessel,
   - equipment and design loading (for ramps)
   - key plan of equipment (doors and ramps)
   - Manufacturer's recommended testing for equipment
   - Description of equipment for bow doors, inner bow doors, bow ramp/doors, side doors, stern doors, central power pack, bridge panel and engine control room panel

b) service conditions,
   - limiting heel and trim of ship for loading/unloading
   - limiting heel and trim for door operations
   - door/ramp operating instructions
   - door/ramp emergency operating instructions

c) maintenance
   - schedule and extent of maintenance
   - trouble-shooting and acceptable clearances
   - Manufacturer's maintenance procedures

d) register of inspections, including inspection of locking, securing and supporting devices, repairs and renewals.

This manual is to be submitted in duplicate to the Society for approval that the above-mentioned items are contained in the OMM and that the maintenance part includes the necessary information with regard to inspections, trouble-shooting and acceptance / rejection criteria.

Note 1: It is recommended that inspections of the door and supporting and securing devices be carried out by ship's personnel at monthly intervals or following any incidents which could result in damage, including heavy weather or contact in the region of the shell doors. A record is to be kept and any damage recorded during such inspections is to be reported to the Society.

7.1.2 Documented operating procedures for closing and securing the side and stern doors are to be kept on board and posted at an appropriate place.

SECTION 7 HATCH COVERS, HATCH COAMINGS AND CLOSING DEVICES

Symbols

p_S : Still water pressure, in kN/m² (see [4.1]

p_W : Wave pressure, in kN/m² (see [4.1])

s : Length, in m, of the shorter side of the plate panel

ℓ : Length, in m, of the longer side of the plate panel

b_P : Width, in m, of the plating attached to the ordinary stiffener or primary supporting member, defined in [3]

w : Net section modulus, in cm³, of the ordinary stiffener or primary supporting member, with an attached plating of width b_p

A_{Sh} : Net shear sectional area, in cm², of the ordinary stiffener or primary supporting member, to be calculated as specified in Ch 4, Sec 3, [3.4], for ordinary stiffeners, and Ch 4, Sec 3, [4.3], for primary supporting members

m : Boundary coefficient for ordinary stiffeners and primary supporting members, taken equal to:

- m = 8 in the case of ordinary stiffeners and primary supporting members simply supported at both ends or supported at one end and clamped at the other
- m = 12 in the case of ordinary stiffeners and primary supporting members clamped at both ends

t_C : Corrosion additions, in mm, defined in [1.5]

R_{eH} : Minimum yield stress, in N/mm², of the material, defined in Ch 4, Sec 1, [2]

R_m : Minimum ultimate tensile strength, in N/mm², of the material, defined in Ch 4, Sec 1, [2]

R_y : Yield stress, in N/mm², of the material, to be taken equal to 235/k N/mm², unless otherwise specified

k : Material factor, defined in Ch 4, Sec 1, [2.3]

c_S : Coefficient, taken equal to:

- $c_S = 1-(s/2\ell)$ for ordinary stiffeners
- $c_S = 1$ for primary supporting members

g : Gravity acceleration, in m/s²:

$g = 9,81$ m/s².

1 General

1.1 Application

1.1.1 *(1/1/2017)*

The requirements in [1] to [8] apply to steel hatch covers in positions 1 and 2 on weather decks, defined in Ch 1, Sec 2, [3.16] for all ship types. Alternatively, compliance to IACS UR S21 A shall be deemed equivalent to requirements in [1] to [8] provided a freeboard calculation in accordance with the IMO International Convention on Load Lines (ICLL) is submitted to the Society for approval.

The requirements in [9] apply to steel covers of small hatches fitted on the exposed fore deck over the forward 0,25L.

1.2 Materials

1.2.1 Steel

The formulae for scantlings given in the requirements in [5] are applicable to steel hatch covers.

Materials used for the construction of steel hatch covers are to comply with the applicable requirements of Part D, Chapter 2 of the Rules for the Classification of the Ships.

1.2.2 Other materials

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

1.3 Net scantlings

1.3.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 4, Sec 2.

1.4 Partial safety factors

1.4.1 The partial safety factors to be considered for checking hatch cover structures are specified in Tab 1.

1.5 Corrosion additions

1.5.1 Corrosion additions for hatch covers

The corrosion addition to be considered for the plating and internal members of hatch covers is the value specified in Tab 2 for the total thickness of the member under consideration.

Table 1 : Hatch covers - Partial safety factors

Partial safety factors covering uncertainties regarding:	Partial safety factors		
	Symbol	Plating	Ordinary stiffeners and primary supporting members
Still water pressure	γ_{S2}	1,00	1,00
Wave pressure	γ_{W2}	1,20	1,20
Material	γ_m	1,02	1,02
Resistance	γ_R	1,22	1,22

Table 2 : Corrosion additions t_c for steel hatch covers

Corrosion addition t_c , in mm	
Plating and stiffeners of single skin hatch cover	2,0
Top and bottom plating of pontoon hatch cover	2,0
Internal structures of pontoon hatch cover	1,5

1.5.2 Corrosion additions for hatch coamings

The corrosion addition to be considered for the hatch coaming structures and coaming stays is equal to 1,5 mm.

1.5.3 Corrosion additions for stainelss steel

For structural members made of stainless steel, the corrosion addition t_c is to be taken equal to 0.

1.5.4 Corrosion additions for aluminium alloys

For structural members made of aluminium alloys, the corrosion addition t_c is to be taken equal to 0.

2 Arrangements

2.1 Height of hatch coamings

2.1.1 The height above the deck of hatch coamings closed by portable covers is to be not less than:

- 600 mm in position 1
- 450 mm in position 2.

2.1.2 The height of hatch coamings in positions 1 and 2 closed by steel covers provided with gaskets and securing devices may be reduced with respect to the above values or the coamings may be omitted entirely.

In such cases the scantlings of the covers, their gasketing, their securing arrangements and the drainage of recesses in the deck are considered by the Society on a case by case basis.

2.1.3

Regardless of the type of closing arrangement adopted, the coamings may have reduced height or be omitted in way of openings in closed superstructures or decks below the main deck.

2.2 Hatch covers

2.2.1 Hatch covers on exposed decks are to be weathertight.

Hatch covers in closed superstructures need not be weathertight.

However, hatch covers fitted in way of ballast tanks, fuel oil tanks or other tanks are to be watertight.

2.2.2

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

2.2.3

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

2.2.4

The breadth of the primary supporting member flange is to be not less than 40% of their depth for laterally unsupported spans greater than 3,0 m. Tripping brackets attached to the flange may be considered as a lateral support for primary supporting members.

2.2.5 The covers used in 'tweendecks are to be fitted with an appropriate system ensuring an efficient stowing when the ship is sailing with open 'tweendecks.

2.2.6 The ends of hatch covers are normally to be protected by efficiently secured galvanised steel strips.

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

Solid fittings are to be welded on the hatch cover where the corners of the containers are resting. These parts are intended to transmit the loads of the container stacks onto the hatch cover on which they are resting and also to prevent horizontal translation of the stacks by means of special intermediate parts arranged between the supports of the corners and the container corners.

Longitudinal stiffeners are to stiffen the hatch cover plate in way of these supports and connect at least the nearest three transverse stiffeners.

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

2.3 Hatch coamings

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

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

2.3.3 Longitudinal coamings are to be extended at least to the lower edge of deck beams.

Where they are not part of continuous deck girders, longitudinal coamings are to extend for at least two frame spaces beyond the end of the openings.

Where longitudinal coamings are part of deck girders, their scantlings are to be as required in Ch 7, Sec 3.

2.3.4 Transverse coamings are to extend below the deck at least to the lower edge of longitudinals.

Transverse coamings not in line with ordinary deck beams below are to extend below the deck at least three longitudinal frame spaces beyond the side coamings.

2.4 Small hatchways

2.4.1 The height of small hatchway coamings is to be not less than 600 mm if located in position 1, and 450 mm if located in position 2.

Where the closing appliances are in the form of hinged steel covers secured weathertight by gaskets and swing bolts, the height of the coamings may be reduced or the coamings may be omitted altogether.

2.4.2 Small hatch covers are to have strength equivalent to that required for main hatchways and are to be of steel, weathertight and generally hinged.

Securing arrangements and stiffening of hatch cover edges are to be such that weathertightness can be maintained in any sea condition.

At least one securing device is to be fitted at each side. Circular hole hinges are considered equivalent to securing devices.

2.4.3 Hold accesses located on the weather deck are to be provided with watertight metallic hatch covers, unless they are protected by a closed superstructure. The same applies to accesses located on the forecastle deck and leading directly to a dry cargo hold through a trunk.

2.4.4 Accesses to cofferdams and ballast tanks are to be manholes fitted with watertight covers fixed with bolts which are sufficiently closely spaced.

2.4.5 Hatchways of special design are considered by the Society on a case by case basis.

3 Width of attached plating

3.1 Ordinary stiffeners

3.1.1 The width of the attached plating to be considered for the check of ordinary stiffeners is to be obtained, in m, from the following formulae:

- where the attached plating extends on both sides of the stiffener:

  $b_P = s$

- where the attached plating extends on one side of the stiffener:

  $b_P = 0,5\ s$

3.2 Primary supporting members

3.2.1 Primary supporting members parallel to ordinary stiffeners

The width of the attached plating to be considered for the yielding and buckling checks of primary supporting members analysed through beam or grillage model is to be obtained, in m, from the following formulae:

- where the plating extends on both sides of the primary supporting member:

  $b_p = b_{p,1} + b_{p,2}$

- where the plating extends on one side of the primary supporting member:

  $b_p = b_{p,1}$

where:

$b_{p,1} = \min(0,65\lambda_p, S_{p,1})$

$b_{p,2} = \min(0,65\lambda_p, S_{p,2})$

λ_p : span, in m, of the considered primary supporting member

S_{P1}, S_{p2} : half distance, in m, between the considered primary supporting member and the adjacent ones, on the two sides.

4 Load model

4.1 Lateral pressures and concentrated loads

4.1.1 General

The still water and wave lateral pressures and concentrated loads, to be considered as acting on hatch covers, are those in [4.1.2] to [4.1.7].

Each case in [4.1.2] to [4.1.7] is not necessarily exhaustive for any specific hatch cover; however, depending on the location of each cover and its intended use, the pressures and loads to be considered as acting on it are to be calculated for one or more of these cases. For example, for a hatch cover located on an exposed deck and covering a ballast tank, the pressures in [4.1.2] and [4.1.3] are to be separately considered. If the same hatch cover is also intended to carry uniform cargoes, the pressures in [4.1.4] are to be individually considered, in addition to the two above.

4.1.2 Hatch covers on exposed decks

The still water lateral pressure and loads are to be considered when the hatch cover is intended to carry uniform cargoes, wheeled cargoes or containers. In these cases, the still water lateral pressures and loads are to be calculated according to [4.1.4] to [4.1.5], as applicable.

The wave lateral pressure is to be considered and is defined in [4.3.1].

4.1.3 Hatch covers in way of liquid cargo or ballast tanks

The still water and wave lateral pressures are to be considered and are defined in Ch 5, Sec 6, [1].

4.1.4 Hatch covers carrying uniform cargoes

The still water and wave lateral pressures are to be considered and are defined in Ch 5, Sec 6, [2].

4.1.5 Hatch covers carrying containers

The still water and wave loads are to be considered and are defined in Ch 5, Sec 6, [3].

4.1.6 Hatch covers carrying wheeled cargoes

The still water and wave loads are to be considered and are defined in Ch 5, Sec 6, [4].

4.1.7 Hatch covers carrying special cargoes

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

4.2 Wave pressure for hatch covers on exposed decks

4.2.1

The wave pressure p_W is defined in Tab 3 according to the hatch cover position.

4.2.2

Where two or more panels are connected by hinges, each individual panel is to be considered separately.

4.3 Load point

4.3.1 Wave lateral pressure for hatch covers on exposed decks

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

- longitudinally, at the hatch cover mid-length
- transversely, on the longitudinal plane of symmetry of the ship
- vertically, at the top of the hatch coaming.

4.3.2 Lateral pressures other than the wave pressure

The lateral pressure is to be calculated:

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

Table 3 : Wave pressure on hatch covers

Wave pressure p_W, in kN/m²			
Freeboard length L_{LL}, in m	Hatchway location	Position 1	Position 2
$L_{LL} \le 100$ m	$0 \le x \le 0,75\ L_{LL}$	$14,9 + 0,195\ L_{LL}$	$11,3 + 0,142\ L_{LL}$
	$0,75\ L_{LL} \le x \le L_{LL}$	$15,8 + \frac{L_{LL}}{3}\left(1 - \frac{5}{3}\frac{x}{L_{LL}}\right) - 3,6\frac{x}{L_{LL}}$	
$L_{LL} \ge 100$ m	$0 \le x \le 0,75\ L_{LL}$	34,3	25,5
	$0,75\ L_{LL} < x \le L_{LL}$	$34,3 + \frac{34,3 p_{FP}}{0,25}\left(\frac{x}{L_{LL}} - 0,75\right)$ **(1)**	

(1) Where a position 1 hatchway is located at least one superstructure standard height, as specified in Ch 1, Sec 2, Tab 2, higher than the freeboard deck, where the pressure p_W may be taken equal to 34,3 kN/m²

Note 1:

p_{FP} : pressure, in kN/m², at the forward perpendicular, to be taken equal to:

- p_{FP} : $49,1 + 0,0726\ (L_{LL} - 100)$ for Type B ships
- p_{FP} : $49,1 + 0,356\ (L_{LL} - 100)$ for Type B-60 or Type B-100 ships

5 Strength check

5.1 General

5.1.1 Application

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

In the latter case, the stresses in the primary supporting members are to be determined by a grillage or a Finite Element analysis. It is to be checked that stresses induced by concentrated loads are in accordance with the criteria in [5.3.4].

5.1.2 Hatch covers supporting wheeled loads

The scantlings of hatch covers supporting wheeled loads are to be obtained in accordance with:

- the applicable requirements of Ch 7, Sec 1 for plating
- the applicable requirements of Ch 7, Sec 2 for ordinary stiffeners
- the applicable requirements of Ch 7, Sec 3 for primary supporting members.

5.1.3 Hatch covers subjected to concentrated loads

For hatch covers supporting concentrated loads, ordinary stiffeners and primary supporting members are generally to be checked by direct calculations, taking into account the stiffener arrangements and their relative inertia. It is to be checked that stresses induced by concentrated loads are in accordance with the criteria in [5.3.4].

5.1.4 Covers of small hatchways

The thickness of covers is to be not less than 8 mm. This thickness is to be increased or an efficient stiffening fitted to the Society's satisfaction where the greatest horizontal dimension of the cover exceeds 0,6 m.

5.2 Plating

5.2.1 Net thickness

The net thickness of steel hatch cover top plating is to be not less than the value obtained, in mm, from the following formula:

$$t = F_p 15,8 s \sqrt{\frac{p_S + p_W}{0,95 R_{eH}}}$$

where:

F_p : factor for combined membrane and bending response, equal to:

- F_p : 1,50 in general
- F_p : $2,375\ \sigma/R_{eH}$ for $\sigma/R_{eH} \geq 0,64$, for the attached plating of primary supporting members

p_S : still water pressure, in kN/m², defined in [4.1]

p_W : wave pressure, in kN/m², defined in [4.2]

σ : normal stess, in kN/m², in the attached plating of primary supporting members, calculated according to [5.3.3] b) or determined through a grillage analysis or a Finite Element analysis, as the case may be.

5.2.2 Minimum net thickness

In addition to [5.2.1], the net thickness, in mm, of hatch cover plating is to be not less than 1% of s or 6 mm, whichever is the greater.

5.2.3 Critical buckling stress check

The compressive stress s in the hatch cover plating, induced by the bending of primary supporting members, either parallel and perpendicular to the direction ordinary stiffeners, calculated according to [5.3.3] or determined through a grillage analysis or a Finite Element analysis, as the case may be, is to comply with the following formula:

$$\frac{\sigma_{Cp}}{\gamma_R \gamma_m} \geq \sigma$$

where σ_{Cp} is critical buckling stress, defined in Ch 7, Sec 1, [5.3.1].

In addition, the bi-axial compression stress in the hatch cover plating, when calculated by means of Finite Element analysis, is to comply with the requirements in Ch 7, Sec 1, [5.4.5].

5.3 Ordinary stiffeners and primary supporting members

5.3.1 General

a) The flange outstand of the primary supporting members is to be not greater than 15 times the flange thickness.

b) The net dimensions of the flat bar ordinary stiffeners and buckling stiffeners are to comply with the following requirement:

$$\frac{h_W}{t_W} \leq 15\sqrt{k}$$

where h_W and t_W are the height and thickness, in mm, of the ordinary stiffener, respectively

5.3.2 Application

The requirements in [5.3.3] to [5.3.7] apply to:

- ordinary stiffeners
- primary supporting members which may be analysed through isolated beam models.

Primary supporting members whose arrangement is of a grillage type and which cannot be analysed through isolated beam models are to be checked by direct calculations, using the checking criteria in [5.3.4].

5.3.3 Normal and shear stress

a) In case that grillage analysis or Finite Element analysis are not carried out, according to the requirements in [5.1.1], the maximum normal stress σ and shear stress τ in the ordinary stiffeners are to be obtained, in N/mm², from the following formulae:

$$\sigma = \frac{s(p_S + p_W)\lambda_s^2 10^3}{m w}$$

$$\tau = \frac{5(s p_S + p_W)\lambda_s}{A_{Sh}}$$

where:

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

p_W : wave pressure, as defined in [4.2]

b) In case that grillage analysis or Finite Element analysis are not carried out, according to the requirements in [5.1.1], the maximum normal stress σ and shear stress τ in the primary supporting members are to be obtained, in N/mm², from the following formulae:

$$\sigma = \frac{s(p_S + p_W)\lambda_m^2 10^3}{mw}$$

$$\tau = \frac{5(sp_S + p_W)\lambda_m}{A_{Sh}}$$

where p_W is the wave pressure, as defined in [4.2] and λ_m is the span of the primary supporting member.

5.3.4 Checking criteria

a) Strength check

It is to be checked that the normal stress σ and the shear stress τ, calculated according to [5.3.3] or determined through a grillage analysis or Finite Element analysis, as the case may be, are to comply with the following formulae:

$$\frac{R_{eH}}{\gamma_R\gamma_m} \geq \sigma$$

$$0,57\frac{R_{eH}}{\gamma_R\gamma_m} \geq \tau$$

b) Critical buckling stress check of the ordinary stiffeners

The compressive stress s in the top flange of ordinary stiffeners, induced by the bending of primary supporting members, parallel to the direction of ordinary stiffeners, calculated according to [5.3.3] or determined through a grillage analysis or a Finite Element analysis, as the case may be, is to comply with the following formula:

$$\frac{\sigma_{Cs}}{\gamma_m\gamma_R} \geq \sigma$$

where:

$$\sigma_{Cs} = \sigma_{Es} \quad \text{for} \quad \sigma_{Es} \leq R_{eH}/2$$

$$\sigma_{Cs} = \sigma_{Es}[1 - R_{eH}/(4_{Es})] \quad \text{for} \quad \sigma_{ES} > R_{eH}/2$$

$$\sigma_{Es} = \min(\sigma_{E1}, \sigma_{E2})$$

σ_{E1} and σ_{E2} are defined in Ch 7, Sec 2, [4.3.1].

In calculating σ_{E2}, C_0 is to be taken equal to:

$$C_0 = \frac{k_p E t_p^3}{3s\left(1 + \frac{1,33 k_p h_W t_p^3}{1000 s t_W^3}\right)} 10^3$$

where:

t_p : net thickness, in mm, of the attached plating

h_W, t_W : height and thickness, in mm, of the ordinary stiffener, respectively.

k_p : 1 - η_p to be taken not less than zero; for flanged ordinary stiffeners, k_p need not be taken less than 0,1

η_p : σ/σ_{Ep}.

σ is is calculated according to [5.3.3] or determined through a grillage analysis

$$\sigma_{Ep} = 3,6E\left(\frac{t_P}{1000s}\right)^2$$

c) Critical buckling stress check of the web panels of the primary supporting members

The shear stress τ in the web panels of the primary supporting members, calculated according to [5.3.3] or determined through a grillage analysis or a Finite Element analysis, as the case may be, is to comply with the following formula:

$$\frac{\tau_C}{\gamma_m\gamma_R} \geq \tau$$

where τ_C is critical shear buckling stress, defined in Ch 7, Sec 1, [5.3.2]

For primary supporting members parallel to the direction of ordinary stiffeners, τ_C is to be calculated considering the actual dimensions of the panels are to be taken for the determination of the stress τ_C.

For primary supporting members perpendicular to the direction of ordinary stiffeners or for hatch covers built without ordinary stiffeners, a presumed square panel of dimension d is to be taken for the determination of the stress τ_C. In such a case, the average shear stress τ between the values calculated at the ends of this panel is to be considered.

d) Deflection limit

The vertical deflection of primary supporting members is to be not more than 0,0056 λ_{max}, where λ_{max} is the greatest span of primary supporting members.

5.3.5 Net section modulus and net shear sectional area

This requirement provides the minimum net section modulus and net shear sectional area of an ordinary stiffener or a primary supporting member subjected to lateral pressure, complying with the checking criteria indicated in [5.3.4].

The net section modulus w, in cm³, and the net shear sectional area A_{Sh}, in cm², of an ordinary stiffener subjected to lateral pressure are to be not less than the values obtained from the following formulae:

$$w = \gamma_m\gamma_R\frac{s(p_S + p_W)\lambda_s^2 10^3}{12R_{eH}}$$

$$A_{Sh} = \gamma_m\gamma_R\frac{5s(p_S + p_W)\lambda_s}{0,57R_{eH}}$$

The net section modulus w, in cm³, and the net shear sectional area A_{Sh}, in cm², of a primary supporting member subject to lateral pressure are to be not less than the values obtained from the following formulae:

$$w = \gamma_m \gamma_R \frac{s(p_S + p_W)\lambda_m^2 10^3}{m R_{eH}}$$

$$A_{Sh} = \gamma_m \gamma_R \frac{5s(p_S + p_W)\lambda_m}{0,57 R_{eH}}$$

5.3.6 Minimum net thickness of web

The net thickness of the ordinary stiffeners and primary supporting members, in mm, is to be not less than the minimum values given in [5.2.2].

5.3.7 Ordinary stiffeners and primary supporting members of variable cross-section

The section modulus of ordinary stiffeners and primary supporting members with a variable cross-section is to be not less than the greater of the values obtained, in cm^3, from the following formulae:

$$w = w_{CS}$$

$$w = \left(1 + \frac{3,2\alpha - \psi - 0,8}{7\psi + 0,4}\right) w_{CS}$$

where:

w_{CS} : Section modulus, in cm^3, for a constant cross-section, obtained according to [5.3.5]

$$\alpha = \frac{\ell_1}{\ell_0}$$

$$\psi = \frac{w_1}{w_0}$$

ℓ_1 : Length of the variable section part, in m, (see Fig 1)

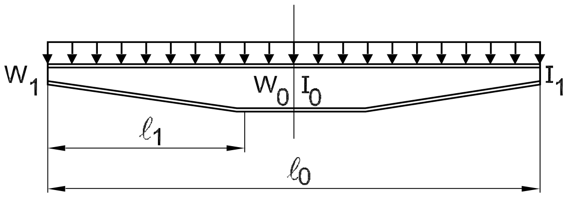
ℓ_0 : Span measured, in m, between end supports (see Fig 1)

w_1 : Section modulus at end, in cm^3 (see Fig 1)

w_0 : Section modulus at mid-span, in cm^3 (see Fig 1).

The use of this formula is limited to the determination of the strength of ordinary stiffeners and primary supporting members in which abrupt changes in the cross-section do not occur along their length.

Figure 1 : Variable cross-section stiffener



6 Hatch coamings

6.1 Stiffening

6.1.1

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

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

Moreover, when covers are fitted with tarpaulins, an angle or a bulb section is to be fitted all around coamings of more than 3 m in length or 600 mm in height; this stiffener is to be fitted at approximately 250 mm below the upper edge. The width of the horizontal flange of the angle is not to be less than 180 mm.

6.1.3 Where hatch covers are fitted with tarpaulins, coamings are to be strengthened by brackets or stays with a spacing not greater than 3 m.

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

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

6.1.4 When two hatches are close to each other, underdeck stiffeners are to be fitted to connect the longitudinal coamings with a view to maintaining the continuity of their strength.

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

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

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

6.2 Load model

6.2.1

The wave lateral pressure to be considered as acting on the hatch coamings are those specified in [6.2.2] and [6.2.3].

6.2.2

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

$$p_{WC} = 290 kN/m^2$$

6.2.3

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

$$p_{WC} = 220 kN/m^2$$

6.3 Scantlings

6.3.1 Plating

In ships intended for the carriage of liquid cargoes, the plate thickness of coamings is also to be checked under liquid internal pressures.

a) Net thickness

The net thickness of the hatch comaing plate is to be not less than the value obtained, in mm, from the following formula:

$$t = 14,7s\sqrt{\gamma_m \gamma_R \frac{p_{WC}}{R_{eH}}}$$

b) Minimum net thickness

In addition to the requirements in a), the net thickness of hatch coaming plate is to be not less than 9,5 mm.

6.3.2 Ordinary stiffeners

The net section modulus w of the longitudinal or transverse ordinary stiffeners of hatch coamings is to be not less than the value obtained, in cm^3, from the following formula:

$$w = \gamma_m \gamma_R \frac{0,85 s p_{WC} \lambda^2 10^3}{m c_p R_{eH}}$$

where:

m : 16 in general

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

: 1,16 in the absence of more precise evaluation.

6.3.3 Coaming stays

The net section modulus w, in cm^3, and the thickness t_W, in mm, of the coaming stays are to be not less than the values obtained from the following formulae:

$$t_W = \gamma_m \gamma_R \frac{1000 H_C s_C p_{WC}}{0,62 h R_{eH}}$$

where:

H_C : stay height, in m

s_C : stay spacing, in m

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

For calculating the section modulus of coaming stays, their face plate area is to be taken into account only when it is welded with full penetration welds to the deck plating and adequate underdeck structure is fitted to support the stresses transmitted by it.

6.3.4 Local details

The design of local details is to comply with the requirements in this Section for the purpose of transferring the pressures on the hatch covers to the hatch coamings and, through them, to the deck structures below. Hatch coamings and supporting structures are to be adequately stiffened to accommodate the loading from hatch covers, in longitudinal, transverse and vertical directions.

The normal stress s and the shear stress t, in N/mm^2, induced in the underdeck structures by the loads transmitted by stays are to comply with the following formulae:

$$\sigma \le \sigma_{ALL}$$

$$\tau \le \tau_{ALL}$$

where:

σ_{ALL} : allowable normal stress, in N/mm^2, equal to 0,95 R_{eH}

τ_{ALL} : allowable shear stress, in N/mm^2, equal to 0,5 R_{eH}.

Unless otherwise stated, weld connections and materials are to be dimensioned and selected in accordance with the requirements in Ch 11, Sec 1 and Part D of the Rules for the Classification of the Ships, respectively.

Double continuous fillet welding is to be adopted for the connections of stay webs with deck plating and the weld throat thickness is to be not less than 0,44 t_W, where t_W is the gross thickness of the stay web.

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

6.3.5 Coamings of small hatchways

The coaming plate thickness is to be not less than the lesser of the following values:

- the thickness for the deck inside line of openings calculated for that position, assuming as spacing of stiffeners the lesser of the values of the height of the coaming and the distance between its stiffeners, if any, or
- 10 mm.

Coamings are to be suitably strengthened where their height exceeds 0,80 m or their greatest horizontal dimension exceeds 1,20 m, unless their shape ensures an adequate rigidity.

7 Weathertightness, closing arrangement and securing devices

7.1 Weathertightness

7.1.1 Where the hatchway is exposed and closed with a single panel, the weathertightness is to be ensured by gaskets and clamping devices sufficient in number and quality.

Weathertightness may also be ensured means of tarpaulins.

7.1.2 The mean spacing of swing bolts or equivalent devices is, in general, to be not greater than:

- 2,0 m for dry cargo holds
- 1,5 m for ballast compartments
- 1,0 m for liquid cargo holds.

7.2 Gaskets

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

This may be achieved by continuous steel to steel contact of the hatch cover skirt plate with the ship's structure or by means of defined bearing pads.

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

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

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

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

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

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

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

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

7.2.6 Metallic contact is required for an earthing connection between the hatch cover and the hull structures. If necessary, this is to be achieved by means of a special connection for the purpose.

7.3 Closing arrangement and securing devices

7.3.1 General

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

The securing and stop arrangements are to be fitted using appropriate means which cannot be easily removed.

In addition to the requirements above, all hatch covers, and in particular those carrying deck cargo, are to be effectively secured against horizontal shifting due to the horizontal forces resulting from ship motions.

Towards the ends of the ship, vertical acceleration forces may exceed the gravity force. The resulting lifting forces are to be considered when dimensioning the securing devices according to [7.3.5] to [7.3.7] Lifting forces from cargo secured on the hatch cover during rolling are also to be taken into account.

Hatch coamings and supporting structure are to be adequately stiffened to accommodate the loading from hatch covers.

Hatch covers provided with special sealing devices, insulated hatch covers, flush hatch covers and those having coamings of a reduced height (see [2.1]) are considered by the Society on a case by case basis.

In the case of hatch covers carrying containers, the scantlings of the closing devices are to take into account the possible upward vertical forces transmitted by the containers.

7.3.2 Arrangements

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

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

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

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

7.3.3 Spacing

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

The spacing of securing arrangements of tank hatch covers in 'tweendecks is to be not greater than 600 mm.

7.3.4 Construction

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

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

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

7.3.5 Area of securing devices

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

$$A = 1{,}4 S_S \left(\frac{235}{R_{eH}}\right)^f$$

where:

S_S : Spacing, in m, of securing devices

f : Coefficient taken equal to:

- 0,75 for $R_{eH} > 235$ N/mm^2,
- 1,00 for $R_{eH} \leq 235$ N/mm^2.

In the above calculations, R_{eH} may not be taken greater than 0,7 R_m.

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

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

7.3.6 Inertia of edges elements

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

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

$$I = 6 p_L S_S^4$$

where:

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

S_S : Spacing, in m, of securing devices.

7.3.7 Diameter of rods or bolts

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

7.3.8 Stoppers

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

Hatch covers are to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 175 kN/m^2.

The equivalent stress in stoppers, their supporting structures and calculated in the throat of the stopper welds is to be equal to or less than the allowable value, equal to 0,8 R_{eH}.

7.4 Tarpaulins

7.4.1 Where weathertightness of hatch covers is ensured by means of tarpaulins, at least two layers of tarpaulins are to be fitted.

Tarpaulins are to be free from jute and waterproof and are to have adequate characteristics of strength and resistance to atmospheric agents and high and low temperatures.

The mass per unit surface of tarpaulins made of vegetable fibres, before the waterproofing treatment, is to be not less than:

- 0,65 kg/m^2 for waterproofing by tarring
- 0,60 kg/m^2 for waterproofing by chemical dressing
- 0,55 kg/m^2 for waterproofing by dressing with black oil.

In addition to tarpaulins made of vegetable fibres, those of synthetic fabrics or plastic laminates may be accepted by the Society provided their qualities, as regards strength, waterproofing and resistance to high and low temperatures, are equivalent to those of tarpaulins made of vegetable fibres.

7.5 Cleats

7.5.1 The arrangements for securing the tarpaulins to hatch coamings are to incorporate cleats of a suitable pattern giving support to battens and wedges and with edges rounded so as to minimise damage to the wedges.

7.5.2 Cleats are to be spaced not more than 600 mm from centre to centre and are to be not more than 150 mm from the hatch corners.

7.5.3 The thickness of cleats is to be not less than 9,5 mm for angle cleats and 11 mm for forged cleats.

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

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

7.6 Wedges, battens and locking bars

7.6.1 Wedges

Wedges are to be of tough wood, generally not more than 200 mm in length and 50 mm in width.

They are generally to be tapered not more than 1 in 6 and their thickness is to be not less than 13 mm.

7.6.2 Battens and locking bars

For all hatchways in exposed positions, battens or transverse bars in steel or other equivalent means are to be provided in order to efficiently secure the portable covers after the tarpaulins are battened down.

Portable covers of more than 1,5 m in length are to be secured by at least two such securing appliances.

8 Drainage

8.1 Arrangement

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

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

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

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

9 Small hatches fitted on the exposed fore deck

9.1 Application

9.1.1 General

The requirements in [9] apply to steel covers of small hatches fitted on the exposed fore deck over the forward 0,25L, for ships of equal to or greater than 80 m in length, where the height of the exposed deck in way of the hatch is less than 0,1L or 22 m above the summer load waterline, whichever is the lesser.

Small hatches are hatches designed for access to spaces below the deck and are capable to be closed weather-tight or watertight, as applicable. Their opening is generally equal to or less than 2,5 m^2.

9.1.2 Small hatches designed for use of emergency escape

Small hatches designed for use of emergency escape are to comply with the requirements in [9], with exception of the requirements in [9.4.1] a) and b), in [9.4.3] and in [9.5].

Securing devices of hatches designed for emergency escape are to be of a quick-acting type (e.g. one action wheel handles are provided as central locking devices for latching/unlatching of hatch cover) operable from both sides of the hatch cover.

9.2 Strength

9.2.1

For small rectangular steel hatch covers, the plate thickness, stiffener arrangement and scantlings are to be not less than those obtained, in mm, from Tab 4 and Fig 2.

Ordinary stiffeners, where fitted, are to be aligned with the metal-to-metal contact points, required in [9.3.1], (see also Fig 2). Primary supporting members are to be continuous. All stiffeners are to be welded to the inner edge stiffener, (see also Fig 3).

9.2.2

The upper edge of the hatchway coamings is to be suitably reinforced by a horizontal section, normally not more than 170 to 190 mm from the upper edge of the coamings.

9.2.3

For small hatch covers of circular or similar shape, the cover plate thickness and reinforcement is to comply with the requirements in [5].

9.2.4

For small hatch covers constructed of materials other than steel, the required scantlings are to provide equivalent strength.

Table 4 : Structural scantlings of small rectangular steel hatch covers

Hatch nominal size h (mm x mm)	Cover plate thickness (mm)	Primary supporting members	Ordinary stiffeners
		Flat Bar (mm x mm); number	
630 x 630	8	-	-
630 x 830	8	100 x 8; 1	-
830 x 630	8	100 x 8; 1	-
830 x 830	8	100 x 10; 1	-
1030 x 1030	8	120 x 12; 1	80 x 8; 2
1330 x 1330	8	150 x 12; 2	100 x 10; 2

9.3 Weathertightness

9.3.1

The hatch cover is to be fitted with a gasket of elastic material. This is to be designed to allow a metal to metal contact at a designed compression and to prevent over compression of the gasket by green sea forces that may cause the securing devices to be loosened or dislodged. The metal-to-metal contacts are to be arranged close to each securing device in accordance with Fig 2, and of sufficient capacity to withstand the bearing force

9.4 Primary Securing Devices

9.4.1

Small hatches located on exposed fore deck are to be fitted with primary securing devices such that their hatch covers can be secured in place and weather-tight by means of a mechanism employing any one of the following methods:

a) Butterfly nuts tightening onto forks (clamps),

b) Quick acting cleats, or

c) Central locking device.

Dogs (twist tightening handles) with wedges are deemed as not acceptable by the Society.

9.4.2

The primary securing method is to be designed and manufactured such that the designed compression pressure is achieved by one person without the need of any tools

9.4.3

For a primary securing method using butterfly nuts, the forks (clamps) are to be of robust design. They are to be designed to minimise the risk of butterfly nuts being dislodged while in use; by means of curving the forks upward, a raised surface on the free end, or a similar method. The plate thickness of unstiffened steel forks is to be not less than 16 mm. An example of arrangement is shown in Fig 3.

9.4.4

For small hatch covers located on the exposed deck forward of the fore-most cargo hatch, the hinges are to be fitted such that the predominant direction of green sea will cause the cover to close, which means that the hinges are normally to be located on the fore edge.

9.4.5

On small hatches located between the main hatches, for example between hatches N. 1 and N. 2, the hinges are to be placed on the fore edge or outboard edge, whichever is practicable for protection from green water in beam sea and bow quartering conditions.

9.5 Secondary Securing Devices

9.5.1

Small hatches on the fore deck are to be fitted with an independent secondary securing device e.g. by means of a sliding bolt, a hasp or a backing bar of slack fit, which is capable of keeping the hatch cover in place, even in the event that the primary securing device became loosened or dislodged. It is to be fitted on the side opposite to the hatch cover hinges.

Figure 2 : Structural arrangement of small rectangular steel hatch covers

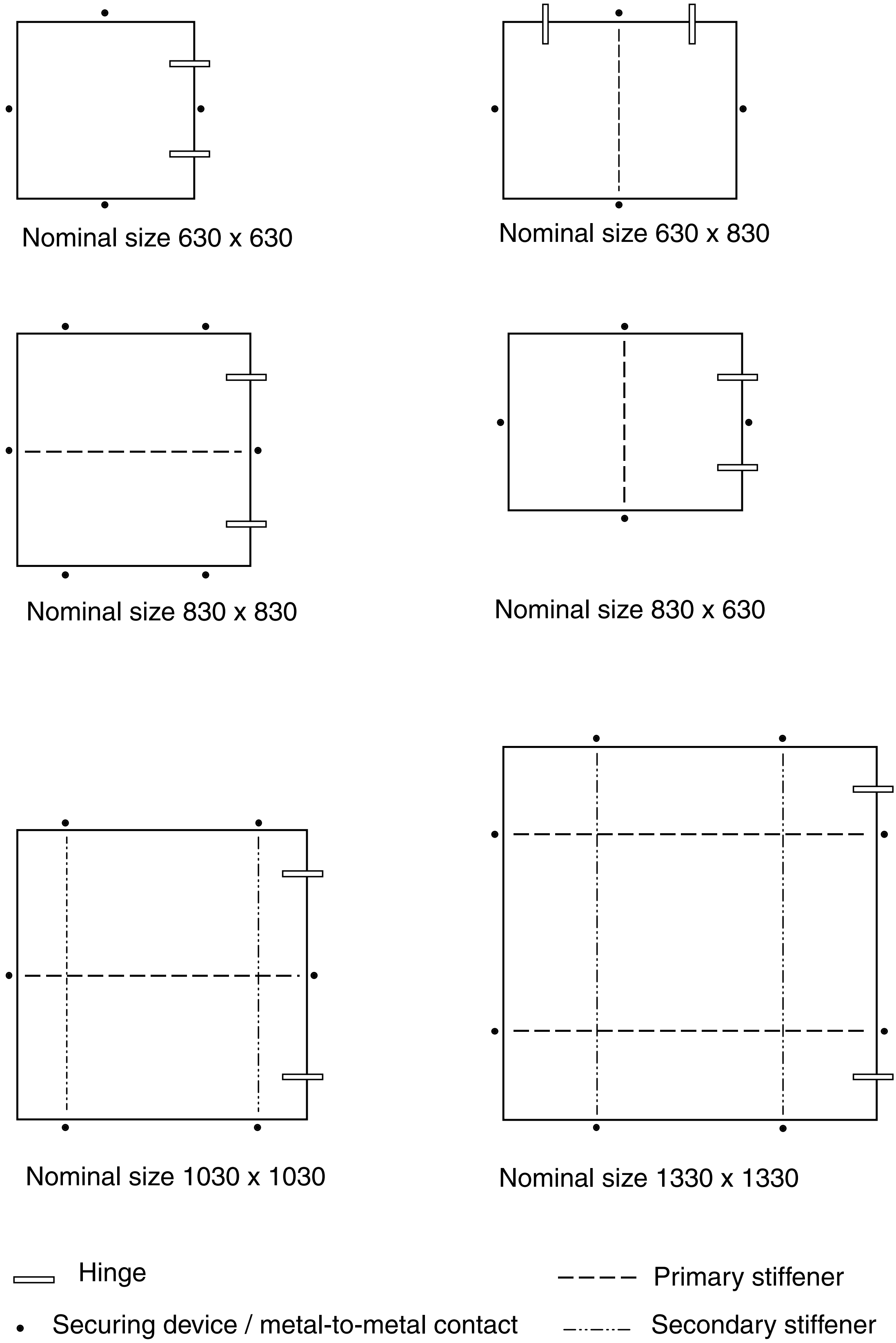
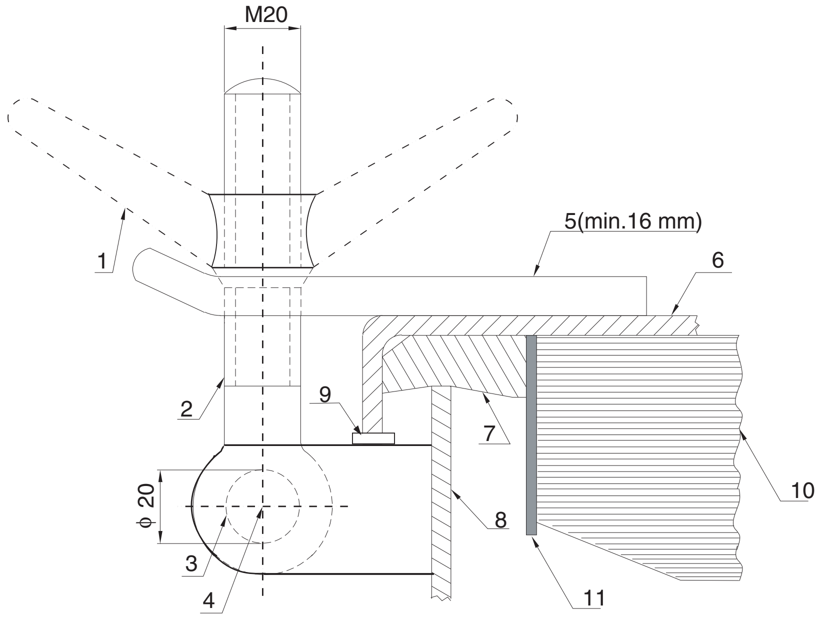


Figure 3 : Example of a primary securing method



Legenda:

1: butterfly nut

2: bolt

3: pin

4: centre of pin

5: fork (clamp) plate

6: hatch cover

7: gasket

8: hatch coaming

9: bearing pad welded on the bracket of a toggle bolt for metal-to-metal contact

10: stiffener

11: inner edge stiffener

Note*: Dimensions in mm*

SECTION 8 MOVABLE DECKS AND INNER RAMPS - EXTERNAL RAMPS

1 Movable decks and inner ramps

1.1 Application

1.1.1 The requirements of this Article apply to movable decks and inner ramps.

1.2 Materials

1.2.1 The decks and inner ramps are to be made of steel or aluminium alloys complying with the requirements of Part D of the Rules for the Classification of the Ships. Other materials of equivalent strength may be used, subject to a case by case examination by the Society.

1.3 Net scantlings

1.3.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 4, Sec 2.

1.4 Plating

1.4.1 The net thickness of plate panels subjected to wheeled loads is to be not less than the value obtained from Ch 7, Sec 1, [4.3], where nP_0 is not to be taken less than 50 kN.

1.5 Supporting structure

1.5.1 General

The supporting structure of movable decks and inner ramps is to be verified through direct calculation, considering the following cases:

- movable deck stowed in upper position, empty and locked, at sea
- movable deck in service, loaded, in lower position, resting on supports or supporting legs and locked, at sea
- movable inner ramp in sloped position, supported by hinges at one end and by a deck at the other, with possible intermediate supports, loaded, at harbour
- movable inner ramp in horizontal position, loaded and locked, at sea.

1.5.2 Loading cases

The scantlings of the structure are to be verified in both sea and harbour conditions for the following cases:

- loaded movable deck or inner ramp under loads according to the vehicle distribution indicated by the Designer
- loaded movable deck or inner ramp under uniformly distributed loads corresponding to a pressure, in kN/m², taken equal to:

$$p = \frac{n_V P_V + P_P}{A_P}$$

- empty movable deck under uniformly distributed masses corresponding to a pressure, in kN/m², taken equal to:

$$p = \frac{P_P}{A_P}$$

where:

n_V : Maximum number of vehicles loaded on the movable deck

P_V : Mass of a vehicle, in kN

P_P : Mass of the movable deck, in kN

A_P : Effective area of the movable deck, in m².

Table 1 : Movable decks and inner ramps Still water and inertial pressures

Ship condition	Load case	Still water pressure p_S and inertial pressure p_W, in kN/m²
Still water condition		$p_S = p$
Upright sea condition	"a"	No inertial pressure
	"b"	$p_{W,X} = p\frac{a_{X1}}{g}$ in x direction $p_{W,Z} = p\frac{a_{Z1}}{g}$ in z direction
Inclined sea condition (negative roll angle)	"c" "d"	$p_{W,Y} = p\frac{C_{FA}a_{Y2}}{g}$ in y direction $p_{W,Z} = p\frac{C_{FA}a_{Z2}}{g}$ in z direction
Harbour condition **(1)**	during lifting	$p_{W,X} = 0{,}035p$ in x direction $p_{W,Y} = 0{,}087p$ in y direction $p_{W,Z} = 0{,}2p$ in z direction
	at rest	$p_{W,X} = 0{,}035p$ in x direction $p_{W,Y} = 0{,}087p$ in y direction $p_{W,Z} = 0$ in z direction

(1) For harbour conditions, a heel angle of 5° and a trim angle of 2° are taken into account.

Note 1:

p : Pressure, in kN/m², to be calculated according to [1.5.2] for the condition considered.

C_{FA} : Combination factor, to be taken equal to:
- $C_{FA} = 0{,}7$ for load case "c"
- $C_{FA} = 1{,}0$ for load case "d"

1.5.3 Still water and inertial pressures

The still water and inertial pressures transmitted to the movable deck or inner ramp structures are obtained, in kN/m², as specified in Tab 1.

1.5.4 Checking criteria

It is to be checked that the combined stress σ_{VM} is in accordance with the criteria defined in Ch 7, Sec 3, [4.3.1].

1.5.5 Allowable deflection

The scantlings of main stiffeners and the distribution of supports are to be such that the deflection of the movable deck or inner ramp does not exceed 5 mm/m.

1.6 Supports, suspensions and locking devices

1.6.1 Scantlings of supports and wire suspensions are to be determined by direct calculation on the basis of the loads in [1.5.2] and [1.5.3], taking account of a safety factor at least equal to 5.

1.6.2 It is to be checked that the combined stress σ_{VM} in rigid supports and locking devices is in accordance with the criteria defined in Ch 7, Sec 3, [4.3.1].

2 External ramps

2.1 General

2.1.1 The external ramps are to be able to operate with a heel angle of 5° and a trim angle of 2°.

2.1.2 The external ramps are to be examined for their watertightness, if applicable, and as a support of vehicles at harbour.

2.1.3 The locking of external ramps in stowage position at sea is examined by the Society on a case by case basis.

2.1.4 The ship's structure under the reactions due to the ramp is examined by the Society on a case by case basis.

3 Vehicle ramps

3.1 General

3.1.1 *(1/1/2017)*

Vehicle ramps are to be verified also according to the Tasneef "Rules for loading and unloading arrangements and for other lifting appliances on board ships".

SECTION 9 ARRANGEMENT OF HULL AND SUPERSTRUCTURE OPENINGS

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the arrangement of hull and superstructure openings excluding hatchways, for which the requirements in Sec 7 apply.

1.2 Definitions

1.2.1 Standard height of superstructure

The standard height of superstructure is that defined in Tab 1.

1.2.2 Standard sheer

The standard sheer is that defined according to regulation 38 of the International Load Line Convention 1966, as amended.

1.2.3 Exposed zones

Exposed zones are the boundaries of superstructures or deckhouses set in from the ship's side at a distance less than or equal to 0,04 B.

1.2.4 Unexposed zones

Unexposed zones are the boundaries of deckhouses set in from the ship's side at a distance greater than 0,04 B.

2 External openings

2.1 General

2.1.1 All external openings leading to compartments assumed intact in the damage analysis, which are below the final damage waterline, are required to be watertight.

2.1.2 External openings required to be watertight in accordance with [2.1.1] are to be of sufficient strength and, except for cargo hatch covers, are to be fitted with indicators on the bridge.

2.1.3 Openings in the shell plating below the deck limiting the vertical extent of damage are to be kept permanently closed while at sea. Should any of these openings be accessible during the voyage, they are to be fitted with a device which prevents unauthorised opening.

2.1.4 Notwithstanding the requirements of [2.1.3], the Society may authorise that particular doors may be opened at the discretion of the Master, if necessary for the operation of the ship and provided that the safety of the ship is not impaired.

2.1.5 Other closing appliances which are kept permanently closed at sea to ensure the watertight integrity of external openings are to be provided with a notice affixed to each appliance to the effect that it is to be kept closed. Manholes fitted with closely bolted covers need not be so marked.

2.2 Closing devices subjected to weapon firing loads

2.2.1 In addition to the applicable requirements of this Section, the net scantlings of closing devices subjected to weapon firing loads are to be not less that those obtained from the applicable formulae in Chapter 7, where the pressures are to be calculated according to Ch 5, Sec 6, [8].

3 Sidescuttles, windows and skylights

3.1 General

3.1.1 Application

The requirements in [3.1]to [3.4] apply to sidescuttles and rectangular windows providing light and air, located in positions which are exposed to the action of sea and/or bad weather.

Table 1 : Standard height of superstructure *(1/1/2017)*

Lenght L_{LL}, in m	Standard height h_S, in m	
	Raised quarter deck	All other superstructures
$L_{LL} \le 30$	0,90	1,80
$30 < L_{LL} < 75$	$0,9+0,00667(L_{LL}-30)$	1,80
$75 \le L_{LL} < 125$	$1,2+0,012(L_{LL}-75)$	$1,8+0,01(L_{LL}-75)$
$L_{LL} \ge 125$	1,80	2,30

3.1.2 Sidescuttle definition

Sidescuttles are round or oval openings with an area not exceeding 0,16 m². Round or oval openings having areas exceeding 0,16 m² are to be treated as windows.

3.1.3 Window definition

Windows are rectangular openings generally, having a radius at each corner relative to the window size in accordance with recognised national or international standards, and round or oval openings with an area exceeding 0,16 m².

3.1.4 Number of openings in the shell plating

The number of openings in the shell plating are to be reduced to the minimum compatible with the design and proper working of the ship.

3.1.5 Material and scantlings

Sidescuttles and windows together with their glasses, deadlights and storm covers, if fitted, are to be of approved design and substantial construction in accordance with, or equivalent to, recognised national or international standards.

Non-metallic frames are not acceptable. The use of ordinary cast iron is prohibited for sidescuttles below the main deck.

3.1.6 Means of closing and opening

The arrangement and efficiency of the means for closing any opening in the shell plating are to be consistent with its intended purpose and the position in which it is fitted is to be generally to the satisfaction of the Society.

3.1.7 Opening of sidescuttles

All sidescuttles, the sills of which are below the bulkhead deck, are to be of such construction as to prevent effectively any person opening them without the consent of the Master of the ship.

Sidescuttles and their deadlights which are not accessible during navigation are to be closed and secured before the ship leaves port.

The Society, at its discretion, may prescribe that the time of opening such sidescuttles in port and of closing and locking them before the ship leaves port is to be recorded in a log book.

3.2 Opening arrangement

3.2.1 General

Sidescuttles may not be fitted in such a position that their sills are below a line drawn parallel to the main deck at side and having its lowest point 0,025B or 0,5 m, whichever is the greater distance, above the waterline corresponding to the deepest draught.

3.2.2 Sidescuttles below 1,4+0,025B m above the water

Where in 'tweendecks the sills of any of the sidescuttles are below a line drawn parallel to the bulkhead deck at side and having its lowest point 1,4+0,025B m above the water when the ship departs from any port, all the sidescuttles in that 'tweendecks are to be closed watertight and locked before the ship leaves port, and they may not be opened before the ship arrives at the next port. In the application of this requirement, the appropriate allowance for fresh water may be made when applicable.

For any ship that has one or more sidescuttles so placed that the above requirements apply when it is floating at its deepest subdivision load line, the Society may indicate the limiting mean draught at which these sidescuttles are to have their sills above the line drawn parallel to the bulkhead deck at side, and having its lowest point 1,4+0,025B above the waterline corresponding to the limiting mean draught, and at which it is therefore permissible to depart from port without previously closing and locking them and to open them at sea under the responsibility of the Master during the voyage to the next port. In tropical zones as defined in the International Convention on Load Lines in force, this limiting draught may be increased by 0,3 m.

3.2.3 Cargo spaces

No sidescuttles may be fitted in any spaces which are appropriated exclusively for the carriage of cargo or coal.

Sidescuttles may, however, be fitted in spaces appropriated alternatively for the carriage of cargo or passengers, but they are to be of such construction as to prevent effectively any person opening them or their deadlights without the consent of the Master.

If cargo is carried in such spaces, the sidescuttles and their deadlights are to be closed watertight and locked before the cargo is shipped. The Society, at its discretion, may prescribe that the time of closing and locking is to be recorded in a log book.

3.2.4 Non-opening type sidescuttles

Sidescuttles are to be of the non-opening type in the following cases:

- where they become immersed by any intermediate stage of flooding or the final equilibrium waterplane in any required damage case for ships subject to damage stability regulations
- where they are fitted outside the space considered flooded and are below the final waterline for those ships where the watertight is reduced on account of subdivision characteristics.

3.2.5 Manholes and flush scuttles

Manholes and flush scuttles in positions 1 or 2, or within superstructures other than enclosed superstructures, are to be closed by substantial covers capable of being made watertight. Unless secured by closely spaced bolts, the covers are to be permanently attached.

3.2.6 Ships with several decks

In ships having several decks above the bulkhead deck, such as passenger ships, the arrangement of sidescuttles and rectangular windows is considered by the Society on a case by case basis.

Particular consideration is to be given to the ship side up to the upper deck and the front bulkhead of the superstructure.

3.2.7 Automatic ventilating scuttles

Automatic ventilating sidescuttles, fitted in the shell plating below the bulkhead deck are considered by the Society on a case by case basis.

3.2.8 Window arrangement

Windows may not be fitted below the watertight deck, in first tier end bulkheads or sides of enclosed superstructures and in first tier deckhouses considered as being buoyant in the stability calculations or protecting openings leading below.

In the front bulkhead of a superstructure situated on the upper deck, in the case of substantially increased water-tight, rectangular windows with permanently fitted storm covers are acceptable.

3.2.9 Skylights

Fixed or opening skylights are to have glass thickness appropriate to their size and position as required for sidescuttles and windows. Skylight glasses in any position are to be protected from mechanical damage and, where fitted in positions 1 or 2, to be provided with permanently attached robust deadlights or storm covers.

3.2.10 Gangway, and cargo ports

Gangway and cargo ports fitted below the bulkhead deck are to be of sufficient strength. They are to be effectively closed and secured watertight before the ship leaves port, and to be kept closed during navigation.

Such ports are in no case to be so fitted as to have their lowest point below a line positioned 230 mm above the water-line corresponding to the deepest draught.

Unless otherwise granted by the Society, these opening are to open outwards.

The number of such openings is to be the minimum compatible with the design and proper working of the ship.

Where it is permitted to arrange cargo ports and other similar openings with their lower edge below the line specified above, additional features are to be fitted to maintain the watertight integrity.

The fitting of a second door of equivalent strength and watertightness is one acceptable arrangement. A leakage detection device is to be provided in the compartment between the two doors. Drainage of this compartment to the bilges, controlled by a readily accessible screw-down valve, is to be arranged. The outer door is to open outwards.

Arrangements for bow doors and their inner doors, side doors and stern doors and their securing are to be in compliance with the requirements specified in Sec 5 and in Sec 6, respectively.

Table 2 : Thickness of toughened glasses in sidescuttles

Clear light diameter of sidescuttle, in mm	Thickness, in mm		
	Type A Heavy series	Type B Medium series	Type C Light series
200	10	8	6
250	12	8	6
300	15	10	8
350	15	12	8
400	19	12	10
450	Not applicable	15	10

3.3 Glasses

3.3.1 General

In general, toughened glasses with frames of special type are to be used in compliance with, or equivalent to, recognised national or international standards.

The use of clear plate glasses is considered by the Society on a case by case basis.

3.3.2 Thickness of toughened glasses in sidescuttles

The thickness of toughened glasses in sidescuttles is to be not less than that obtained, in mm, from Tab 2.

Type A, B or C sidescuttles are to be adopted according to the requirements of Tab 3, where:

- Zone 1 is the zone comprised between a line, parallel to the sheer profile, with its lowest points at a distance above the waterline corresponding to the deepest draught equal to 0,025B m, or 0,5 m, whichever is the greater, and a line parallel to the previous one and located 1,4 m above it
- Zone 2 is the zone located above Zone A and bounded at the top by the main deck
- Zone 3 is the first tier of superstructures or deckhouses
- Zone 4 is the second tier of deckhouses
- Zone 5 is the third and higher tiers of deckhouses.

3.3.3 Thickness of toughened glasses in rectangular windows

The thickness of toughened glasses in rectangular windows is to be not less than that obtained, in mm, from Tab 4.

Dimensions of rectangular windows other than those in Tab 4 are considered by the Society on a case by case basis.

3.3.4 Thickness of glasses forming screen bulkheads or internal boundaries of deckhouses

The thickness of glasses forming screen bulkheads on the side of enclosed promenade spaces and that for rectangular windows in the internal boundaries of deckhouses which are protected by such screen bulkheads are considered by the Society on a case by case basis.

The Society may require both limitations on the size of rectangular windows and the use of glasses of increased thickness in way of front bulkheads which are particularly exposed to heavy sea.

3.3.5 Thickness of glasses subjected to weapon firing loads

The thickness of glasses subjected to weapon firing dynamic loads is to be not less than the value obtained, in mm, from the following formulae:

$$t = 17,5d\sqrt{\frac{p_W}{\sigma_{ALL}}}\text{ for sidescuttles}$$

$$t = 31,6s\sqrt{\beta\frac{p_W}{\sigma_{ALL}}}\text{ for windows}$$

where

p_W : pressure, in kN/m², induced by weapon firing dynamic loads, to be calculated according to the requirements specified in Ch 5, Sec 6, [8], as the case may be

d : clear light diameter, in m, of the sidescuttle

s : clear light diameter, in m, of the sidescuttle β : coefficient to be obtained in Fig 1

σ_{ALL} : allowable stress, in N/mm². For toughened glasses, in general, it is to be taken equal to:

σ_{ALL} = 40 N/mm²

Other values may be accepted if adequate documentation is provided to the Society.

For glasses built in two or more layers, t is the equivalent thickness of the single layer glass having the same strength of the multiple layer glass under consideration.

3.3.6 *(1/1/2017)*

For windows and sidescuttles with dimensions different from those indicated in Table 2 and Table 4 the thickness calculation of the glasses is to be obtained according to Standard ISO 21005, considering the pressure indicated in Sec 4, [2.2.2].

3.4 Deadlight arrangement

3.4.1 General

Sidescuttles to the following spaces are to be fitted with efficient, hinged inside deadlights:

- spaces below the main deck
- spaces within the first tier of enclosed superstructures
- first tier deckhouses on the main deck protecting openings leading below or considered buoyant in stability calculations.

3.4.2 Watertight deadlights

Efficient, hinged inside deadlights so arranged that they can be easily and effectively closed and secured watertight, are to be fitted to all sidescuttles except that abaft one eighth of the ship's length from the forward perpendicular and above a line drawn parallel to the bulkhead deck at side and having its lowest point at a height of 3,7+0,025B m above the waterline corresponding to the deepest draught.

3.4.3 Openings at the side shell in the second tier

Sidescuttles and windows at the side shell in the second tier, protecting direct access below or considered buoyant in the stability calculations, are to be provided with efficient, hinged inside deadlights capable of being effectively closed and secured weathertight.

3.4.4 Openings set inboard in the second tier

Sidescuttles and windows set inboard from the side shell in the second tier, protecting direct access below to spaces listed in [3.4.1] are to be provided with either efficient, hinged inside deadlights or, where they are accessible, permanently attached external storm covers of approved design and substantial construction capable of being effectively closed and secured weathertight.

Cabin bulkheads and doors in the second tier separating sidescuttles and windows from a direct access leading below may be accepted in place of fitted deadlights or storm covers.

Note 1: Deadlights in accordance with recognised standards are fitted to the inside of windows and sidescuttles, while storm covers of comparable specifications to deadlights are fitted to the outside of windows, where accessible, and may be hinged or portable.

Figure 1 : Coefficent β

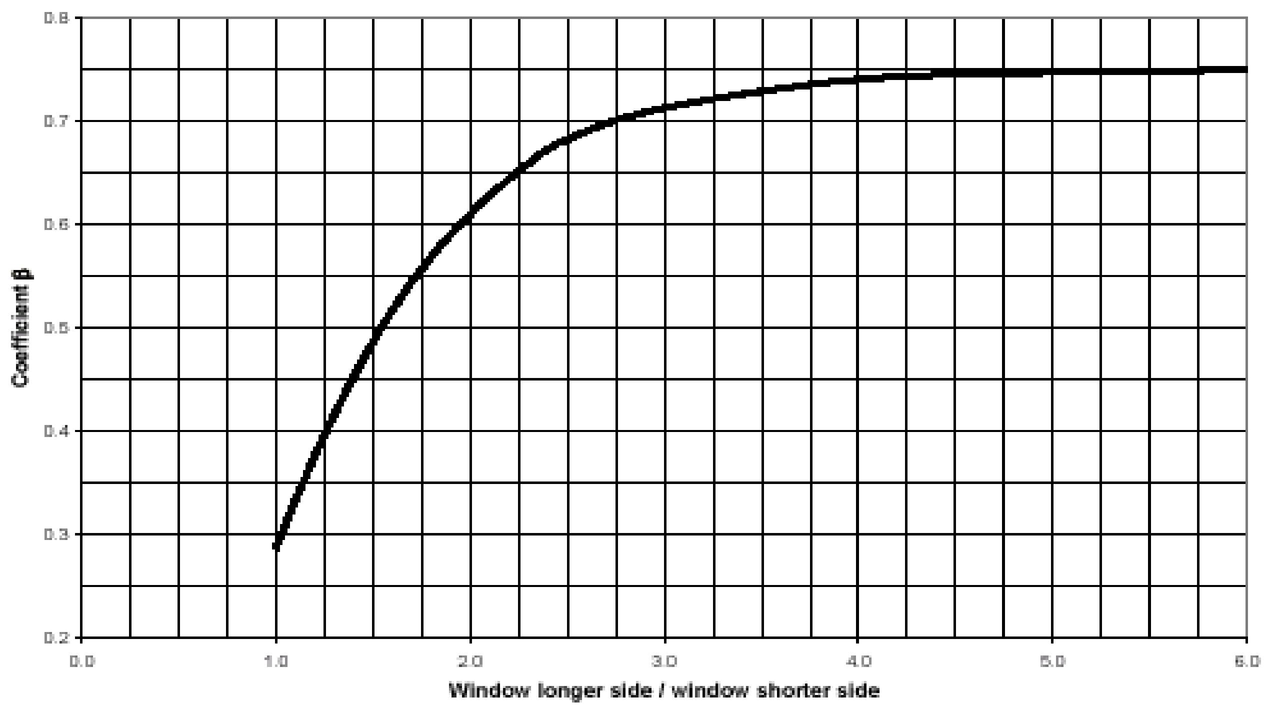


Table 3 : Types of sidescuttles

<table>
<tr><td>Zone</td><td colspan="2">Aft of 0,875 L from the aft end</td><td>Fwd of 0,875 L from the aft end</td></tr>
<tr><td>5</td><td colspan="2">Type C</td><td>Type B</td></tr>
<tr><td rowspan="2">4</td><td colspan="2">Protecting openings giving direct access to spaces below the main deck: Type B</td><td rowspan="2">Type B</td></tr>
<tr><td colspan="2">Not protecting openings giving direct access to spaces below the main deck: Type C</td></tr>
<tr><td rowspan="3">3</td><td colspan="2">Exposed zones: Type B</td><td rowspan="3">Type B</td></tr>
<tr><td rowspan="2">Unexposed zones</td><td>Protecting openings giving direct access to spaces below the main deck: Type B</td></tr>
<tr><td>Not protecting openings giving direct access to spaces below the main deck: Type C</td></tr>
<tr><td>2</td><td colspan="2">Type B</td><td>Type A</td></tr>
<tr><td>1</td><td colspan="2">Type A</td><td>Type A</td></tr>
</table>

Table 4 : Thickness of toughened glasses in rectangular windows

Nominal size (clear light) of rectangular window, in mm^2	Thickness, in mm		Total minimum of closing appliances of openingtype rectangular windows **(1)**
	Unexposed zone of first tier, exposed zone of second tier	Unexposed zone of second tier, exposed zone of third tier and above	
300 x 425	10	8	4
355 x 500	10	8	4
400 x 560	12	8	4
450 x 630	12	8	4
500 x 710	15	10	6
560 x 800	15	10	6
900 x 630	19	12	6
1000 x 710	19	12	8
1100 x 800	Not applicable	15	8

(1) Swing bolts and circular hole hinges of glass holders of opening type rectangular windows are considered as closing appliances.

3.4.5 Deckhouses on superstructures of less than standard height

Deckhouses situated on a raised quarterdeck or on a superstructure of less than standard height may be treated as being on the second tier as far as the provision of deadlights is concerned, provided the height of the raised quarterdeck or superstructure is not less than the standard quarterdeck height.

3.4.6 Openings protected by a deckhouse

Where an opening in a superstructure deck or in the top of a deckhouse on the main deck which gives access to a space below the main deck or to a space within an enclosed superstructure is protected by a deckhouse, then it is considered that only those sidescuttles fitted in spaces which give direct access to an open stairway need to be fitted with deadlights.

4 Discharges

4.1 Arrangement of discharges

4.1.1 Inlets and discharges

All inlets and discharges in the shell plating are to be fitted with efficient and accessible arrangements for preventing the accidental admission of water into the ship.

4.1.2 Inboard opening of ash-shoot, rubbish-shoot, etc.

The inboard opening of each ash-shoot, rubbish-shoot, etc. is to be fitted with an efficient cover.

If the inboard opening is situated below the bulkhead deck, the cover is to be watertight, and in addition an automatic non-return valve is to be fitted in the shoot in an easily accessible position above the waterline corresponding to the deepest draught. When the shoot is not in use, both the cover and the valve are to be kept closed and secured.

4.2 Arrangement of garbage chutes

4.2.1 Inboard end above the waterline

The inboard end is to be located above the waterline formed by an 8,5° heel, to port or starboard, at the deepest draught but not less than 1000 mm above the waterline corresponding to the deepest draught.

Where the inboard end of the garbage chute exceeds 0,01L above the waterline corresponding to the deepest draught, valve control from the main deck is not required, provided the inboard gate valve is always accessible under service conditions.

4.2.2 Inboard end below the waterline

Where the inboard end of a garbage chute is below the margin line then:

- the inboard end hinged cover/valve is to be watertight
- the valve is to be a screw-down non-return valve fitted in an easily accessible position above the waterline corresponding to the deepest draught
- the screw-down non-return valve is to be controlled from a position above the bulkhead deck and provided with open/shut indicators. The valve control is to be clearly marked: "Keep closed when not in use".

4.2.3 Gate valves

For garbage chutes, two gate valves controlled from the working deck of the chute may be accepted instead of a non-return valve with a positive means of closing it from a position above the main deck. In addition, the lower gate valve is to be controlled from a position above the main deck. An interlock system between the two valves is to be arranged.

The distance between the two gate valves is to be adequate to allow the smooth operation of the interlock system.

4.2.4 Hinged cover and discharge flap

The upper gate valve, as required in [4.2.3], may be replaced by a hinged weathertight cover at the inboard end of the chute together with a discharge flap which replaces the lower gate valve.

The cover and discharge flap are to be arranged with an interlock so that the flap cannot be operated until the hopper cover is closed.

4.2.5 Marking of valve and hinged cover

The gate valve controls and/or hinged cover are to be clearly marked: "Keep closed when not in use".

4.3 Scantlings of garbage chutes

4.3.1 Material

The chute is to be constructed of steel. Other equivalent materials are considered by the Society on a case by case basis.

4.3.2 Wall thickness

The wall thickness of the chute up to and including the cover is to be not less than that obtained, in mm, from Tab 5.

Table 5 : Wall thickness of garbage chutes

External diameter d, in mm	Thickness, in mm
$d \leq 80$	7,0
$80 < d < 180$	7,0 + 0,03 (d - 80)
$180 \leq d \leq 220$	10,0 + 0,063 (d - 180)

5 Freeing ports

5.1 General provisions

5.1.1 General

Where bulwarks on the weather portions of main or superstructure decks form wells, ample provision is to be made for rapidly freeing the decks of water and for draining them.

A well is any area on the deck exposed to the weather, where water may be entrapped. Wells are considered to be deck areas bounded on four sides by deck structures; however, depending on their configuration, deck areas bounded on three or even two sides by deck structures may be deemed wells.

5.1.2 Freeing port areas

The minimum required freeing port areas in bulwarks on the main deck are specified in Tab 6.

Table 6 : Freeing port area in bulwark located on main deck

Ship types or ship particulars	Area A of freeing ports, in m²	Applicable requirement
Ships fitted with a trunk included in freeboard calculation and/or breadth ≥ 0,6B	$0,33\ \ell_B\ h_B$	[5.3.1]
Ships fitted with continuous or substantially continuous trunk and/or hatch coamings	A_2	[5.3.1]
Ships fitted with non-continuous trunk and/or hatch coamings	A_3	[5.3.2]
Ships fitted with open superstructure	A_S for superstructures A_W for wells	[5.4.2] [5.4.3]
Other ships	A_1	[5.2.1]

Note 1:
ℓ_B : Length, in m, of bulwark in a well at one side of the ship
h_B : Mean height, in m, of bulwark in a well of length ℓ_B.

5.1.3 Freeing port arrangement

Where a sheer is provided, two thirds of the freeing port area required is to be provided in the half of the well nearer the lowest point of the sheer curve.

One third of the freeing port area required is to be evenly spread along the remaining length of the well.

Where the exposed main deck or an exposed superstructure deck has little or no sheer, the freeing port area is to be spread along the length of the well.

However, bulwarks may not have substantial openings or accesses near the breaks of superstructures, unless they are effectively detached from the superstructure sides.

5.1.4 Freeing port positioning

The lower edge of freeing ports is to be as near the deck as practicable, at not more than 100 mm above the deck.

All the openings in the bulwark are to be protected by rails or bars spaced approximately 230 mm apart.

5.1.5 Freeing port closures

If shutters or closures are fitted to freeing ports, ample clearance is to be provided to prevent jamming. Hinges are to have pins or bearings of non-corrodible material. If shutters are fitted with securing appliances, these appliances are to be of approved construction.

5.1.6 Gutter bars

Gutter bars greater than 300 mm in height fitted around the weather decks of tankers, in way of cargo manifolds and cargo piping, are to be treated as bulwarks. The freeing port area is to be calculated in accordance with the applicable requirements of this Section.

5.2 Freeing port area in a well not adjacent to a trunk or hatchways

5.2.1 Freeing port area

Where the sheer in way of the well is standard or greater than the standard, the freeing port area on each side of the ship for each well is to be not less than that obtained, in m², in Tab 7.

In ships with no sheer, the above area is to be increased by 50%. Where the sheer is less than the standard, the percentage of increase is to be obtained by linear interpolation.

Wells on raised quarterdecks are to be treated as being on main decks.

5.2.2 Minimum freeing port area for a deckhouse having breadth not less than 0,8 B

Where a flush deck ship is fitted amidships with a deckhouse having breadth not less than 0,8 B and the width of the passageways along the side of the ship less than 1,5 m, the freeing port area is to be calculated for two separate wells, before and abaft the deckhouse. For each of these wells, the freeing port area is to be obtained from Tab 7, where ℓ_B is to be taken equal to the actual length of the well considered (in this case the limitation $\ell_B \le 0{,}7$ L may not be applied).

5.2.3 Minimum freeing port area for screen bulkhead

Where a screen bulkhead is fitted across the full breadth of the ship at the fore end of a midship deckhouse, the weather deck is to be considered as divided into two wells, irrespective of the width of the deckhouse, and the freeing port area is to be obtained in accordance with [5.2.1].

Table 7 : Freeing port area in a well not adjacent to a trunk or hatchways

Location	Area A_1 of freeing ports, in m²	
	$\ell_B \le 20$	$\ell_B > 20$
main deck and raised quarterdecks	$0{,}7 + 0{,}035\ell_B + A_C$	$0{,}07\ell_B + A_C$
Superstructure decks	$0{,}35 + 0{,}0175\ell_B + 0{,}5A_C$	$0{,}035\ell_B + 0{,}5A_C$

Note 1:

ℓ_B : Length, in m, of bulwark in the well, to be taken not greater than 0,7 L

A_C : Area, in m², to be taken, with its sign, equal to:

$$A_C = \frac{\ell_W}{25}(h_B - 1{,}2) \qquad \text{for } h_B > 1{,}2$$

$$A_C = 0 \qquad \text{for } 0{,}9 \le h_B \le 1{,}2$$

$$A_C = \frac{\ell_W}{25}(h_B - 0{,}9) \qquad \text{for } h_B < 0{,}9$$

h_B : Mean height, in m, of the bulwark in a well of length ℓ_B.

5.3 Freeing port area in a well contiguous to a trunk or hatchways

5.3.1 Freeing area for continuous trunk or continuous hatchway coaming

Where the ship is fitted with a continuous trunk not included in the calculation of damage stability or where continuous or substantially continuous hatchway side coamings are fitted between detached superstructures, the freeing port area is to be not less than that obtained, in m², from Tab 8.

Table 8 : Freeing port area in a well contiguous to a continuous trunk or hatchways

Breadth B_H, in m, of hatchway or trunk	Area A_2 of freeing ports, in m²
$B_H \le 0{,}4B$	$0{,}2\ \ell_B\ h_B$
$0{,}4B < B_H < 0{,}75B$	$\left[0{,}2 - 0{,}286\left(\frac{B_H}{B} - 0{,}4\right)\right]\ell_B h_B$
$B_H \ge 0{,}75B$	$0{,}1\ \ell_B\ h_B$

Note 1:

ℓ_B : Length, in m, of bulwark in a well at one side of the ship

h_B : Mean height, in m, of bulwark in a well of length ℓ_B.

Where the ship is fitted with a continuous trunk having breadth not less than 0,6 B, included in the calculation of damage stability, and where open rails on the weather parts of the main deck in way of the trunk for at least half the length of these exposed parts are not fitted, the freeing port area in the well contiguous to the trunk is to be not less than 33% of the total area of the bulwarks.

5.3.2 Freeing area for non-continuous trunk or hatchway coaming

Where the free flow of water across the deck of the ship is impeded due to the presence of a non-continuous trunk, hatchway coaming or deckhouse in the whole length of the well considered, the freeing port area in the bulwark of this well is to be not less than that obtained, in m², from Tab 9.

5.4 Freeing port area in an open space within superstructures

5.4.1 General

In ships having superstructures on the freeboard or superstructure decks, which are open at either or both ends to wells formed by bulwarks on the open decks, adequate provision for freeing the open spaces within the superstructures is to be provided.

Table 9 : Freeing port area in a well contiguous to non-continuous trunk or hatchways

Free flow area f_P, in m²	Freeing port area A_3, in m²
$f_P \leq A_1$	A_2
$A_1 < f_P < A_2$	$A_1 + A_2 - f_P$
$f_P \geq A_2$	A_1

Note 1:

f_P : Free flow area on deck, equal to the net area of gaps between hatchways, and between hatchways and superstructures and deckhouses up to the actual height of the bulwark

A_1 : Area of freeing ports, in m², to be obtained from Tab 6

A_2 : Area of freeing ports, in m², to be obtained from Tab 7.

5.4.2 Freeing port area for open superstructures

The freeing port area on each side of the ship for the open superstructure is to be not less than that obtained, in m², from the following formula:

$$A_S = A_1 c_{SH}\left[1 - \left(\frac{\ell_W}{\ell_T}\right)^2\right]\left(\frac{b_0 h_S}{2\,\ell_T h_W}\right)$$

where:

ℓ_T : Total well length, in m, to be taken equal to:

$\ell_T = \ell_W + \ell_S$

ℓ_W : Length, in m, of the open deck enclosed by bulwarks

ℓ_S : Length, in m, of the common space within the open superstructures

A_1 : Freeing port area, in m², required for an open well of length ℓ_T, in accordance with Tab 6, where A_C is to be taken equal to zero

c_{SH} : Coefficient which accounts for the absence of sheer, if applicable, to be taken equal to:

c_{SH} = 1,0 in the case of standard sheer or sheer greater than standard sheer

c_{SH} = 1,5 in the case of no sheer

b_0 : Breadth, in m, of the openings in the end bulkhead of enclosed superstructures

h_S : Standard superstructure height, in m, defined in [1.2.1]

h_W : Distance, in m, of the well deck above the main deck.

5.4.3 Freeing port area for open well

The freeing port area on each side of the ship for the open well is to be not less than that obtained, in m², from the following formula:

$$A_W = A_1 c_{SH}\left(\frac{h_S}{2\,h_W}\right)$$

A_1 : Freeing port area, in m², required for an open well of length ℓ_W, in accordance with Tab 7

c_{SH}, h_S, h_W, ℓ_W:Defined in [5.4.2].

The resulting freeing port areas for the open superstructure A_S and for the open well A_W are to be provided along each side of the open space covered by the open superstructure and each side of the open well, respectively.

6 Machinery space openings

6.1 Engine room skylights

6.1.1 Engine room skylights in positions 1 or 2 are to be properly framed, securely attached to the deck and efficiently enclosed by steel casings of suitable strength. Where the casings are not protected by other structures, their strength will be considered by the Society on a case by case basis.

6.2 Closing devices

6.2.1 Machinery casings

Openings in machinery space casings in positions 1 or 2 are to be fitted with doors of steel or other equivalent materials, permanently and strongly attached to the bulkhead, and framed, stiffened and fitted so that the whole structure is of equivalent strength to the unpierced bulkhead and weathertight when closed. The doors are to be capable of being operated from both sides and generally to open outwards to give additional protection against wave impact.

Other openings in such casings are to be fitted with equivalent covers, permanently attached in their proper position.

6.2.2

Machinery casings are to be protected by an enclosed poop or bridge of at least standard height, or by a deckhouse of equal height and equivalent strength, provided that machinery casings may be exposed if there are no openings giving direct access from the main deck to the machinery spaces.

However, a weathertight door is permitted in the machinery casing, provided that it leads to a space or passageway which is as strongly constructed as the casing and is separated from the stairway to the engine room by a second weathertight door of steel or other equivalent material.

6.2.3 Height of the sill of the door

The height of the sill of the door is to be not less than:

- 600 mm above the deck if in position 1
- 380 mm above the deck if in position 2
- 230 mm in all other cases.

6.2.4 Double doors

Where casings are not protected by other structures, double doors (i.e. inner and outer doors) are required. An inner sill of 230 mm in conjunction with the outer sill of 600 mm is to be provided.

6.2.5 Fiddly openings

Fiddly openings are to be fitted with strong covers of steel or other equivalent material permanently attached in their proper positions and capable of being secured weathertight.

6.3 Coamings

6.3.1

Coamings of any fiddly, funnel or machinery space ventilator in an exposed position on the main deck or superstructure deck are to be as high above the deck as is reasonable and practicable.

In general, ventilators necessary to continuously supply the machinery space and, on demand, the emergency generator room are to have coamings whose height is in compliance with [8.1.2], but need not be fitted with weathertight closing appliances.

Ventilators necessary to continuously supply the emergency generator room, if this is considered buoyant in the stability calculations or protecting an opening leading below, are to have coamings of sufficient height to comply with [8.1.2], without having to fit weathertight closing appliances.

Where, due to the ship's size and arrangement, this is not practicable, lesser heights for machinery space and emergency generator room ventilator coamings, fitted with weathertight closing appliances in accordance with [8.1.3] or [8.1.4], may be permitted by the Society in combination with other suitable arrangements to ensure an uninterrupted, adequate supply of ventilation to these spaces.

7 Companionway

7.1 General

7.1.1 Openings in main deck

Openings in main deck other than hatchways, machinery space openings, manholes and flush scuttles are to be protected by an enclosed superstructure or by a deckhouse or companionway of equivalent strength and weathertightness.

7.1.2 Openings in superstructures

Openings in an exposed superstructure deck or in the top of a deckhouse on the main deck which give access to a space below the main deck or a space within an enclosed superstructure are to be protected by an efficient deckhouse or companionway.

7.1.3 Openings in superstructures having height less than standard height

Openings in the top of a deckhouse on a raised quarterdeck or superstructure of less than standard height, having a height equal to or greater than the standard quarterdeck height are to be provided with an acceptable means of closing but need not be protected by an efficient deckhouse or companionway provided the height of the deckhouse is at least the height of the superstructure.

7.2 Scantlings

7.2.1 Companionways on exposed decks protecting openings leading into enclosed spaces are to be of steel and strongly attached to the deck and are to have adequate scantlings.

7.3 Closing devices

7.3.1 Doors

Doorways in deckhouses or companionways leading to or giving access to spaces below the main deck or to enclosed superstructures are to be fitted with weathertight doors. The doors are to be made of steel, to be capable of being operated from both sides and generally to open outwards to give additional protection against wave impact.

Alternatively, if stairways within a deckhouse are enclosed within properly constructed companionways fitted with weathertight doors, the external door need not be watertight.

Where the closing appliances of access openings in superstructures and deckhouses are not weathertight, interior deck openings are to be considered exposed, i.e. situated in the open deck.

7.3.2 Height of sills

The height above the deck of sills to the doorways in companionways is to be not less than:

- 600 mm in position 1
- 380 mm in position 2.

Where access is not provided from above, the height of the sills to doorways in a poop bridge or deckhouse on the main deck is to be 600 mm.

Where access is provided to spaces inside a bridge or poop from the deck as an alternative to access from the main deck, the height of the sills into the bridge or poop is to be 380 mm. This also applies to deckhouses on the main deck.

8 Ventilators

8.1 Closing appliances

8.1.1 General

Ventilator openings are to be provided with efficient weathertight closing appliances of steel or other equivalent material.

8.1.2 Closing appliance exemption

Ventilators need not be fitted with closing appliances, unless specifically required by the Society, if the coamings extend for more than:

- 4,5 m above the deck in position 1
- 2,3 m above the deck in position 2.

8.1.3 Closing appliances for ships of not more than 100 m in length

In ships of not more than 100 m in length, the closing appliances are to be permanently attached to the ventilator coamings.

8.1.4 Closing appliances for ships of more than 100 m in length

Where, in ships of more than 100 m in length, the closing appliances are not permanently attached, they are to be conveniently stowed near the ventilators to which they are to be fitted.

8.1.5 Ventilation of machinery spaces and emergency generator room

In order to satisfactorily ensure, in all weather conditions:

- the continuous ventilation of machinery spaces,
- and, when necessary, the immediate ventilation of the emergency generator room,

the ventilators serving such spaces are to comply with [8.1.2], i.e. their openings are to be so located that they do not require closing appliances.

8.1.6 Reduced height of ventilator coamings for machinery spaces and emergency generator room

Where, due to the ship's size and arrangement, the requirements in [8.1.5] are not practicable, lesser heights may be accepted for machinery space and emergency generator room ventilator coamings fitted with weathertight closing appliances in accordance with [8.1.1], [8.1.3] and [8.1.4] in combination with other suitable arrangements, such as separators fitted with drains, to ensure an uninterrupted, adequate supply of ventilation to these spaces.

8.1.7 Closing arrangements of ventilators led overboard or through enclosed superstructures

Closing arrangements of ventilators led overboard to the ship side or through enclosed superstructures are considered by the Society on a case by case basis. If such ventilators are led overboard more than 4,5 m above the main deck, closing appliances may be omitted provided that satisfactory baffles and drainage arrangements are fitted.

8.2 Coamings

8.2.1 General

Ventilators in positions 1 or 2 to spaces below main decks or decks of enclosed superstructures are to have coamings of steel or other equivalent material, substantially constructed and efficiently connected to the deck.

Ventilators passing through superstructures other than enclosed superstructures are to have substantially constructed coamings of steel or other equivalent material at the main deck.

8.2.2 Scantlings

The scantlings of ventilator coamings exposed to the weather are to be not less than those obtained from Tab 10.

In exposed locations or for the purpose of compliance with buoyancy calculations, the height of coamings may be required to be increased to the satisfaction of the Society.

Table 10 : Scantlings of ventilator coamings

Feature	Scantlings
Height of the coaming, in mm, above the deck	h = 900 in position 1 h = 760 in position 2
Thickness of the coaming, in mm **(1)**	$t = 5,5 + 0,01\ d_V$ with $7,5 \le t \le 10,0$
Support	If h > 900 mm, the coaming is to be suitably stiffened or supported by stays.
(1) Where the height of the ventilator exceeds the height h, the thickness of the coaming may be gradually reduced, above that height, to a minimum of 6,5 mm. **Note 1:** d_V : Internal diameter of the ventilator, in mm.	

8.3 Strength check of ventilators subject to green sea loads

8.3.1 Application

The requirements in [8.3] apply to strength checks of the ventilator pipes and their closing devices located within the forward quarter length of the ship, for ships of length 80 m or more, where the height of the exposed deck in way of the item is less than 0,1L or 22 m above the waterline corresponding to the deepest draught, whichever is the lesser.

8.3.2 Green sea loads

The green sea pressure p acting on ventilator pipes and their closing devices is to be obtained, in kN/m, from the following formula:

$$p = 0{,}5\rho V^2 C_d C_s C_p$$

where:

- ρ : density, t/m³, of sea water, to be taken equal to 1,025 t/m³
- V : velocity, in m/s, of water over the fore deck, to be taken equal to 13,5 m/sec
- C_d : shape coefficient:
  - C_d= 0,5 for pipes
  - C_d= 1,3 for ventilator heads in genera
  - C_d= 0,8 for a ventilator head of cylindrical form with its axis in the vertical direction
- C_s : slamming coefficient, to be taken equal to 3,2
- C_p : protection coefficient:
  - C_p : 0,7 for pipes and ventilator heads located immediately behind a breakwater or forecastle,
  - C_p : 1,0 elsewhere and immediately behind a bulwark.

8.3.3 Green sea forces

Forces acting in the horizontal direction on the ventilator and its closing device are to be calculated from [8.3.2]using the largest projected area of each component.

8.3.4 Strength requirements

Bending moments and stresses in ventilator pipes are to be calculated at the following critical positions:

- at penetration pieces
- at weld or flange connections
- at toes of supporting brackets.

Bending stresses in the net section are to be equal to or less than 0,8 R_{eH}, where R_{eH} is the minimum yield stress or 0,2% proof stress, in N/mm^2, of the steel at room temperature, defined in Ch 4, Sec 1, [2]. Irrespective of corrosion protection, a corrosion addition equal to 2.0 mm is then to be applied to the net scantling.

Pipe thicknesses and bracket heights are to be obtained from Tab 11, for standard ventilators of 900 mm height closed by heads having projected area not greater than the one specified in Tab 11.

Where brackets are required, three or more radial brackets are to be fitted. Brackets thickness is to be not less than 8 mm, bracket length is to be not less than 100 mm and bracket height is to be obtained from Tab 11, but need not extend over the joint flange for the head. Bracket toes at the deck are to be suitably supported.

For ventilators of height greater than 900 mm, brackets or alternative means of support are to be fitted. Pipe thickness is not to be taken less than that specified in Pt C, Ch 1, Sec 10, [9.1.8] a).

All component parts and connections of ventilators are to be capable of withstanding the loads defined in [8.3.2].

Rotating type mushroom ventilator heads are deemed not suitable for application in the areas defined in [8.3.1].

9 Tank cleaning openings

9.1 General

9.1.1 Ullage plugs, sighting ports and tank cleaning openings may not be arranged in enclosed spaces.

10 Closure of chain lockers

10.1 General

10.1.1 *(1/1/2017)*

Spurling pipes and chain lockers are to be watertight up to the weather deck.

Bulkheads between separate chain lockers (see Fig 2), or which form a common boundary of chain lockers (see Fig 3), need not however be watertight.

Where means of access is provided, it is to be closed by a substantial cover and secured by closely spaced bolts.

Where a means of access to spurling pipes or cable lockers is located below the weather deck, the access cover and its securing arrangements are to be in accordance with recognised standards (e.g. ISO 5894-1999 or equivalent) for watertight manhole covers. Butterfly nuts and/or hinged bolts are prohibited as the securing mechanism for the access cover.

Table 11 : 900 mm Ventilator Pipe Thickness and Bracket Standards

Nominal pipe diameter (mm)	Minimum fitted gross thickness LL 36(c) (mm)	Maximum projected area of head (cm^2)	Height of brackets (mm)
80A	6.3	-	
100A	7.0	-	
150A	8.5	-	
200A	8.5	550	-
250A	8.5	880	-
300A	8.5	1200	-
350A	8.5	2000	-
400A	8.5	2700	-
450A	8.5	3300	-
500A	8.5	4000	-
Note 1: For other ventilator heights, the relevant requirements in [8.3.4] are to be applied.			

Spurling pipes through which anchor chains are led are to be provided with permanently attached closing appliances to minimise water ingress.

Figure 2 : Separate chain lockers

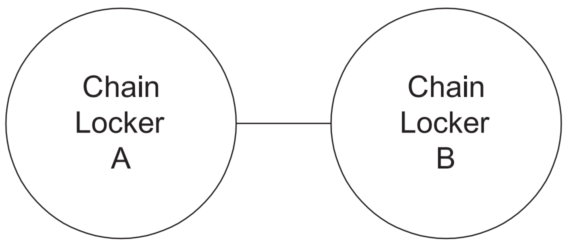
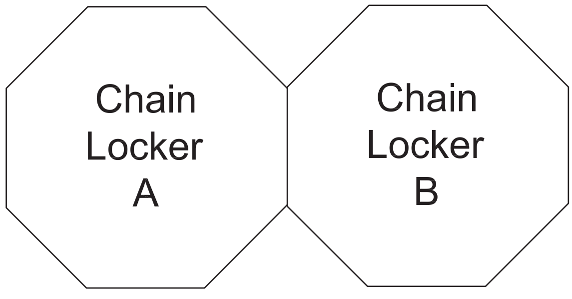


Figure 3 : Chain locker with a common boundary



SECTION 10 HELICOPTER DECKS

1 General

1.1 Application

1.1.1 *(1/1/2017)*

For the scantling of Helicopter decks see Additional Class Notation **HELICOPTER**, Pt E, Ch 4, Sec 2.