



Buckling Assessment of Plated Structures

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**Rule Note
NI 615 DT R02 E**

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VERITAS**

MARINE & OFFSHORE - GENERAL CONDITIONS

1. INDEPENDENCY OF THE SOCIETY AND APPLICABLE TERMS

- 1.1. The Society shall remain at all times an independent contractor and neither the Society nor any of its officers, employees, servants, agents or subcontractors shall be or act as an employee, servant or agent of any other party hereto in the performance of the Services.
- 1.2. The operations of the Society in providing its Services are exclusively conducted by way of random inspections and do not, in any circumstances, involve monitoring or exhaustive verification.
- 1.3. The Society acts as a services provider. This cannot be construed as an obligation bearing on the Society to obtain a result or as a warranty. The Society is not and may not be considered as an underwriter, broker in Unit's sale or chartering, expert in Unit's valuation, consulting engineer, controller, naval architect, manufacturer, shipbuilder, repair or conversion yard, charterer or shipowner; none of them above listed being relieved of any of their expressed or implied obligations as a result of the interventions of the Society.
- 1.4. The Services are carried out by the Society according to the applicable Rules and to the Bureau Veritas Code of Ethics. The Society only is qualified to apply and interpret its Rules.
- 1.5. The Client acknowledges the latest versions of the Conditions and of the applicable Rules applying to the Services' performance.
- 1.6. Unless an express written agreement is made between the Parties on the applicable Rules, the applicable Rules shall be the rules applicable at the time of the Services' performance and contract's execution.
- 1.7. The Services' performance is solely based on the Conditions. No other terms shall apply whether express or implied.

2. DEFINITIONS

- 2.1. "Certificate(s)" means class certificates, attestations and reports following the Society's intervention. The Certificates are an appraisal given by the Society to the Client, at a certain date, following surveys by its surveyors on the level of compliance of the Unit to the Society's Rules or to the documents of reference for the Services provided. They cannot be construed as an implied or express warranty of safety, fitness for the purpose, seaworthiness of the Unit or of its value for sale, insurance or chartering.
- 2.2. "Certification" means the activity of certification in application of national and international regulations or standards, in particular by delegation from different governments that can result in the issuance of a certificate.
- 2.3. "Classification" means the classification of a Unit that can result or not in the issuance of a class certificate with reference to the Rules.
- 2.4. "Client" means the Party and/or its representative requesting the Services.
- 2.5. "Conditions" means the terms and conditions set out in the present document.
- 2.6. "Industry Practice" means International Maritime and/or Offshore industry practices.
- 2.7. "Intellectual Property" means all patents, rights to inventions, utility models, copyright and related rights, trade marks, logos, service marks, trade dress, business and domain names, rights in trade dress or get-up, rights in goodwill or to sue for passing off, unfair competition rights, rights in designs, rights in computer software, database rights, topography rights, moral rights, rights in confidential information (including know-how and trade secrets), methods and protocols for Services, and any other intellectual property rights, in each case whether capable of registration, registered or unregistered and including all applications for and renewals, reversions or extensions of such rights, and all similar or equivalent rights or forms of protection in any part of the world.
- 2.8. "Parties" means the Society and Client together.
- 2.9. "Party" means the Society or the Client.
- 2.10. "Register" means the register published annually by the Society.
- 2.11. "Rules" means the Society's classification rules, guidance notes and other documents. The Rules, procedures and instructions of the Society take into account at the date of their preparation the state of currently available and proven technical minimum requirements but are not a standard or a code of construction neither a guide for maintenance, a safety handbook or a guide of professional practices, all of which are assumed to be known in detail and carefully followed at all times by the Client.
- 2.12. "Services" means the services set out in clauses 2.2 and 2.3 but also other services related to Classification and Certification such as, but not limited to: ship and company safety management certification, ship and port security certification, training activities, all activities and duties incidental thereto such as documentation on any supporting means, software, instrumentation, measurements, tests and trials on board.
- 2.13. "Society" means the classification society 'Bureau Veritas Marine & Offshore SAS', a company organized and existing under the laws of France, registered in Nanterre under the number 821 131 844, or any other legal entity of Bureau Veritas Group as may be specified in the relevant contract, and whose main activities are Classification and Certification of ships or offshore units.
- 2.14. "Unit" means any ship or vessel or offshore unit or structure of any type or part of it or system whether linked to shore, river bed or sea bed or not, whether operated or located at sea or in inland waters or partly on land, including submarines, hovercrafts, drilling rigs, offshore installations of any type and of any purpose, their related and ancillary equipment, subsea or not, such as well head and pipelines, mooring legs and mooring points or otherwise as decided by the Society.

3. SCOPE AND PERFORMANCE

- 3.1. The Society shall perform the Services according to the applicable national and international standards and Industry Practice and always on the assumption that the Client is aware of such standards and Industry Practice.

3.2. Subject to the Services performance and always by reference to the Rules, the Society shall:

- review the construction arrangements of the Unit as shown on the documents provided by the Client;
- conduct the Unit surveys at the place of the Unit construction;
- class the Unit and enters the Unit's class in the Society's Register;
- survey the Unit periodically in service to note that the requirements for the maintenance of class are met. The Client shall inform the Society without delay of any circumstances which may cause any changes on the conducted surveys or Services.

The Society will not:

- declare the acceptance or commissioning of a Unit, nor its construction in conformity with its design, such activities remaining under the exclusive responsibility of the Unit's owner or builder;
- engage in any work relating to the design, construction, production or repair checks, neither in the operation of the Unit or the Unit's trade, neither in any advisory services, and cannot be held liable on those accounts.

4. RESERVATION CLAUSE

- 4.1. The Client shall always: (i) maintain the Unit in good condition after surveys; (ii) present the Unit after surveys; (iii) present the Unit for surveys; and (iv) inform the Society in due course of any circumstances that may affect the given appraisal of the Unit or cause to modify the scope of the Services.
- 4.2. Certificates referring to the Society's Rules are only valid if issued by the Society.
- 4.3. The Society has entire control over the Certificates issued and may at any time withdraw a Certificate at its entire discretion including, but not limited to, in the following situations: where the Client fails to comply in due time with instructions of the Society or where the Client fails to pay in accordance with clause 6.2 hereunder.

5. ACCESS AND SAFETY

- 5.1. The Client shall give to the Society all access and information necessary for the efficient performance of the requested Services. The Client shall be the sole responsible for the conditions of presentation of the Unit for tests, trials and surveys and the conditions under which tests and trials are carried out. Any information, drawings, etc. required for the performance of the Services must be made available in due time.
- 5.2. The Client shall notify the Society of any relevant safety issue and shall take all necessary safety-related measures to ensure a safe work environment for the Society or any of its officers, employees, servants, agents or subcontractors and shall comply with all applicable safety regulations.

6. PAYMENT OF INVOICES

- 6.1. The provision of the Services by the Society, whether complete or not, involve, for the part carried out, the payment of fees thirty (30) days upon issuance of the invoice.
- 6.2. Without prejudice to any other rights hereunder, in case of Client's payment default, the Society shall be entitled to charge, in addition to the amount not properly paid, interests equal to twelve (12) months LIBOR plus two (2) per cent as of due date calculated on the number of days such payment is delinquent. The Society shall also have the right to withhold certificates and other documents and/or to suspend or revoke the validity of certificates.
- 6.3. In case of dispute on the invoice amount, the undisputed portion of the invoice shall be paid and an explanation on the dispute shall accompany payment so that action can be taken to solve the dispute.

7. LIABILITY

- 7.1. The Society bears no liability for consequential loss. For the purpose of this clause consequential loss shall include, without limitation:
 - Indirect or consequential loss;
 - Any loss and/or deferral of production, loss of product, loss of use, loss of bargain, loss of revenue, loss of profit or anticipated profit, loss of business and business interruption, in each case whether direct or indirect.

The Client shall save, indemnify, defend and hold harmless the Society from the Client's own consequential loss regardless of cause.

- 7.2. In any case, the Society's maximum liability towards the Client is limited to one hundred and fifty per-cents (150%) of the price paid by the Client to the Society for the performance of the Services. This limit applies regardless of fault by the Society, including breach of contract, breach of warranty, tort, strict liability, breach of statute.
- 7.3. All claims shall be presented to the Society in writing within three (3) months of the Services' performance or (if later) the date when the events which are relied on were first discovered by the Client. Any claim not so presented as defined above shall be deemed waived and absolutely time barred.

8. INDEMNITY CLAUSE

- 8.1. The Client agrees to release, indemnify and hold harmless the Society from and against any and all claims, demands, lawsuits or actions for damages, including legal fees, for harm or loss to persons and/or property tangible, intangible or otherwise which may be brought against the Society, incidental to, arising out of or in connection with the performance of the Services except for those claims caused solely and completely by the negligence of the Society, its officers, employees, servants, agents or subcontractors.

9. TERMINATION

- 9.1. The Parties shall have the right to terminate the Services (and the relevant contract) for convenience after giving the other Party thirty (30) days' written notice, and without prejudice to clause 6 above.

9.2. In such a case, the class granted to the concerned Unit and the previously issued certificates shall remain valid until the date of effect of the termination notice issued, subject to compliance with clause 4.1 and 6 above.

10. FORCE MAJEURE

10.1. Neither Party shall be responsible for any failure to fulfil any term or provision of the Conditions if and to the extent that fulfilment has been delayed or temporarily prevented by a force majeure occurrence without the fault or negligence of the Party affected and which, by the exercise of reasonable diligence, the said Party is unable to provide against.

10.2. For the purpose of this clause, force majeure shall mean any circumstance not being within a Party's reasonable control including, but not limited to: acts of God, natural disasters, epidemics or pandemics, wars, terrorist attacks, riots, sabotages, impositions of sanctions, embargoes, nuclear, chemical or biological contaminations, laws or action taken by a government or public authority, quotas or prohibition, expropriations, destructions of the worksite, explosions, fires, accidents, any labour or trade disputes, strikes or lockouts

11. CONFIDENTIALITY

11.1. The documents and data provided to or prepared by the Society in performing the Services, and the information made available to the Society, are treated as confidential except where the information:

- is already known by the receiving Party from another source and is properly and lawfully in the possession of the receiving Party prior to the date that it is disclosed;
- is already in possession of the public or has entered the public domain, otherwise than through a breach of this obligation;
- is acquired independently from a third party that has the right to disseminate such information;
- is required to be disclosed under applicable law or by a governmental order, decree, regulation or rule or by a stock exchange authority (provided that the receiving Party shall make all reasonable efforts to give prompt written notice to the disclosing Party prior to such disclosure).

11.2. The Society and the Client shall use the confidential information exclusively within the framework of their activity underlying these Conditions.

11.3. Confidential information shall only be provided to third parties with the prior written consent of the other Party. However, such prior consent shall not be required when the Society provides the confidential information to a subsidiary.

11.4. The Society shall have the right to disclose the confidential information if required to do so under regulations of the International Association of Classifications Societies (IACS) or any statutory obligations.

12. INTELLECTUAL PROPERTY

- 12.1. Each Party exclusively owns all rights to its Intellectual Property created before or after the commencement date of the Conditions and whether or not associated with any contract between the Parties.
- 12.2. The Intellectual Property developed for the performance of the Services including, but not limited to drawings, calculations, and reports shall remain exclusive property of the Society.

13. ASSIGNMENT

- 13.1. The contract resulting from these Conditions cannot be assigned or transferred by any means by a Party to a third party without the prior written consent of the other Party.
- 13.2. The Society shall however have the right to assign or transfer by any means the said contract to a subsidiary of the Bureau Veritas Group.

14. SEVERABILITY

14.1. Invalidity of one or more provisions does not affect the remaining provisions.

14.2. Definitions herein take precedence over other definitions which may appear in other documents issued by the Society.

14.3. In case of doubt as to the interpretation of the Conditions, the English text shall prevail.

15. GOVERNING LAW AND DISPUTE RESOLUTION

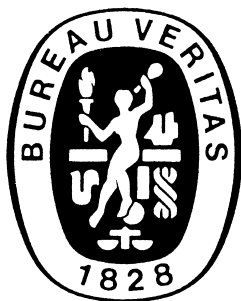
15.1. The Conditions shall be construed and governed by the laws of England and Wales.

15.2. The Society and the Client shall make every effort to settle any dispute amicably and in good faith by way of negotiation within thirty (30) days from the date of receipt by either one of the Parties of a written notice of such a dispute.

15.3. Failing that, the dispute shall finally be settled by arbitration under the LCIA rules, which rules are deemed to be incorporated by reference into this clause. The number of arbitrators shall be three (3). The place of arbitration shall be London (UK).

16. PROFESSIONAL ETHICS

- 16.1. Each Party shall conduct all activities in compliance with all laws, statutes, rules, and regulations applicable to such Party including but not limited to: child labour, forced labour, collective bargaining, discrimination, abuse, working hours and minimum wages, anti-bribery, anti-corruption. Each of the Parties warrants that neither it, nor its affiliates, has made or will make, with respect to the matters provided for hereunder, any offer, payment, gift or authorization of the payment of any money directly or indirectly, to or for the use or benefit of any official or employee of the government, political party, official, or candidate.
- 16.2. In addition, the Client shall act consistently with the Society's Code of Ethics of Bureau Veritas, <http://www.bureauveritas.com/home/about-us/ethics-and-compliance>



GUIDANCE NOTE NI 615

Buckling Assessment of Plated Structures

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SECTION 1

GENERAL

1 General

1.1 Application

1.1.1 This Guidance Note contains the strength criteria for buckling and ultimate strength of local supporting members, primary supporting members and other structures such as pillars, corrugated bulkheads and brackets.

1.1.2 This Guidance Note is to be applied for buckling of plated structures when it is referred to in the applicable Rules.

1.2 Assumption

1.2.1 For each structural member, the characteristic buckling strength is to be taken as the most unfavourable/critical buckling failure mode.

1.2.2 Unless otherwise specified, the scantling requirements of structural members in this Guidance Note are based on net scantling.

1.2.3 In this Guidance Note, compressive and shear stresses are to be taken as positive, tension stresses are to be taken as negative.

1.3 Scope

1.3.1 The buckling checks are to be performed according to:

- Sec 2 for the slenderness requirements of plates, longitudinal and transverse stiffeners, primary supporting members and brackets
- Sec 3 for the prescriptive buckling requirements of plates, longitudinal and transverse stiffeners, primary supporting members and other structures
- Sec 4 for the buckling requirements of the FE analysis for the plates, stiffened panels and other structures
- Sec 5 for the buckling capacity of prescriptive and FE buckling requirements.

1.3.2 Stiffeners

The buckling check of the stiffeners referred to in this Guidance Note is applicable to the stiffeners fitted along the long edge of the buckling panel.

1.3.3 Enlarged stiffeners

Enlarged stiffeners, with or without web stiffening, used for Permanent Means of Access (PMA) are to comply with the following requirements:

- a) slenderness requirements for primary supporting members:
 - for enlarged stiffener web, see Sec 2, [4.1.1], item a)
 - for enlarged stiffener flange, see Sec 2, [4.1.1], item b) and Sec 2, [5.1]
 - for stiffeners fitted on enlarged stiffener web, see Sec 2, [3.1.1].
- b) buckling strength of prescriptive requirements:
 - for enlarged stiffener web, see Sec 3, [3.2]
 - for stiffeners fitted on enlarged stiffener web, see Sec 3, [3.1] and Sec 3, [3.3].
- c) all structural elements used for PMA are to be complied with for the buckling requirements of the FE analysis in Sec 4 when applicable
- d) buckling strength of longitudinal PMA platforms without stiffeners fitted on enlarged stiffener web is to be checked using the criteria for local supporting members in Sec 3, [3.1] and Sec 3, [3.3].

2 Definitions

2.1 General

2.1.1 Buckling definition

‘Buckling’ is used as a generic term to describe the strength of structures, generally under in-plane compressions and/or shear and lateral loads. The buckling strength or capacity can take into account the internal redistribution of loads depending on the load situation, slenderness and type of structure.

2.1.2 Buckling capacity

Buckling capacity based on this principle gives a lower bound estimate of ultimate capacity, or the maximum load the panel can carry without suffering major permanent set.

Buckling capacity assessment utilises the positive elastic post-buckling effect for plates and accounts for load redistribution between the structural components, such as between plating and stiffeners. For slender structures, the capacity calculated using this method is typically higher than the ideal elastic buckling stress (minimum Eigen value). Accepting elastic buckling of structural components in slender stiffened panels implies that large elastic deflections and reduced in-plane stiffness will occur at higher buckling utilisation levels.

2.1.3 Assessment methods

The buckling assessment is carried out according to one of the two following methods, taking into account different boundary condition types:

- Method A:

All the edges of the elementary plate panel are forced to remain straight (but free to move in the in-plane directions) due to the surrounding structure/neighbouring plates. The elementary plate is integrated in the structure, which means that it is surrounded by plates that give a strong in plane support. A typical example is a double bottom girder supporting a longitudinal bulkhead.

- Method B:

The edges of the elementary plate panel are not forced to remain straight due to low in-plane stiffness at the edges and/or no surrounding structure/neighbouring plates. The elementary plate is not surrounded by plates which means that the in-plane support is weak. A typical example is a double bottom girder not supporting a longitudinal bulkhead.

2.2 Buckling utilisation factor

2.2.1 The utilisation factor η is defined as the ratio between the applied loads and the corresponding ultimate capacity or buckling strength.

2.2.2 For combined loads, the utilisation factor η_{act} is to be defined as the ratio of the applied equivalent stress and the corresponding buckling capacity, as shown in Fig 1, and is to be taken as:

$$\eta_{act} = \frac{W_{act}}{W_u} = \frac{1}{\gamma_c}$$

where:

W_{act} : Applied equivalent stress, in N/mm²:

- for plates:

$$W_{act} = \sqrt{\sigma_x^2 + \sigma_y^2 + \tau^2}$$

- for stiffeners:

$$W_{act} = \sigma_a + \sigma_b + \sigma_w$$

σ_x, σ_y : Membrane stresses, in N/mm², applied, respectively, in x direction and in y direction

τ : Membrane shear stress applied in xy plane, in N/mm²

σ_a : Actual stress in the stiffener, in N/mm², as defined in Sec 5, [2.3]

σ_b : Bending stress in the stiffener, in N/mm², as defined in Sec 5, [2.3]

σ_w : Warping stress in the stiffener, in N/mm², as defined in Sec 5, [2.3]

W_u : Equivalent buckling capacity, in N/mm², to be taken as:

- for plates:

$$W_u = \sqrt{\sigma_{cx}^2 + \sigma_{cy}^2 + \tau_c^2}$$

- for stiffeners:

$$W_u = \frac{R_{eH-S}}{S}$$

$\sigma_{cx}, \sigma_{cy}, \tau_c$: Critical stresses, in N/mm², defined in Sec 5, [2.2] for plates and in Sec 5, [2.3] for stiffeners

R_{eH-S} : Specified minimum yield stress of the stiffener, in N/mm²

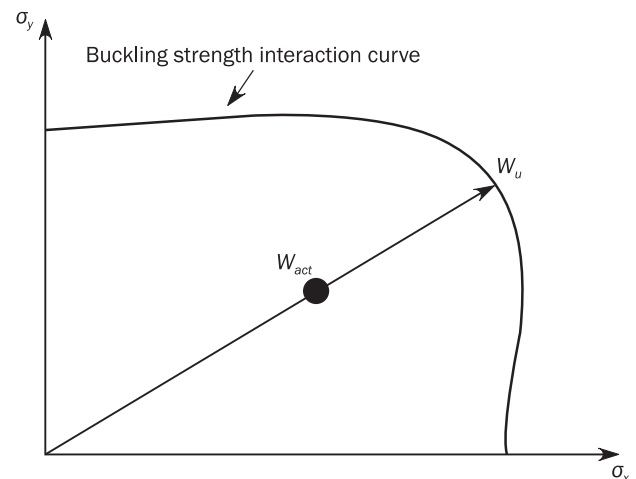
S : Partial safety factor, as defined in Sec 5

γ_c : Stress multiplier factor at failure.

For each typical failure mode, the corresponding capacity of the panel is calculated by applying the actual stress combination and then increasing or decreasing the stresses proportionally until collapse.

Fig 1 illustrates the buckling capacity and the buckling utilisation factor of a structural member subjected to σ_x and σ_y stresses.

Figure 1 : Example of buckling capacity and buckling utilisation factor



2.3 Allowable buckling utilisation factor

2.3.1 General structural elements

The allowable buckling utilisation factor η_{all} is defined in the applicable Rules.

2.4 Buckling acceptance criteria

2.4.1 A structural member is considered to have an acceptable buckling strength when it satisfies the following criterion:

$$\eta_{act} \leq \eta_{all}$$

where:

η_{act} : Buckling utilisation factor based on the applied stress, defined in [2.2.2]

η_{all} : Allowable buckling utilisation factor as defined in [2.3].

SECTION 2

SLENDERNESS REQUIREMENTS

Symbols

b_{f-out}	: Maximum distance, in mm, from mid-thickness of the web to the flange edge, as shown in Fig 1
b	: Breadth of the unstiffened part of the plating between stiffeners and/or primary supporting members, in mm
ℓ	: Span of stiffeners, in mm
s	: Stiffener spacing, in mm
h_w	: Depth of stiffener web, in mm, as shown in Fig 1
R_{eH}	: Specified minimum yield stress, in N/mm ²
ℓ_b	: Effective length of bracket edge, in mm, as defined in Tab 3
s_{eff}	: Effective width of stiffener attached plating, in mm, taken equal to: $s_{eff} = 0,8$
t_f	: Net thickness of stiffener flange, in mm
t_p	: Net thickness of plate, in mm
t_w	: Net thickness of stiffener web, in mm.

1 Structural elements

1.1 General

1.1.1 All the structural elements are to comply with the applicable slenderness and proportion requirements given in Articles [2] to [4].

2 Plates

2.1 Net thickness of plate panels

2.1.1 The net thickness of plate panels is to satisfy the following criterion:

$$t_p \geq \frac{b}{C} \sqrt{\frac{R_{eH}}{235}}$$

where:

- C : Slenderness coefficient taken as:
- $C = 100$ for hull envelope
 - $C = 125$ for the other structures.
- R_{eH} : Specified minimum yield stress of the plate material, in N/mm².

A lower specified minimum yield stress may be used in this slenderness criterion provided the requirements specified in Sec 3 and Sec 4 are satisfied for the strake assumed in the same lower specified minimum yield stress value.

This requirement does not apply to the bilge plates within the cylindrical part of the ship and radius gunwale.

3 Stiffeners

3.1 Proportions of stiffeners

3.1.1 Net thickness of all stiffener types

The net thickness of stiffeners is to satisfy the following criteria:

- a) Stiffener web plate:

$$t_w \geq \frac{h_w}{C_w} \sqrt{\frac{R_{eH}}{235}}$$

- b) Stiffener flange:

$$t_f \geq \frac{b_{f-out}}{C_f} \sqrt{\frac{R_{eH}}{235}}$$

where:

- C_w, C_f : Slenderness coefficients given in Tab 1.

3.1.2 Net dimensions of angle bars and T-bars

The total flange breadth b_f , in mm, for angle bars and T-bars is to satisfy the following criterion:

$$b_f \geq 0,25 h_w$$

Figure 1 : Stiffener scantling parameters

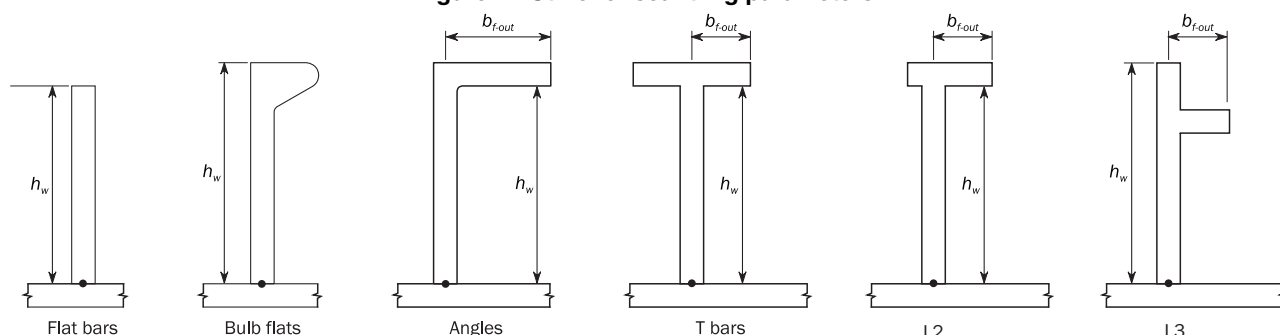


Table 1 : Slenderness coefficients C_w and C_f

Type of stiffeners	C _w	C _f
Angle, L2 and L3 bars	75	12
T-bars	75	12
Bulb bars	45	–
Flat bars	22	–

4 Primary supporting members

4.1 Proportions and stiffness

4.1.1 Proportions of web plates and flanges

The net thicknesses (web plate and flange) of primary supporting members are to satisfy the following criteria:

a) Web plates:

$$t_w \geq \frac{s_w}{C_w} \sqrt{\frac{R_{eH}}{235}}$$

b) Flanges:

$$t_f \geq \frac{b_{f-out}}{C_f} \sqrt{\frac{R_{eH}}{235}}$$

where:

- s_w : Plate breadth, in mm, taken as the spacing of the web stiffeners
- C_w : Slenderness coefficient for the web plates taken as C_w = 100
- C_f : Slenderness coefficient for the flanges taken as: C_f = 12

4.1.2 Stiffness of deck transverse primary supporting members

The net moment of inertia I_{psm-n50}, in cm⁴, of deck transverse primary members supporting deck longitudinals subject to axial compressive hull girder stress is to comply, within the

central half of the bending span, with the following criterion:

$$I_{psm-n50} \geq 300 \frac{\ell_{bdg}^4}{S^3} I_{st}$$

where:

- I_{psm-n50} : Net moment of inertia, in cm⁴, of deck transverse primary supporting members with an effective width of attached plating equal to 0,8 S
- ℓ_{bdg} : Effective bending span of deck transverse primary supporting members, in m, as defined in the applicable Rules
- S : Spacing of deck transverse primary supporting members, in m, as defined in the applicable Rules
- I_{st} : Net moment of inertia of deck stiffeners, in cm⁴, within the central half of the bending span, taken equal to:
$$I_{st} = 1,43 \ell^2 A_{eff} \frac{R_{eH}}{235}$$
- A_{eff} : Net sectional area of the stiffener, including its effective attached plating s_{eff}, in cm²
- R_{eH} : Specified minimum yield stress of the material of the stiffener attached plating, in N/mm².

4.2 Web stiffeners fitted on primary supporting members

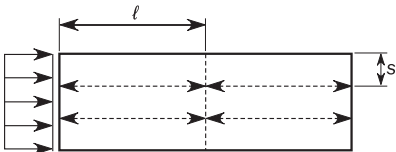
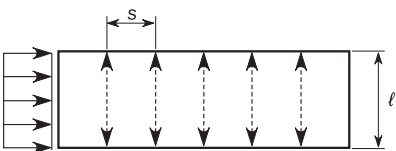
4.2.1 Proportions of web stiffeners

The net thicknesses (web plate and flange) and dimensions of the web stiffeners fitted on primary supporting members are to satisfy the requirements specified in [3.1.1] and [3.1.2].

4.2.2 Stiffness of web stiffeners

The net moment of inertia I_{st}, in cm⁴, of web stiffeners fitted on primary supporting members, with effective attached plating s_{eff}, is not to be less than the minimum moment of inertia defined in Tab 2.

Table 2 : Stiffness criteria for web stiffeners fitted on primary supporting members (PSM)

Stiffener arrangement		Minimum moment of inertia of web stiffeners, in cm ⁴
A		$I_{st} \geq 0,72 \ell^2 A_{eff} \frac{R_{eH}}{235}$
B		$I_{st} \geq 1,14 \ell s^2 t_w \left(2,5 \frac{1000 \ell}{s} - 2 \frac{s}{1000 \ell} \right) \frac{R_{eH}}{235} 10^{-5}$
Note 1: ℓ : Length of the web stiffeners, in m: - for web stiffeners welded to local supporting members, the length is to be measured between the flanges of the local support members - for sniped web stiffeners, the length is to be measured between the lateral supports, i.e. corresponds to the total distance between the flanges of the primary supporting member, as shown for stiffener arrangement B Note 2: A_{eff} : Net sectional area, in cm², of the web stiffener, including its effective attached plating s_{eff} t_w : Net web thickness of the primary supporting member, in mm R_{eH} : Specified minimum yield stress of the material of the web plate of the primary supporting member, in N/mm².		

5 Brackets

5.1 Tripping brackets

5.1.1 Unsupported flange length

The unsupported length of the flange of the primary supporting members, in m, i.e. the distance between tripping brackets, is to satisfy the following criterion:

$$S_b \leq \text{Max} \left(b_f C \sqrt{\frac{A_{f-n50}}{A_{f-n50} + \frac{A_{w-n50}}{3}}} \left(\frac{235}{R_{eH}} \right) ; S_{b-\text{min}} \right)$$

where:

- b_f : Flange breadth of primary supporting members, in mm
- C : Slenderness coefficient taken as:
 - $C = 0,022$ for symmetrical flanges
 - $C = 0,033$ for asymmetrical flanges
- A_{f-n50} : Net cross-sectional area of the flange, in cm^2
- A_{w-n50} : Net cross-sectional area of the web plate, in cm^2
- R_{eH} : Specified minimum yield stress of the PSM material, in N/mm^2
- $S_{b-\text{min}}$: Minimum unsupported flange length, in m, taken as:
 - $S_{b-\text{min}} = 3,0$ m for cargo tank/hold region, on tank/hold boundaries or on hull envelope including external decks
 - $S_{b-\text{min}} = 4,0$ m for the other areas.

5.1.2 Edge stiffening

The tripping brackets on primary supporting members are to be stiffened by a flange or an edge stiffener if the effective length of the edge ℓ_b , as defined in Tab 3, in mm, is greater than $75 t_b$, where:

- t_b : Net web thickness of the brackets, in mm.

5.2 End brackets

5.2.1 Proportions

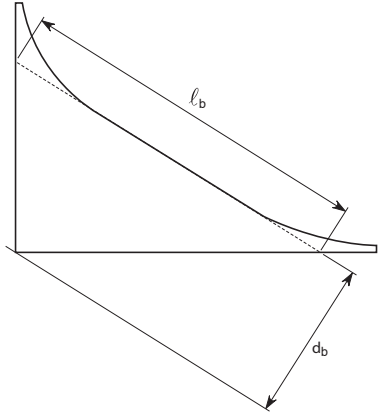
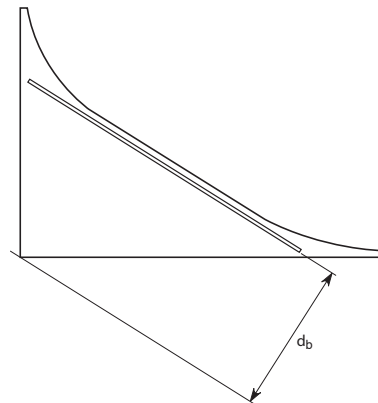
The net web thickness, in mm, of the end brackets subjected to compressive stresses is to satisfy the following criterion:

$$t_b \geq \frac{d_b}{C} \sqrt{\frac{R_{eH}}{235}}$$

where:

- d_b : Bracket depth, in mm, as defined in Tab 3
- C : Slenderness coefficient as defined in Tab 3
- R_{eH} : Specified minimum yield stress of the end bracket material, in N/mm^2 .

Table 3 : Slenderness coefficient C for proportions of brackets

Mode	C
Brackets without edge stiffener 	$C = 20 \left(\frac{d_b}{\ell_b} \right) + 16$ with: $0,25 \leq \frac{d_b}{\ell_b} \leq 1,0$
Brackets with edge stiffener 	$C = 70$

5.3 Edge reinforcement

5.3.1 Reinforcement of bracket edges

The web depth h_w , in mm, of the edge stiffeners in way of brackets is to satisfy the following criterion:

$$h_w \geq \text{Max} \left(C \ell_b \sqrt{\frac{R_{eH}}{235}} \cdot 10^{-3} ; 50 \right)$$

where:

- C : Slenderness coefficient, taken as:
 - $C = 75$ for end brackets
 - $C = 50$ for tripping brackets
- R_{eH} : Specified minimum yield stress of the stiffener material, in N/mm^2 .

5.3.2 Proportions of edge stiffeners

The net thicknesses (web plate and flange) and dimensions of the edge stiffeners are to satisfy the requirements specified in [3.1.1] and [3.1.2].

6 Other structures

6.1 Pillars

6.1.1 Proportions of I-section pillars

The net thicknesses (web plate and flanges) and dimensions of I-section pillars are to comply with the requirements specified in [3.1.1] and [3.1.2].

6.1.2 Proportions of box section pillars

The net thickness of thin-walled box section pillars is to comply with the requirements specified in [3.1.1], item a).

6.1.3 Proportions of circular section pillars

The net thickness t , in mm, of circular section pillars is to comply with the following criterion:

$$t \geq \frac{r}{50}$$

where:

r : Mid-thickness radius of the circular section, in mm.

6.2 Edge reinforcement in way of openings

6.2.1 Depth of edge stiffeners

When fitted as shown in Fig 2, the web depth h_w , in mm, of edge stiffeners in way of openings is to satisfy the following criterion:

$$h_w \geq \text{Max} \left(C \ell \sqrt{\frac{R_{eH}}{235}} ; 50 \right)$$

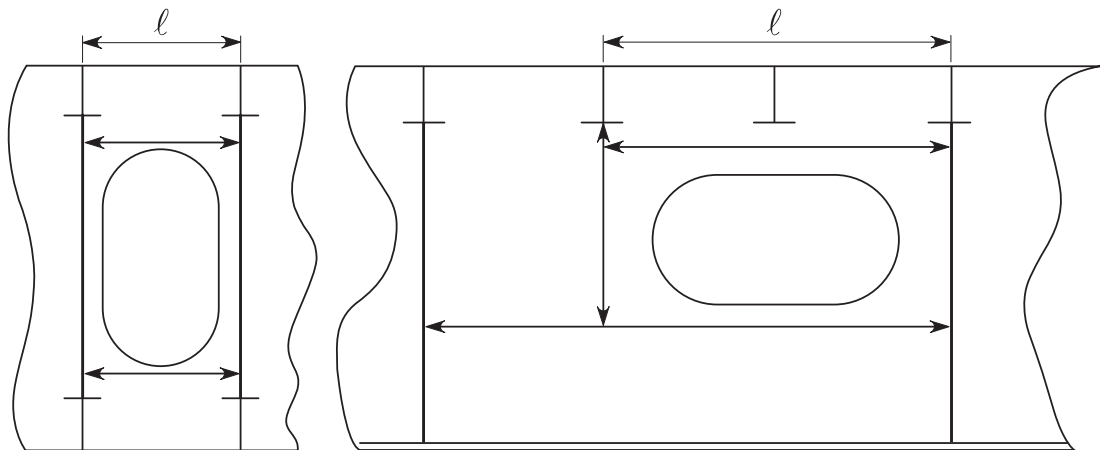
where:

- C : Slenderness coefficient taken as:
 $C = 50$
- R_{eH} : Specified minimum yield stress of the edge stiffener material, in N/mm².

6.2.2 Proportions of edge stiffeners

The net thicknesses (web plate and flange) and dimensions of the edge stiffeners are to satisfy the requirements specified in [3.1.1] and [3.1.2].

Figure 2 : Typical edge reinforcements



SECTION 3

PRESCRIPTIVE BUCKLING REQUIREMENTS

Symbols

- η_{all} : Allowable buckling utilisation factor, as defined in Sec 1, [2.3]
- EPP : Elementary Plate Panel, i.e. the unstiffened part of the plating between stiffeners and/or primary supporting members
- LCP : Load Calculation Point, as defined in the applicable Rules.

1 General

1.1 Scope

1.1.1 This Section applies to plate panels, including curved plate panels, and stiffeners subject to hull girder compression and shear stresses. In addition the following structural members subject to compressive stresses are to be checked:

- corrugations of transverse vertically corrugated bulkheads
- corrugations of longitudinal corrugated bulkheads
- struts
- pillars
- cross ties.

1.1.2 The hull girder buckling strength requirements apply along the full length of the ship.

1.1.3 Design load sets

The buckling checks are to be performed for all design load sets, with pressure combination defined in the applicable Rules.

For each design load set, and for all dynamic load cases, the lateral pressure is to be determined and applied at a load calculation point as described in the applicable Rules. It is to be applied together with the hull girder stress combinations given in [2.1].

1.2 Equivalent plate panel

1.2.1 In longitudinal stiffening arrangement, when the plate thickness varies over the width b of a plate panel, the buckling check is to be performed for an equivalent plate panel width, combined with the smaller plate thickness t_1 . The width b_{eq} of this equivalent plate panel, in mm, is defined by the following formula:

$$b_{eq} = \ell_1 + \ell_2 \left(\frac{t_1}{t_2} \right)^{1.5}$$

where:

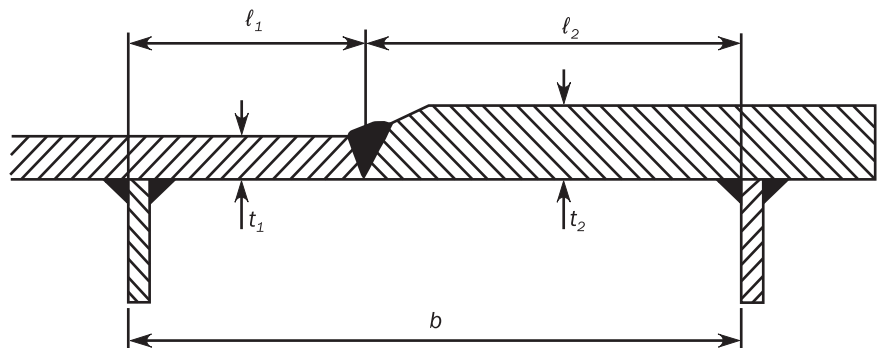
- ℓ_1 : Width of the part of the plate panel with the smaller net plate thickness t_1 , in mm, as defined in Fig 1
- ℓ_2 : Width of the part of the plate panel with the greater net plate thickness t_2 , in mm, as defined in Fig 1.

1.2.2 In transverse stiffening arrangement, when an EPP is made with different thicknesses, the buckling check of the plate and stiffeners is to be made for each thickness considered constant on the EPP, the stresses and pressures being estimated for the EPP at the LCP.

1.2.3 Materials

When the plate panel is made of different materials, the minimum yield strength is to be used for the buckling assessment.

Figure 1 : Plate thickness change over the width b



2 Hull girder stress

2.1 General

2.1.1 Each elementary plate panel and each stiffener are to satisfy the criteria defined in [3] with the following stress combinations:

a) Longitudinal stiffening arrangement:

$$\sigma_x = \sigma_{hg}$$

$$\sigma_y = 0$$

$$\tau = \tau_{hg}$$

b) Transverse stiffening arrangement:

$$\sigma_x = 0$$

$$\sigma_y = \sigma_{hg}$$

$$\tau = \tau_{hg}$$

where:

σ_{hg} : Hull girder bending stress, in N/mm², in the elementary plate panel or in the stiffener, determined according to the applicable Rules

τ_{hg} : Hull girder shear stress, in N/mm², in the elementary plate panel or in the stiffener attached plating, determined according to the applicable Rules.

3 Buckling criteria

3.1 Overall stiffened panels

3.1.1 The buckling strength of overall stiffened panels is to satisfy the following criterion:

$$\eta_{\text{Overall}} \leq \eta_{\text{all}}$$

where:

η_{Overall} : Maximum utilisation factor, as defined in Sec 5, [2.1].

3.2 Elementary plate panels

3.2.1 The buckling strength of elementary plate panels is to satisfy the following criterion:

$$\eta_{\text{Plate}} \leq \eta_{\text{all}}$$

where:

η_{Plate} : Maximum plate utilisation factor calculated according to SP-A, as defined in Sec 5, [2.2].

For the determination of η_{Plate} of the vertically stiffened side shell plating of single side skin ships between hopper and topside tanks, the cases 12 and 16 of Sec 5, Tab 4 corresponding to the shorter edge of the plate panel clamped are to be considered together with a mean σ_y stress and $\Psi_y=1$.

3.3 Stiffeners

3.3.1 The buckling strength of stiffeners is to satisfy the following criterion:

$$\eta_{\text{Stiffener}} \leq \eta_{\text{all}}$$

where:

$\eta_{\text{Stiffener}}$: Maximum stiffener utilisation factor, as defined in Sec 5, [2.3].

Note 1: This criterion check can only be fulfilled when the overall stiffened panel criterion, as defined in [3.1.1], is satisfied.

3.4 Vertically corrugated transverse and longitudinal bulkheads

3.4.1 The shear buckling strength of vertically corrugated transverse and longitudinal bulkheads is to satisfy the following criterion:

$$\eta_{\text{Shear}} \leq \eta_{\text{all}}$$

where:

η_{Shear} : Maximum shear corrugated bulkhead utilisation factor:

$$h_{\text{Shear}} = \frac{\tau_{\text{bhd}}}{\tau_c}$$

τ_{bhd} : Shear stress, in N/mm², in the bulkhead taken as:

- for longitudinal bulkheads: the hull girder shear stress defined in Article [2]
- for transverse bulkheads: the shear stress in the corrugation defined in the applicable Rules

τ_c : Shear critical stress, in N/mm², as defined in Sec 5, [2.2.3].

3.5 Horizontally corrugated longitudinal bulkheads

3.5.1 Each corrugation, within the extension of half flange, web and half flange, is to satisfy the following criterion:

$$\eta \leq \eta_{\text{all}}$$

where:

η : Overall column utilisation factor, as defined in Sec 5, [3.1].

3.6 Struts, pillars and cross ties

3.6.1 The compressive buckling strength of struts, pillars and cross ties is to satisfy the following criterion:

$$\eta \leq \eta_{\text{all}}$$

where:

η : Maximum buckling utilisation factor of struts, pillars or cross ties, as defined in Sec 5, [3.1].