Rules for Classification and Construction

I Ship Technology

2 Inland Navigation Vessels

2 Hull Design and Construction

Edition 2011

The following Rules come into force on 1 November 2011.

Alterations to the preceding Edition are marked by beams at the text margin.

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Table of Contents

Section 7 Hull Outfitting

Section 8 Construction and Testing

Section 1

General

A. General

1. Symbols and definitions

1.1 Symbols and units

1.1.1 Symbols

L = Rule length [m], defined in 1.2.1

B = breadth [m], defined in 1.2.2

D = depth [m], defined in 1.2.3

T = draught [m], defined in 1.2.4

Δ = displacement [t] at draught T

C_B = block coefficient

$$= \frac{\Delta}{L \cdot B \cdot T}$$

1.1.2 Units

Unless otherwise specified, the units used in the Rules are as indicated in Table 1.1.

Table 1.1 Units

Designation	Usual Symbol	Units
Vessel's dimensions	See 1.1.1	m
Hull girder section modulus	Z	cm^3
Density	ρ	t/m^3
Concentrated loads	P	kN
Linearly distributed loads	q	kN/m
Surface distributed loads (pressure)	p	kN/m^2
Thickness	t	mm
Span of ordinary stiffeners and primary supporting members	ℓ	m
Spacing of ordinary stiffeners and primary supporting members	s, S	m
Bending moment	M	kN·m
Stresses	σ, τ	N/mm^2
Section modulus of ordinary stiffeners and primary supporting members	w	cm^3
Sectional area of ordinary stiffeners and primary supporting members	A	cm^2
Vessel speed	V	km/h

1.2 Definitions

1.2.1 Rule length

The Rule length L is the distance [m] measured on the load waterline from the forward side of the stem to the after side of the rudder post, or to the centre of the rudder stock where there is no rudder post. L is to be not less than 96 % and need not exceed 97 % of the extreme length on the load waterline.

In the case of vessels having neither a rudder post (e.g. vessels fitted with azimuth thrusters) nor a rudder (e.g. pushed barges) the Rule length L is to be taken equal to the length of the load waterline.

In vessels with unusual stem or stern arrangements, the Rule length L is to be considered on a case-by-case basis.

1.2.2 Breadth

The breadth B is the greatest moulded breadth, measured amidships below the weather deck.

1.2.3 Depth

The depth D is the distance [m] measured vertically on the midship transverse section, from the base line to the top of the deck beam at side on the uppermost continuous deck.

1.2.4 Draught

The draught T is the distance [m] measured vertically on the midship transverse section, from the base line to the load waterline.

1.2.5 Ends of Rule length and midship

The fore end (FE) of the Rule length L, see Fig. 1.1, is the perpendicular to the load waterline at the forward side of the stem.

The aft end (AE) of the Rule length L, see Fig. 1.1, is the perpendicular to the waterline at a distance L aft of the fore end.

The midship is the perpendicular to the waterline at a distance 0,5·L aft of the fore end.

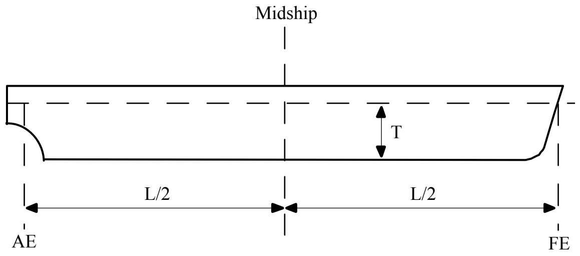


Fig. 1.1 Ends and midship

1.2.6 Superstructure

A superstructure is a decked structure connected to the strength deck defined in 1.2.8, extending from side to side of the vessel or with the side plating not being inboard of the shell plating more than 0,04·B.

1.2.7 Deckhouse

A deckhouse is a decked structure other than a superstructure, located on the strength deck defined in 1.2.8 or above.

1.2.8 Strength deck

The strength deck (main deck) is the uppermost continuous deck contributing to the hull girder longitudinal strength.

1.2.9 Weather deck

The weather deck is the uppermost continuous exposed deck.

1.2.10 Bulkhead deck

The bulkhead deck is the uppermost deck up to which the transverse watertight bulkheads and the shell are carried.

1.3 Vessel parts

1.3.1 General

For the purpose of application of the Rules, the vessel is considered as divided into the following four parts:

- fore part
- central part
- machinery space, where applicable
- aft part

1.3.2 Fore part

The fore part includes the structures of the stems and those:

- located in the part before the cargo zone in the case of vessels with a separated cargo zone (separated by bulkheads)
- located in the part extending over 0,1·L behind the stem in all other cases unless otherwise mentioned

1.3.3 Central part

The central part includes the structures within the greater of:

- the region extending over 0,5·L through the midship section
- the region located between the fore part and
  - the machinery space, if located aft
  - the aft part, otherwise

1.3.4 Aft part

The aft part includes the structures located aft of the after peak bulkhead.

1.4 Reference co-ordinate system

1.4.1 The vessel's geometry and loads are defined with respect to the following right-hand co-ordinate system (see Fig. 1.2)

- Origin: at the intersection among the longitudinal plane of symmetry of vessel, the aft end of L and the baseline
- X axis: longitudinal axis, positive forwards
- Y axis: transverse axis, positive towards portside
- Z axis: vertical axis, positive upwards

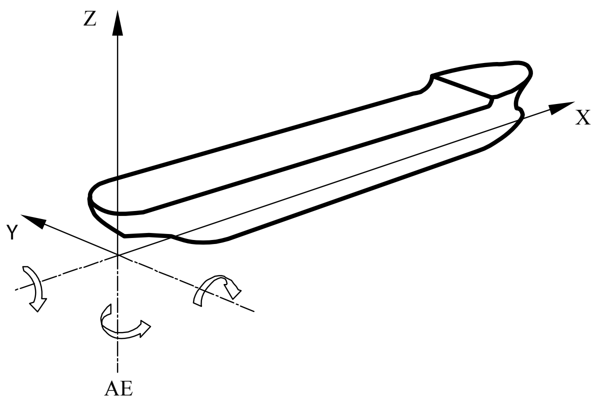


Fig. 1.2 Reference co-ordinate system

1.4.2 Positive rotations are oriented in anticlockwise direction about the X, Y and Z axes.

2. Application

2.1 Structural requirements

2.1.1 These Rules contain the requirements for determination of the minimum scantlings, applicable to all types of inland waterway displacement vessels, up to 135 m in length, of normal form, speed and proportions, made in welded steel construction.

2.1.2 The requirements of these Rules apply also to those steel vessels in which parts of the hull, e.g. superstructures or movable decks, are built in aluminium alloys.

2.1.3 Vessels with length exceeding 135 m, vessels whose hull materials are different than those mentioned in 2.1.1 and 2.1.2 and vessels with novel features or unusual hull design are to be individually considered by GL, on the basis of the principles and criteria adopted in the Rules.

2.1.4 High speed craft is to comply with applicable GL Rules.

Where the vessel speed exceeds 40 km/h, the safety guidelines defined by Statutory Regulations are to be considered.

2.2 Limits of application to lifting appliances

2.2.1 The fixed parts of lifting appliances, considered as an integral part of the hull, are the structures permanently connected by welding to the vessel's hull (for instance crane pedestals, masts, king posts, derrick heel seatings, etc., excluding cranes, derrick booms, ropes, rigging accessories, and, generally, any dismountable parts). The shrouds of masts embedded in the vessel's structure are considered as fixed parts.

2.2.2 The fixed parts of lifting appliances and their connections to the vessel's structure are covered by the Rules, even when the certification of lifting appliances is not required.

2.3 Rules applicable to various vessel parts

The various Sections and Letters of the Rules are to be applied for the scantlings of vessel parts according to Table 1.2.

2.4 Rules applicable to other vessel items

The various Sections and Letters of the Rules are to be applied for the scantlings of other vessel items according to Table 1.3.

Table 1.2 Rules applicable for the scantling of vessel parts

Part	Applicable Section and Letter	
	General	Specific
Fore part	Section 2 Section 3 Section 8	Section 6, A.
Central part L ≥ 40 m		Section 4 Section 5 Chapter 4
Central part L < 40 m		Section 5, F. Chapter 4
Aft part		Section 6, B.

Table 1.3 Rules applicable for the scantling of other items

Item	Applicable Section
Machinery space	Section 6, C.
Superstructures and deckhouses	Section 6, D.
Hatch covers	Section 6, E.
Movable decks and ramps	Section 6, F.
Arrangement for hull and superstructure openings	Section 6, G.
Rudders	Section 7, A.
Other hull outfitting	Section 7

B. Documentation for Review/Approval

1. Documentation to be submitted

1.1 Documentation to be submitted for all vessels

1.1.1 The plans and documents to be submitted to GL for review/approval are listed in Table 1.4

The above plans and documents are to be supplemented by further documentation which depends on the type and service notation and, possibly, the additional Class Notation assigned to the vessel.

Structural plans are to show details of connections of the various parts and, in general, are to specify the materials used, including their manufacturing processes, welding procedures and heat treatments.

1.1.2 GL reserves the right to ask for further documents and drawings considered necessary.

Irrespective of this, the Rules of construction also apply to components and details not shown in the submitted drawings.

1.1.3 Any deviation from reviewed/approved drawings is subject to GL's approval before work is commenced.

1.1.4 The application of GL's Construction Rules does not exclude any patent claims.

1.1.5 Plans and documents to be submitted for information

In addition to those in 1.1.1, the following plans and documents are to be submitted to GL for information:

– general arrangement

– capacity plan, indicating the volume and position of the centre of gravity of all compartments and tanks

– lines plan

– hydrostatic curves

– lightweight distribution

In addition, when direct calculation analyses are carried out by the designer according to the Rules requirements, they are to be submitted to GL.

Table 1.4 Plans and documents to be submitted for review/approval for all vessels

Plan or document	Containing also information on
Midship section Transverse sections Longitudinal sections Shell expansion Decks and profiles Double bottom Pillar arrangements Framing plan	Class characteristics Main dimensions Maximum draught Block coefficient for the length between perpendiculars at the maximum draught Frame spacing Contractual service speed Density of cargoes Setting pressure of safety relief valves, if any Assumed loading and unloading procedure Design loads on decks and double bottom Steel grades Location and height of air vent outlets of various compartments Corrosion protection Openings in decks and shell and relevant compensations Boundaries of flat areas in bottom and sides Details of structural reinforcements and/or discontinuities Details related to welding
Watertight subdivision bulkheads Watertight tunnels	Openings and their closing appliances, if any
Fore part structure	Location and height of air vent outlets of various compartments
Transverse thruster, if any, general arrangement, tunnel structure, connections of thruster with tunnel and hull structures	
Aft part structure	Location and height of air vent outlets of various compartments
Machinery space structures Foundations of propulsion machinery	Type, power and r.p.m. of propulsion machinery Mass and centre of gravity of machinery and boilers, if any Mass of liquids contained in the engine room
Superstructures and deckhouses Machinery space casing	Extension and mechanical properties of the aluminium alloy used (where applicable)
Hatch covers, if any	Design loads on hatch covers Sealing and securing arrangements, type and position of locking bolts Distance of hatch covers from the load waterline and from the fore end
Movable decks and ramps, if any	
Windows and side scuttles, arrangements and details	
Scuppers and sanitary discharges	
Bulwarks and freeing ports	Arrangement and dimensions of bulwarks and freeing ports on the main deck and superstructure deck
Rudder [1]	Maximum ahead service speed
Sternframe or sternpost, sterntube Propeller shaft boss and brackets [1]	
Hawse pipes	
Plan of outer doors and hatchways	
Plan of manholes	
Plan of access to and escape from spaces	
Plan of ventilation	Use of spaces
Plan of watertight doors and scheme of relevant manoeuvring devices	Manoeuvring devices Electrical diagrams of power control and position indication circuits
Equipment	List of equipment Construction and breaking load of steel wires Material, construction, breaking load and relevant elongation of synthetic ropes

[1] Where other steering or propulsion systems are adopted (e.g. steering nozzles or azimuth propulsion systems), the plans showing the relevant arrangement and structural scantlings are to be submitted.

Section 2

Materials and Structure Design Principles

A. Materials

1. General

1.1 Usable materials

1.1.1 The characteristics of the materials to be used in the construction of inland navigation vessels are to comply with the applicable GL Rules for Materials and Welding (II).

Only base materials from manufacturers which are approved by GL in the applicable relevant base material grades shall be used.

1.1.2 Aluminium alloys

The use of aluminium alloys is to comply with the requirements of 3.

1.2 Manufacturing processes of materials

The following requirements presume that cold or hot manufacturing processes are carried out in compliance with current sound working practice and the applicable requirements of GL Rules for Materials and Welding. In particular:

– parent material is to be within the limits stated for the specified type of material for which they are intended

– cold or hot manufacturing processes may need to be followed by an adequate heat treatment.

2. Steels for hull structure

2.1 Application

2.1.1 Table 2.1 gives the mechanical characteristics of steels currently used in the construction of inland navigation vessels.

Table 2.1 Mechanical properties of hull steels

Steel grades ($t \le 100$mm)	Minimum yield stress R_{eH} [N/mm^2]	Ultimate minimum tensile strength R_m [N/mm^2]
A-B-D	235	400 – 520
A32-D32	315	440 – 570
A36-D36	355	490 – 630
A40- D40 [1]	390	510 – 660

[1] $t \le 50$mm

2.1.2 When steels with a minimum yield stress R_{eH} greater than 235 N/mm^2 are used, hull scantlings are to be determined by taking into account the material factor k defined in 2.4.

2.1.3 When no other information is available, the minimum guaranteed yield stress R_{eH} and the Young's modulus E of steels used at temperatures between 90 °C and 300 °C may be taken respectively equal to:

$$R_{eH} = R_{eH0} \cdot \left(1,04 - \frac{0,75}{1000} \cdot \theta\right) \quad [\text{N/mm}^2]$$

$$E = E_0 \cdot \left(1,03 - \frac{0,5}{1000} \cdot \theta\right) \quad [\text{N/mm}^2]$$

R_{eH0} = value of the minimum guaranteed yield stress at ambient temperature

E_0 = value of the Young's modulus at ambient temperature

θ = service temperature [°C]

2.2 Information to be kept on board

It is advised to keep on board a plan indicating the steel types and grades adopted for the hull structures. Where steels other than those indicated in Table 2.1 are used, their mechanical and chemical properties, as well as any workmanship requirements or recommendations, are to be available on board together with the above plan.

2.3 Dimensional tolerances

2.3.1 Plates and wide flats

For plates and wide flats, an under thickness tolerance of 0,3 mm is permitted.

2.3.2 Sections and bars

For sections and bars, the under thickness tolerance is to be in accordance with the requirements of a recognised international or national standard.

2.4 Material factor k

Unless otherwise specified, the material factor k is defined in Table 2.2, as a function of the minimum yield stress R_{eH}.

For higher strength hull structural steel with other nominal yield stresses up to 390 N/mm^2, the material factor k may be determined by the following formula:

$$k = \frac{295}{R_{eH} + 60}$$

Steels with a yield stress lower than 235 N/mm^2 or greater than 390 N/mm^2 are considered by GL on a case-by-case basis.

Table 2.2 Material factor k

R_{eH} [N/mm^2]	k
235	1
315	0,78
355	0,72
390	0,66

2.5 Grades of steel

2.5.1 Mild steel grades A, B and D

The distribution of the steel grades used in the different regions of the vessel is indicated in Table 2.3.

Steel of grade D may be required for members consisting in plates more than 20 mm thick in areas liable to important static or dynamic stress concentrations.

Table 2.3 Distribution of steel grades in midship and holds or tanks regions

	t ≤ 15	15 < t ≤ 20	t > 20
Bilge, sheerstrake, stringer plate	A	B	D
Side shell	A	A	A
Deck and bottom	A	A	B
Deck plates at the corners of hatches	A	B	D

2.5.2 High tensile strength structural steel grades AH and DH

In Table 2.4 the grades of the higher strength hull structural steels are marked by the letter "H".

The distribution of the steel grades used in the midship, holds or tanks regions, according to the type of vessel concerned is given in Table 2.4.

Outside these regions, the thickness of high tensile strength steel shall be kept unchanged until the region where the thickness of ordinary steel is the same for the vessel considered.

Table 2.4 Distribution of steel grades in midship and hold or tank regions

	t ≤ 20	t > 20
Bilge, sheerstrake and stringer plate	AH	DH
Side shell	AH	AH
Deck and bottom	AH	DH
Deck plates at the corners of long hatches	AH	DH

2.5.3 For strength members not mentioned in these tables, grade A/AH may generally be used.

2.5.4 Where structural members are completely or partly made from higher strength hull structural steel, a suitable notation will be entered into the ship's certificate.

2.5.5 In the drawings submitted for approval, it is to be shown which structural members are made of higher strength hull structural steel. These drawings are to be placed on board in case any repairs are to be carried out.

2.5.6 Vessels carrying corrosive liquids

Where corrosive liquids are to be carried, the plates and sections of the hull of vessels with built-in cargo tanks and the independent cargo tanks are to be built in a material approved by GL.

2.6 Grades of steel for structures exposed to low temperatures

The selection of steel grades to be used for the structural members exposed to low temperatures (– 20 °C or below) is to be in compliance with GL Rules for Materials and Welding.

2.7 Connections with higher strength steel

2.7.1 Outside the higher strength steel area, scantlings of longitudinal elements in normal strength steel are to be calculated assuming that the midship area is made in normal strength steel.

2.7.2 Regarding welding of higher strength hull structural steel, see GL Rules for Materials and Welding.

2.8 Connections between steel and aluminium

2.8.1 Any direct contact between steel and aluminium alloy is to be avoided (e.g. by means of zinc or cadmium plating of the steel parts and application of a suitable coating on the corresponding light alloy parts).

2.8.2 Any heterogeneous jointing system is considered by GL on a case by case basis.

2.8.3 The use of transition joints made of aluminium/steel clad plates or profiles is considered by GL on a case-by-case basis (see also 3.3).

3. Aluminium alloy structures

3.1 Application

3.1.1 The use of aluminium alloys is normally authorized, instead of steel, provided that equivalent strength is maintained.

The arrangements adopted are to comply, where applicable, with the requirements of the International Conventions and National Regulations.

3.1.2 Use of aluminium alloys on tankers

The use of aluminium alloys is authorized for wheelhouses located aft of aft cofferdam or forward of fore cofferdam

3.1.3 Influence of welding on mechanical characteristics

Welding heat lowers locally the mechanical strength of aluminium alloys hardened by work hardening.

Consequently, where necessary, a drop in the mechanical characteristics of welded structures with respect to those of the parent material is to be considered in the heat-affected zone.

3.2 Material factor

3.2.1 The material factor for aluminium alloys is to be obtained from the following formula:

$$k = \frac{235}{R_{p0,2} \cdot \eta_1}$$

$R_{p0,2}$ = minimum yield stress [N/mm^2] of the parent material in delivery condition.

η_1 = joint coefficient given in Table 2.5.

Table 2.5 Joint coefficient for aluminium alloys

Aluminium alloy	η_1
Alloys without work-hardening treatment (series 5000 in annealed condition 0 or annealed flattened condition H111)	1
Alloys hardened by work hardening (series 5000 other than condition 0 or H111)	$R'_{p0,2} / R_{p0,2}$
Alloys hardened by heat treatment (series 6000) [1]	$R'_{p0,2} / R_{p0,2}$

$R'_{p0,2}$ = minimum yield stress [N/mm^2] of metal in welded condition.

[1] When no information is available, coefficient η_1 is to be taken equal to the metallurgical efficiency coefficient β defined in Table 2.6.

Table 2.6 Aluminium alloy: Metallurgical efficiency coefficient β

Aluminium alloy	Temper Condition	Thickness, in mm	β
6005A (open sections)	T5 or T6	$t \leq 6$	0,45
		$t > 6$	0,40
6005A (closed sections)	T5 or T6	all	0,50
6061 (Sections)	T6	all	0,53
6082 (Sections)	T6	all	0,45

3.2.2 In the case of welding of two different aluminium alloys, the material factor k to be considered for the scantlings of welds is to be the greater material factor of the aluminium alloys of the assembly.

3.3 Transition joints

3.3.1 General

The aluminium material is to comply with GL Rules for Materials and Welding and the steel is to be of an appropriate grade complying with the requirements of these Rules.

3.3.2 Explosion transition joints

Explosion bonded composite aluminium/steel transition joints used for the connection of aluminium structures to steel plating are to comply with GL Rules for Materials and Welding.

3.3.3 Rolled transition joints

The use of rolled bonded composite aluminium/steel transition joints will be examined by GL on a case-by-case basis.

4. Other materials

4.1 General

4.1.1 Other materials and products such as parts made of iron castings, where allowed, products made of copper and copper alloys, rivets, anchors, chain cables, cranes, masts, derricks, accessories and wire ropes are generally to comply with the applicable GL Rules for Materials and Welding.

4.1.2 The use of plastics, wood or other special materials not covered by these Rules is to be considered by GL on a case-by-case basis.

In such a case, GL states the requirements for the acceptance of the materials concerned.

4.1.3 Materials used in welding processes are to comply with the applicable GL Rules for Materials and Welding.

B. Strength Principles

1. Symbols

w = section modulus [cm^3] of an ordinary stiffener or primary supporting member, as the case may be, with an attached plating of width b_p

h_w = web height [mm] of an ordinary stiffener or a primary supporting member, as the case may be

t_w = web thickness [mm] of an ordinary stiffener or a primary supporting member, as the case may be

b_f = face plate width [mm] of an ordinary stiffener or a primary supporting member, as the case may be

t_f = face plate thickness [mm] of an ordinary stiffener or a primary supporting member, as the case may be

t_p = thickness [mm] of the plating attached to an ordinary stiffener or a primary supporting member, as the case may be

s = spacing [m] of ordinary stiffeners

S = spacing [m] of primary supporting members

ℓ = span [m] of an ordinary stiffener or a primary supporting member, as the case may be, measured between the supporting members

ℓ_b = length [m] of brackets

I = moment of inertia [cm^4] of an ordinary stiffener or a primary supporting member, as the case may be, without attached plating, around its neutral axis parallel to the plating

I_B = moment of inertia [cm^4] of an ordinary stiffener or a primary supporting member, as the case may be, with bracket and without attached plating, around its neutral axis parallel to the plating, calculated at mid-length of the bracket

k = material factor defined in A.2.4 and A.3.2

2. General strength principles

2.1 Structural continuity

2.1.1 The variation in scantlings between the midship region and the fore and aft parts is to be gradual.

2.1.2 Attention is to be paid to the structural continuity:

– in way of changes in the framing system

– at the connections of primary or ordinary stiffeners

– in way of the ends of the fore and aft parts, and machinery space

– in way of ends of superstructures

2.1.3 Where stress concentrations may occur in way of structural discontinuities, adequate compensation and reinforcements are to be provided.

2.1.4 Primary supporting members are to be arranged in such a way that they ensure adequate continuity of strength. Abrupt changes in height or in cross-section are to be avoided.

2.2 Rounding off of scantlings

2.2.1 Plate thicknesses

The rounding off of plate thicknesses is to be obtained from the following procedure:

a) the net thickness (see 6.) is calculated in accordance with the rule requirements

b) corrosion addition t_C (see 7.) is added to the calculated net thickness, and this gross thickness is rounded off to the nearest half-millimetre

c) the rounded net thickness is taken equal to the rounded gross thickness, obtained in b), minus the corrosion addition t_C.

2.2.2 Stiffener section moduli

Stiffener section moduli as calculated in accordance with the rule requirements are to be rounded off to the nearest standard value; however, no reduction may exceed 3 %.

3. Plating

3.1 Insert plates and doublers

3.1.1 A local increase in plating thickness is generally to be achieved through insert plates. Local doublers, which are normally only allowed for temporary repair, may however be accepted by GL on a case-by-case basis.

In any case, doublers and insert plates are to be made of materials of a quality at least equal to that of the plates on which they are welded.

3.1.2 Doublers having width [mm] greater than:

– 20 times their thickness, for thicknesses equal to or less than 15 mm

– 25 times their thickness, for thicknesses greater than 15 mm

are to be fitted with slot welds, to be effected according to Section 8, A.2.6.

3.1.3 When doublers fitted on the outer shell and strength deck within 0,5·L amidships are accepted by GL, their width and thickness are to be such that slot welds are not necessary according to the requirements in 2.1.2. Outside this area, the possibility of fitting doublers requiring slot welds will be considered by GL on a case-by-case basis.

4. Ordinary stiffeners

4.1 Stiffener not perpendicular to the attached plating

Where the angle between the section web and the attached plating is less than 70°, the actual section modulus may be obtained [cm^3] from the following formula:

$w = w_0 \cdot \sin \alpha$

w_0 = actual section modulus [cm^3] of the stiffener assumed to be perpendicular to the plating

α = angle between the stiffener web and the attached plating, to be measured at mid-span of the section.

4.2 Span of ordinary stiffeners

The span ℓ of ordinary stiffeners is to be measured as shown in Fig. 2.1 to Fig. 2.4.

Instead of the true length of curved frames, the length of the chord between the supporting points can be selected.

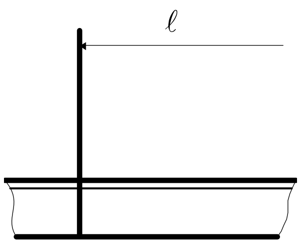


Fig. 2.1 Ordinary stiffener without brackets

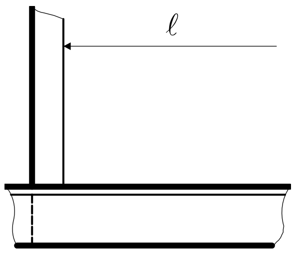


Fig. 2.2 Ordinary stiffener with a stiffener at one end

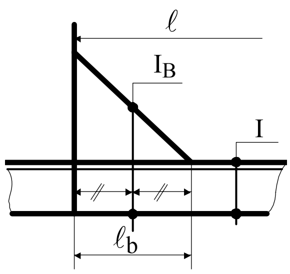


Fig. 2.3 Ordinary stiffener with end bracket

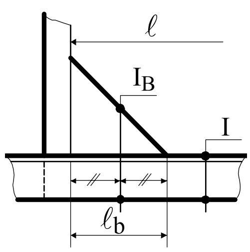


Fig. 2.4 Ordinary stiffener with a bracket and a stiffener at one end

4.3 Width of attached plating

4.3.1 Yielding check

The width of the attached plating to be considered for the yielding check of ordinary stiffeners is to be obtained [m] from the following formulae:

– where the plating extends on both sides of the ordinary stiffener:

$b_P = s$

– where the plating extends on one side of the ordinary stiffener (i.e. ordinary stiffeners bounding openings):

$b_P = 0{,}5 \cdot s$

4.3.2 Buckling check

The attached plating to be considered for the buckling check of ordinary stiffeners is defined in C.3.3.

4.4 Sections

The main characteristics of sections currently used are given in F.

4.5 Built sections

4.5.1 Geometric properties

The geometric properties of built sections as shown in Fig. 2.5 may be calculated as indicated in the following formulae.

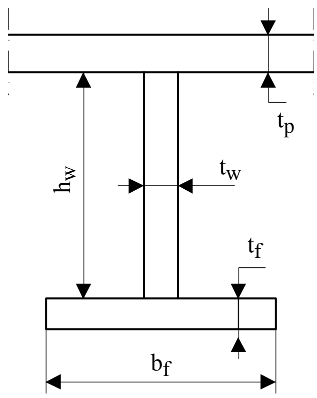


Fig. 2.5 Dimensions of a built section

The shear sectional area of a built section with attached plating is to be obtained [cm^2] from the following formula:

$$A_{sh} = \frac{h_w \cdot t_w}{100}$$

The section modulus of a built section with attached plating of sectional area A_a [mm^2] is to be obtained [cm^3] from the following formula:

$$w = \frac{h_w \cdot t_f \cdot b_f}{1000} + \frac{t_w \cdot h^2 \cdot w}{6000} \cdot \left(1 + \frac{A_a - t_f \cdot b_f}{A_a + \frac{t_w \cdot h_w}{2}}\right)$$

The distance from mid-plate thickness of face plate to neutral axis is to be obtained [cm] from the following formula:

$$v = \frac{h_w \cdot \left(A_a + 0{,}5 \cdot t_w \cdot h_w\right)}{10 \cdot \left(A_a + t_f \cdot b_f + t_w \cdot h_w\right)}$$

The moment of inertia of a built section with attached plating is to be obtained [cm^4] from the following formula:

$$I = w \cdot v$$

These formulae are applicable provided that:

$$A_a \geq t_f \cdot b_f$$

$$\frac{h_w}{t_p} \geq 10$$

$$\frac{h_w}{t_f} \geq 10$$

4.6 End connections

4.6.1 Continuous ordinary stiffeners

Where ordinary stiffeners are continuous through primary supporting members, they are to be connected to the web plating so as to ensure proper transmission of loads, e.g. by means of one of the connection details shown in Fig. 2.6 to Fig. 2.9. In the case of high values for the design loads, additional stiffening is required.

Connection details other than those shown in Fig. 2.6 to Fig. 2.9 may be considered by GL on a case-by-case basis. In some cases, GL may require the details to be supported by direct calculations submitted for review.

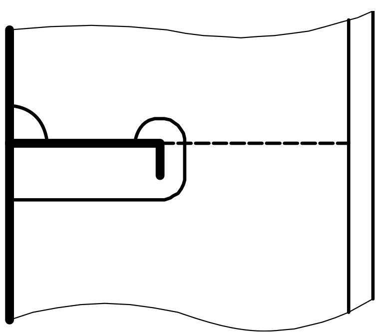


Fig. 2.6 End connection of ordinary stiffener without collar plate

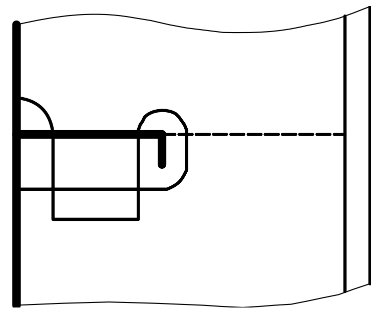


Fig. 2.7 End connection of ordinary stiffener Collar plate

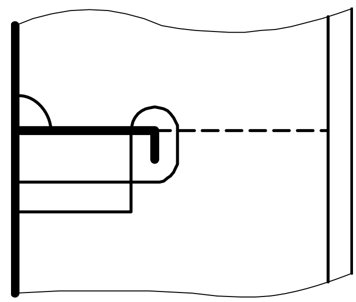


Fig. 2.8 End connection of ordinary stiffener One large collar plate

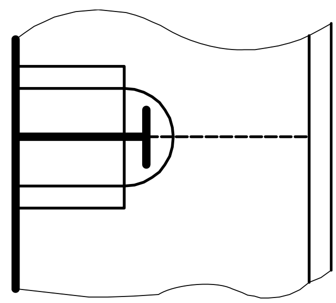


Fig. 2.9 End connection of ordinary stiffener Two large collar plates

4.6.2 Intercostal ordinary stiffeners

Where ordinary stiffeners are cut at primary supporting members, brackets are to be fitted to ensure the structural continuity. Their section modulus and their sectional area are to be not less than those of the ordinary stiffeners.

All brackets for which:

$$\frac{\ell_b}{t} > 60$$

ℓ_b = length [mm] of the free edge of the bracket

t = bracket net thickness [mm]

are to be flanged or stiffened by a welded face plate.

The sectional area [cm^2] of the flange or the face plate is to be not less than $0{,}01 \cdot \ell_b$.

The width of the face plate is to be not less than $10 \cdot t$.

4.6.3 Bracketed ordinary stiffeners

4.6.3.1 For the scantlings of brackets the required section modulus of the section is decisive. Where sections of different section moduli are connected to each other, the scantlings of the brackets are generally governed by the smaller section.

4.6.3.2 The net thickness of brackets is not to be less than:

$$t = c \cdot \sqrt[3]{\frac{W}{k_1}}$$

c = 1,2 for non-flanged brackets

= 0,95 for flanged brackets

k_1 = material factor k for the section according A. 2.4 and 3.2

W = section modulus of smaller section [cm^3]

t_{min} = 5,0 mm

t_{max} = web thickness of smaller section

4.6.3.3 The arm length of brackets is not to be less than:

$$\ell = 46,2 \cdot \sqrt[3]{\frac{W}{k_1}} \cdot \sqrt{k_2} \cdot c_t$$

ℓ = 100 mm

$$c_t = \sqrt{\frac{t}{t_a}}$$

t_a = "as built" thickness of bracket [mm]

≥ t according 4.7.2

W = see 4.7.2

k_2 = material factor k for the bracket according to A.2.4 and 3.2

The arm length ℓ is the length of the welded connection.

Note

For deviating arm lengths, the thickness of brackets is to be estimated by direct calculations considering sufficient safety against buckling.

4.6.3.4 The throat thickness a of the welded connection is to be determined according to Section 8, A.4.8.

4.6.3.5 Where flanged brackets are used, the width of flange is to be determined according to the following formula:

$$b = 40 + \frac{W}{30} \quad [mm]$$

b is not to be taken less than 50 mm and need not be taken greater than 90 mm.

4.6.4 Sniped ends of stiffeners

Stiffeners may be sniped at the ends if the thickness of the plating supported by the stiffeners is not less than:

$$t = c \cdot \sqrt{\frac{p \cdot s \cdot (\ell - 0,5 \cdot s)}{R_{eH}}}$$

p = stiffener design load [kN/m^2]

c = coefficient

= 15,8 for watertight bulkheads and for tank bulkheads

= 19,6 for all other components

5. Primary supporting members

5.1 Span of primary supporting members

The span of primary supporting members is to be determined in compliance with 4.2.

5.2 Width of attached plating

5.2.1 Girders

5.2.1.1 The effective breadth of plating e_m of frames and girders may be determined according to Table 2.7, considering the type of loading.

Special calculations may be required for determining the effective breadth of one-sided or non-symmetrical flanges.

5.2.1.2 The effective cross sectional area of plates is not to be less than the cross sectional area of the face plate.

5.2.1.3 The effective width of stiffeners and girders subjected to compressive stresses may be determined according to C.2.2, but is in no case to be taken greater than the effective breadth determined by 5.2.1.1.

Table 2.7 Effective breadth e_m of frames and girders

ℓ/e	0	1	2	3	4	5	6	7	≥ 8
e_{m1}/e	0	0,36	0,64	0,82	0,91	0,96	0,98	1,00	1,0
e_{m2}/e	0	0,20	0,37	0,52	0,65	0,75	0,84	0,89	0,9

e_{m1} is to be applied where girders are loaded by uniformly distributed loads or else by not less than 6 equally spaced single loads.

e_{m2} is to be applied where girders are loaded by 3 or less single loads.

Intermediate values may be obtained by direct interpolation.

ℓ = length between zero-points of bending moment curve, i.e. unsupported span in case of simply supported girders and 0,6 × unsupported span in case of constraint of both ends of girder

e = width of plating supported, measured from centre to centre of the adjacent unsupported fields

5.2.2 Cantilevers

Where cantilevers are fitted at every frame, the effective breadth of plating may be taken as the frame spacing. Where cantilevers are fitted at a greater spacing, the effective breadth of plating at the respective cross section may approximately be taken as the distance of the cross section from the point on which the load is acting, however, not greater than the spacing of the cantilevers.

5.2.3 Corrugated bulkheads

The width of attached plating of corrugated bulkhead primary supporting members is to be determined as follows:

- when primary supporting members are parallel to the corrugations and are welded to the corrugation flanges, the width of the attached plating is to be calculated in accordance with 5.2.2 and 5.2.3, and is to be taken not greater than the corrugation flange width
- when primary supporting members are perpendicular to the corrugations, the width of the attached plating is to be taken equal to the width of the primary supporting member face plate.

5.3 Geometric properties

5.3.1 Built sections

The geometric properties of primary supporting members (including primary supporting members of double hull structures, such as double bottom floors and girders) are generally determined in accordance with 4.5.1, reducing the web height h_w by the depth of the cut-outs for the passage of the ordinary stiffeners, if any.

5.4 Bracketed end connections

5.4.1 Arm lengths of end brackets are to be equal, as far as practicable.

The height of end brackets is to be not less than that of the weakest primary supporting member.

5.4.2 The scantlings of end brackets are generally to be such that the section modulus of the primary supporting member with end brackets is not less than that of the primary supporting member at mid-span.

5.4.3 The bracket web thickness is to be not less than that of the weakest primary supporting member.

5.4.4 The face plate of end brackets is to have a width not less than the width of the primary supporting member faceplates.

Moreover, the thickness of the face plate is to be not less than that of the bracket web.

5.4.5 In addition to the above requirements, the scantlings of end brackets are to comply with the applicable requirements given in Section 5, B. to E.

5.5 Bracketless end connections

5.5.1 In the case of bracketless end connections between primary supporting members, the strength continuity is to be obtained as schematically shown in Fig. 2.10 or by any other method which GL may consider equivalent.

5.5.2 In general, the continuity of the face plates is to be ensured.

5.6 Cut-outs and holes

5.6.1 Cut-outs for the passage of ordinary stiffeners are to be as small as possible and well rounded with smooth edges.

In general, the depth of cut-outs is to be not greater than 50 % of the depth of the primary supporting member. Other cases are to be covered by calculations submitted to GL.

5.6.2 Openings may not be fitted in way of toes of end brackets.

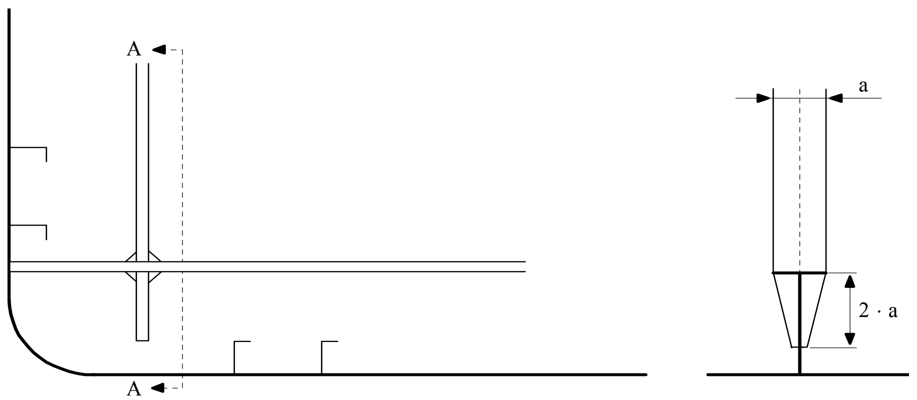


Fig. 2.10 Connection of two primary supporting members

5.7 Stiffening arrangement

5.7.1 General

Webs of primary supporting members are generally to be stiffened where the height [mm] is greater than 100 t, where t is the web thickness [mm] of the primary supporting member.

In general, the web stiffeners of primary supporting members are to be spaced not more than 110 t.

5.7.2 Longitudinal framing system

In way of each longitudinal the transverses are to be stiffened. This stiffener is to extend between the longitudinal and the upper faceplate of the transverse, without any connection with that faceplate.

The stiffener is to be made of a flat, the width b and thickness t of which [mm] are not to be less than:

$$b = \frac{20}{3}\sqrt{w_\ell}$$

$$t = \frac{2}{3}\sqrt{w_\ell}$$

w_ℓ being the section modulus of the longitudinal [cm^3].

However, on deck transverses, side shell transverses or longitudinal bulkhead transverses, stiffeners may be provided only every two longitudinal spacings.

GL may waive this rule where the transverse is a rolled section or where it is otherwise covered by calculations.

The sectional area of the connection of the transverse stiffener to the longitudinal and to the transverses is not to be less than the stiffener rule sectional area.

5.7.3 Tripping brackets (see Fig. 2.11) welded to the face plate are generally to be fitted:

- at intervals not exceeding 20 times the face plate width
- at the toe of end brackets
- at rounded face plates
- in way of cross ties
- in way of concentrated loads

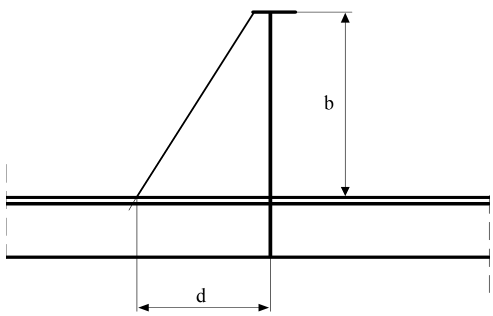


Fig. 2.11 Primary supporting member: web stiffener in way of ordinary stiffener

Where the width of the symmetrical face plate is greater than 400 mm, backing brackets are to be fitted in way of the tripping brackets.

5.7.4 The arm length of tripping brackets is to be not less than the greater of the following values [m]:

$$d = 0{,}38 \cdot b$$

$$= 0{,}85 \cdot b \cdot \sqrt{\frac{s_t}{t}}$$

b = height [m] of tripping brackets, shown in Fig. 2.11

s_t = spacing [m] of tripping brackets

t = thickness [mm] of tripping brackets.

5.7.5 The thickness of the tripping brackets is not to be less than the web thickness of the primary supporting member.

6. Hull scantling principle

6.1 Calculation point

6.1.1 General

The calculation point is to be considered with respect to the reference co-ordinate system defined in Section 1, A.1.4.

6.1.2 Plating

The elementary plate panel is the smallest unstiffened part of plating. Unless otherwise specified, the loads 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

6.1.3 Ordinary stiffeners

Unless otherwise specified, the loads are to be calculated at mid-span of the ordinary stiffener considered.

6.1.4 Primary supporting members

Unless otherwise specified, the loads are to be calculated at mid-span of the primary supporting member considered.

6.2 Bracket coefficients

6.2.1 Ordinary stiffeners

These Rules apply to ordinary stiffeners without end brackets, with a bracket at one end or with two equal end brackets.

The bracket coefficients β_b and β_s, of ordinary stiffeners are to be obtained from Table 2.8.

Table 2.8 Bracket coefficients

Brackets at ends	β_b	β_s
0	1	1
1	0,90	0,95
2	0,81	0,90

6.2.2 Primary supporting members

Conventional parameters of end brackets are given in Fig. 2.12. Special consideration is to be given to conditions different from those shown.

The bracket coefficients β_b and β_s, of primary supporting members are to be determined using the following formulae, and are not to be less than the values given in Table 2.8:

$$\beta_b = \left(1 - \sum_{i=1}^{n} \frac{\ell_{bi}}{\ell}\right)^2$$

$$\beta_s = 1 - \sum_{i=1}^{n} \frac{\ell_{bi}}{\ell}$$

ℓ = span [m] of primary supporting member, defined in 4.2

$\ell_{bi} = \ell_b - 0{,}25 \cdot h_w$

$\ell_{bi} \geq 0$

$\ell_b = \text{MIN}\,(d;\, b)$

d, b = length [m] of brackets arms, defined in Fig. 2.12

h_w = height [m] of the primary supporting member (see Fig. 2.12)

n = number of end brackets

6.3 Coefficients for vertical structural members λ_b and λ_s

The coefficients λ_b and λ_s to be used for the scantlings of vertical structural members are to be determined as follows:

$$\lambda_s = 2 \cdot \lambda_b - 1$$

λ_b is the greater of:

$$= 1 + 0{,}2 \cdot \frac{p_{Sd} - p_{Su}}{p_{Sd} + p_{Su}}$$

$$= 1 - 0{,}2 \cdot \frac{p_{Sd} - p_{Su}}{p_{Sd} + p_{Su}}$$

p_{Su} = still water pressure [kN/m^2] at the upper end of the structural member considered

p_{Sd} = still water pressure [kN/m^2] at the lower end of the structural member considered.

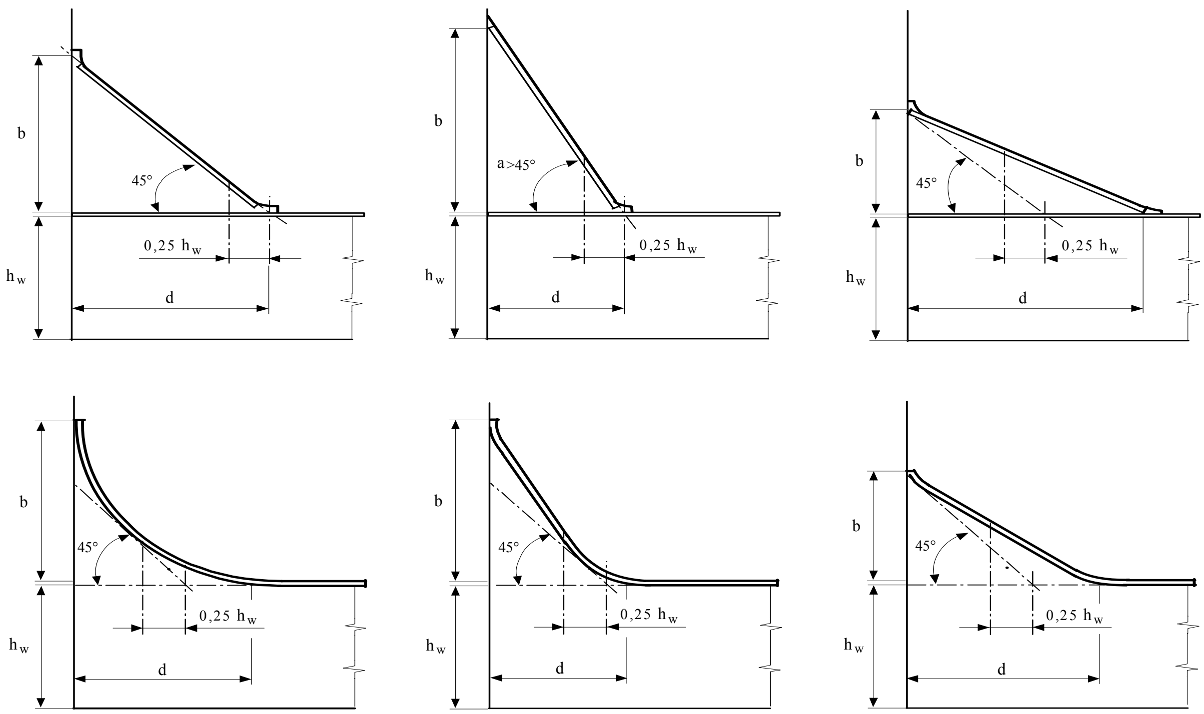


Fig. 2.12 Characteristics of primary supporting member brackets

6.4 Plate panels

6.4.1 Thickness

The required thickness of plating subjected to lateral pressures may be reduced according to the aspect ratio and curvature of the panel considered, according to the formula:

$$t = t_0 \cdot c_a \cdot c_r$$

t_0 = plating thickness [mm] as required in terms of the lateral pressure

c_a = aspect ratio defined in 6.4.2

c_r = coefficient of curvature defined in 6.4.3.

6.4.2 Aspect ratio

The aspect ratio of a plate panel is given by following formula:

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

s = length [m] of the shorter side of the plate panel

ℓ = length [m] of the longer side of the plate panel

6.4.3 Curvature of plate panels

The coefficient of curvature of plate pane is given by the following formula:

$$c_r = 1 - 0,5 \cdot \frac{s}{r} \ge 0,75$$

r = radius of curvature [m]

7. Net strength characteristic calculation

7.1 General

7.1.1 The scantlings obtained by applying the criteria specified in these Rules are net scantlings, i.e. those which provide the strength characteristics required to sustain the loads, excluding any addition for corrosion. Exceptions are the scantlings of:

– rudder structures and hull appendages in Section 7.

– massive pieces made of steel forgings, steel castings or iron castings

7.1.2 The required strength characteristics are:

– thickness, for plating including that which constitutes primary supporting members

– section modulus, shear sectional area, moments of inertia and local thickness, for ordinary stiffeners and, as the case may be, primary supporting members

– section modulus, moments of inertia and single moment for the hull girder

7.1.3 The vessel is to be built at least with the gross scantlings obtained by reversing the procedure described in 7.2.

7.2 Designer's proposal based on gross scantlings

7.2.1 General criteria

If the designer provides the gross scantlings of each structural element, the structural checks are to be carried out on the basis of the net strength characteristics, derived as specified in 7.2.2 to 7.2.5.

7.2.2 Plating

The net thickness is to be obtained by deducting the corrosion addition t_C from the gross thickness.

7.2.3 Ordinary stiffeners

The net transverse section is to be obtained by deducting the corrosion addition t_C from the gross thickness of the elements which constitute the stiffener profile.

The net strength characteristics are to be calculated for the net transverse section. As an alternative, the net section modulus may be obtained from the following formula:

$$w = w_G \cdot (1 - \alpha \cdot t_C) - \beta \cdot t_C$$

w_G = stiffener gross section modulus [cm^3]

α, β = coefficients defined in Table 2.9.

Table 2.9 Coefficients α and β

Type of ordinary stiffeners		α	β
Flat bars	$- w_G > 17\ cm^3$	0,066	1,6
Flanged profiles	$- w_G > 17\ cm^3$	0,101	1,6
Bulb profiles:	$- w_G \le 200\ cm^3$	0,070	0,4
	$- w_G > 200\ cm^3$	0,035	7,4

7.2.4 Primary supporting members

The net transverse section is to be obtained by deducting the corrosion addition t_C from the gross thickness of the elements which constitute the primary supporting members.

The net strength characteristics are to be calculated for the net transverse section.

7.2.5 Hull girder

For the hull girder, the net hull transverse sections are to be considered as being constituted by plating and stiffeners having net scantlings calculated on the basis of the corrosion additions t_C, according to 7.2.2 to 7.2.4.

7.3 Designer's proposal based on net scantlings

7.3.1 Net strength characteristics and corrosion additions

If the designer provides the net scantlings of each structural element, the structural checks are to be carried out on the basis of the proposed net strength characteristics.

The designer is also to provide the corrosion additions or the gross scantlings of each structural element. The proposed corrosion additions are to be not less than the values specified in 8.

7.3.2 Hull girder net strength characteristic calculation

For the hull girder, the net hull girder transverse sections are to be considered as being constituted by plating and stiffeners having the net scantlings proposed by the designer.

8. Corrosion additions

8.1 Values of corrosion additions

8.1.1 General

The values of the corrosion additions specified in this Article are to be applied in relation to the relevant corrosion protection measures prescribed in Section 8, B.1.

The designer may define values of corrosion additions greater than those specified in 8.1.2.

8.1.2 Corrosion additions for steel other than stainless steel

The corrosion addition for each of the two sides of a structural member, t_{C1} or t_{C2}, is specified in Table 2.10.

– for plating with a net thickness greater than 8 mm, the total corrosion addition t_C [mm] for both sides of the structural member is obtained by the following formula:

$$t_C = t_{C1} + t_{C2}$$

– for plating with a net thickness less than or equal to 8 mm, the smallest of the following values:

  – 25 % of the net thickness of the plating

  – $t_C = t_{C1} + t_{C2}$

For an internal member within a given compartment, the total corrosion addition t_C is obtained from the following formula:

$$t_C = 2 \cdot t_{C1}$$

When a structural element is affected by more than one value of corrosion addition (e.g. plate in a dry bulk cargo hold extending in the double bottom), the scantling criteria are generally to be applied considering the severest value of corrosion addition applicable to the member.

8.1.3 Corrosion additions for stainless steel and aluminium alloys

For structural members made of stainless steel or aluminium alloys, the corrosion addition is to be taken equal to 0,25 mm, for one side exposure ($t_{C1} = t_{C2} = 0{,}25$ mm)

Table 2.10 Corrosion additions [mm] for one side exposure (t_{c1} or t_{c2})

Compartment type		General [1]
Ballast tank		1,00
Cargo tank and fuel oil tank	Plating of horizontal surfaces	0,75
	Plating of non-horizontal surfaces	0,50
	Ordinary stiffeners and primary supporting members	0,50
Dry bulk cargo hold	General	1,00
	Inner bottom plating Side plating for single hull vessel Inner side plating for double hull vessel Transverse bulkhead plating	1,75
	Frames, ordinary stiffeners and primary supporting members	0,50
Hopper well of dredging vessels		2,00
Accommodation space		0,00
Compartments and areas other than those mentioned above		0,50

1 General: corrosion additions are applicable to all members of the considered item.

C. Proof of Buckling Strength

The calculation method is based on DIN standard 18800.

1. Definitions

a = length of single or partial plate field [mm]

b = breadth of single plate field [mm]

α = aspect ratio of single plate field

= a / b

n = number of single plate field breadths within the partial or total plate field

t = nominal plate thickness [mm]

= $t_a - t_C$ [mm]

t_a = plate thickness as built [mm]

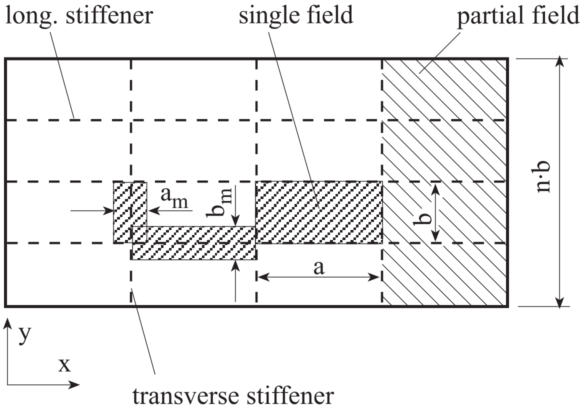
t_C = corrosion addition according to K. [mm]

σ_x = membrane stress in x-direction [N/mm²]

σ_y = membrane stress in y-direction [N/mm²]

τ = shear stress in the x-y plane [N/mm²]

Compressive and shear stresses are to be taken positive, tension stresses are to be taken negative.



longitudinal : stiffener in the direction of the length a
transverse : stiffener in the direction of the breath b

Fig. 2.13 Definition of plate fields subject to buckling

Note

If the stresses in the x- and y-direction already contain the Poisson effect, the following modified stress values may be used:

Both stresses σ_x^* und σ_y^* are to be compressive stresses, in order to apply the stress reduction according to the following formulae:

$$\sigma_x = \left(\sigma_x^* - 0,3 \cdot \sigma_y^*\right) / 0,91$$

$$\sigma_y = \left(\sigma_y^* - 0,3 \cdot \sigma_x^*\right) / 0,91$$

σ_x^*, σ_y^* = *stresses containing the Poisson effect*

Where compressive stress fulfils the condition $\sigma_y^* < 0,3 \cdot \sigma_x^*$, then $\sigma_y = 0$ and $\sigma_x = \sigma_x^*$.

Where compressive stress fulfils the condition $\sigma_x^* < 0,3 \cdot \sigma_y^*$, then $\sigma_x = 0$ and $\sigma_y = \sigma_y^*$.

When at least σ_x^* or σ_y^* is tension stress, then $\sigma_x = \sigma_x^*$ and $\sigma_y = \sigma_y^*$.

ψ = edge stress ratio according to Table 2.12

F_1 = correction factor for boundary condition at the long. stiffeners according to Table 2.11

Table 2.11 Correction factor F_1

1,0	for stiffeners sniped at both ends
Guidance values where both ends are effectively connected to adjacent structures*:	
1,05	for flat bars
1,10	for bulb sections
1,20	for angle and tee-sections
1,30	for girders of high rigidity (e.g. bottom transverses)
* Exact values may be determined by direct calculations.	

σ_e = reference stress

$$= 0,9 \cdot E \left(\frac{t}{b}\right)^2 \quad [\mathrm{N/mm^2}]$$

E = Young's modulus

$= 2,06 \cdot 10^5$ N/mm² for steel

$= 0,69 \cdot 10^5$ N/mm² for aluminium alloys

R_{eH} = nominal yield point [N/mm²] for hull structural steels according to A.2.

= 0,2 % proof stress [N/mm²] for aluminium alloys

S = safety factor

= 1,1 in general

= 1,2 for structures which are exclusively exposed to local loads

= 1,05 for combinations of statistically independent loads

For constructions of aluminium alloys, the safety factors are to be increased in each case by 0,1.

λ = reference degree of slenderness

$$= \sqrt{\frac{R_{eH}}{K \cdot \sigma_e}}$$

K = buckling factor according to Tables 2.12 and 2.13

In general, the ratio of plate field breadth to plate thickness shall not exceed b/t = 100.

2. Proof of single plate fields

2.1 Proof is to be provided that the following condition is complied with for the single plate field a · b:

$$\left(\frac{|\sigma_x| \cdot S}{\kappa_x \cdot R_{eH}}\right)^{e_1} + \left(\frac{|\sigma_y| \cdot S}{\kappa_y \cdot R_{eH}}\right)^{e_2} - B\left(\frac{\sigma_x \cdot \sigma_y \cdot S^2}{R_{eH}^2}\right)$$

$$+ \left(\frac{|\tau| \cdot S \cdot \sqrt{3}}{\kappa_\tau \cdot R_{eH}}\right)^{e_3} \leq 1{,}0$$

Each term of the above condition shall not exceed 1,0.

The reduction factors κ_x, κ_y and κ_τ are given in Table 2.12 and/or 2.13.

Where $\sigma_x \leq 0$ (tension stress), $\kappa_x = 1{,}0$.

Where $\sigma_y \leq 0$ (tension stress), $\kappa_y = 1{,}0$.

The exponents e_1, e_2 and e_3 as well as the factor B are calculated or set respectively:

Exponents $e_1 - e_3$ and factor B	**plate field**	
	plane	**curved**
e_1	$1+\kappa_x^4$	1,25
e_2	$1+\kappa_y^4$	1,25
e_3	$1+\kappa_x \cdot \kappa_y \cdot \kappa_\tau^2$	2,0
B σ_x and σ_y positive (compression stress)	$(\kappa_x \cdot \kappa_y)^5$	0
B σ_x or σ_y negative (tension stress)	1	—

2.2 Effective width of plating

The effective width of plating may be determined by the following formulae:

$b_m = \kappa_x \cdot b$ for longitudinal stiffeners

$a_m = \kappa_y \cdot a$ for transverse stiffeners

see also Fig. 2.13.

The effective width of plating is not to be taken greater than the effective breadth obtained from B.4.3 and B.5.2.

Table 2.12 Plane plate fields

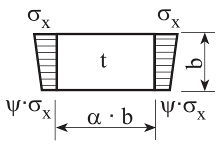
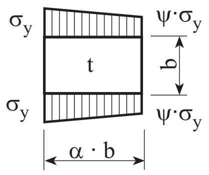
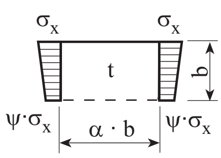
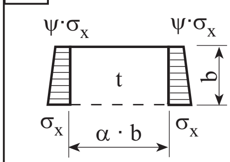
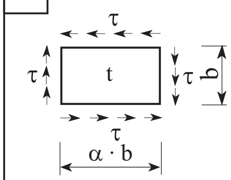
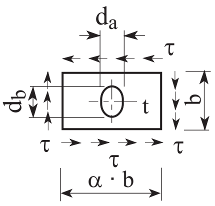
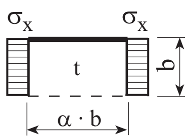
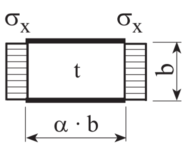
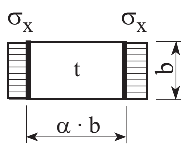
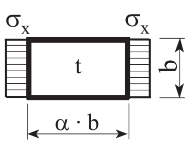
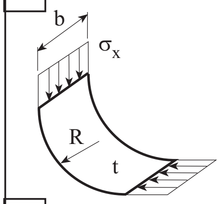
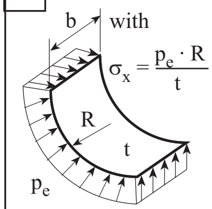
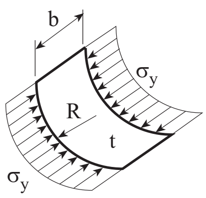
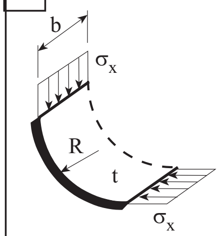
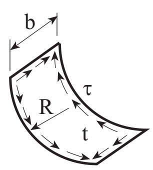
Load case	Edge stress ratio ψ	Aspect ratio α	Buckling factor K	Reduction factor κ
1 	$1 \ge \psi \ge 0$	$\alpha > 1$	$K = \frac{8,4}{\psi + 1,1}$	$\kappa_x = 1$ for $\lambda \le \lambda_c$ $\kappa_x = c\left(\frac{1}{\lambda} - \frac{0,22}{\lambda^2}\right)$ for $\lambda > \lambda_c$ $c = (1,25 - 0,12\psi) \le 1,25$ $\lambda_c = \frac{c}{2}\left(1 + \sqrt{1 - \frac{0,88}{c}}\right)$
	$0 > \psi > -1$		$K = 7,63 - \psi\,(6,26 - 10\,\psi)$	
	$\psi \le -1$		$K = (1 - \psi)^2 \cdot 5,975$	
2 	$1 \ge \psi \ge 0$	$\alpha \ge 1$	$K = F_1\left(1 + \frac{1}{\alpha^2}\right)^2 \frac{2,1}{(\psi+1,1)}$	$\kappa_y = c\left(\frac{1}{\lambda} - \frac{R+F^2\,(H-R)}{\lambda^2}\right)$ $c = (1,25 - 0,12\psi) \le 1,25$ $R = \lambda\left(1 - \frac{\lambda}{c}\right)$ for $\lambda < \lambda_c$ $R = 0,22$ for $\lambda \ge \lambda_c$ $\lambda_c = \frac{c}{2}\left(1 + \sqrt{1 - \frac{0,88}{c}}\right)$ $F = \left(1 - \frac{\frac{K}{0,91} - 1}{\lambda_p^2}\right) c_1 \ge 0$ $\lambda_p^2 = \lambda^2 - 0,5 \qquad 1 \le \lambda_p^2 \le 3$ $c_1 = 1$ for σ_y due to direct loads $c_1 = \left(1 - \frac{F_1}{\alpha}\right) \ge 0$ for σ_y due to bending (in general) $c_1 = 0$ for σ_y due to bending in extreme load cases (e. g. w. t. bulkheads) $H = \lambda - \frac{2\lambda}{c\,(T + \sqrt{T^2 - 4})} \ge R$ $T = \lambda + \frac{14}{15\lambda} + \frac{1}{3}$
	$0 > \psi > -1$	$1 \le \alpha \le 1,5$	$K = F_1\left[\left(1 + \frac{1}{\alpha^2}\right)^2 \frac{2,1\,(1+\psi)}{1,1} - \frac{\psi}{\alpha^2}\,(13,9 - 10\,\psi)\right]$	
		$\alpha > 1,5$	$K = F_1\left[\left(1 + \frac{1}{\alpha^2}\right)^2 \frac{2,1\,(1+\psi)}{1,1} - \frac{\psi}{\alpha^2}\left(5,87 + 1,87\,\alpha^2 + \frac{8,6}{\alpha^2} - 10\,\psi\right)\right]$	
	$\psi \le -1$	$1 \le \alpha \le \frac{3\,(1-\psi)}{4}$	$K = F_1\left(\frac{1-\psi}{\alpha}\right)^2 5,975$	
		$\alpha > \frac{3\,(1-\psi)}{4}$	$K = F_1\left[\left(\frac{1-\psi}{\alpha}\right)^2 3,9675 + 0,5375\left(\frac{1-\psi}{\alpha}\right)^4 + 1,87\right]$	
3 	$1 \ge \psi \ge 0$	$\alpha > 0$	$K = \frac{4\,(0,425 + 1/\alpha^2)}{3\,\psi + 1}$	$\kappa_x = 1$ for $\lambda \le 0,7$ $\kappa_x = \frac{1}{\lambda^2 + 0,51}$ for $\lambda > 0,7$
	$0 > \psi \ge -1$		$K = 4\left(0,425 + \frac{1}{\alpha^2}\right)(1 + \psi) - 5 \cdot \psi\,(1 - 3,42\,\psi)$	
4 	$1 \ge \psi \ge -1$	$\alpha > 0$	$K = \left(0,425 + \frac{1}{\alpha^2}\right)\frac{3 - \psi}{2}$	

Table 2.12 Plane plate fields *(continued)*

Load case	Edge stress ratio ψ	Aspect ratio α	Buckling factor K	Reduction factor κ
5 	—		$K = K_\tau \cdot \sqrt{3}$	
		$\alpha \geq 1$	$K_\tau = \left[5{,}34 + \frac{4}{\alpha^2}\right]$	
		$0 < \alpha < 1$	$K_\tau = \left[4 + \frac{5{,}34}{\alpha^2}\right]$	$\kappa_\tau = 1$ for $\lambda \leq 0{,}84$ $\kappa_\tau = \frac{0{,}84}{\lambda}$ for $\lambda > 0{,}84$
6 	—		$K = K' \cdot r$ K' = K according to load case 5 r = Reduction factor $r = (1 - \frac{d_a}{a})(1 - \frac{d_b}{b})$ with $\frac{d_a}{a} \leq 0{,}7$ and $\frac{d_b}{b} \leq 0{,}7$	
7 	—	$\alpha \geq 1{,}64$	$K = 1{,}28$	$\kappa_x = 1$ for $\lambda \leq 0{,}7$
		$\alpha < 1{,}64$	$K = \frac{1}{\alpha^2} + 0{,}56 + 0{,}13\,\alpha^2$	$\kappa_x = \frac{1}{\lambda^2 + 0{,}51}$ for $\lambda > 0{,}7$
8 	—	$\alpha \geq \frac{2}{3}$	$K = 6{,}97$	
		$\alpha < \frac{2}{3}$	$K = \frac{1}{\alpha^2} + 2{,}5 + 5\,\alpha^2$	
9 	—	$\alpha \geq 4$	$K = 4$	$\kappa_x = 1$ for $\lambda \leq 0{,}83$
		$4 > \alpha > 1$	$K = 4 + \left[\frac{4-\alpha}{3}\right]^4 2{,}74$	$\kappa_x = 1{,}13\left[\frac{1}{\lambda} - \frac{0{,}22}{\lambda^2}\right]$ for $\lambda > 0{,}83$
		$\alpha \leq 1$	$K = \frac{4}{\alpha^2} + 2{,}07 + 0{,}67\,\alpha^2$	
10 	—	$\alpha \geq 4$	$K = 6{,}97$	
		$4 > \alpha > 1$	$K = 6{,}97 + \left[\frac{4-\alpha}{3}\right]^4 3{,}1$	
		$\alpha \leq 1$	$K = \frac{4}{\alpha^2} + 2{,}07 + 4\,\alpha^2$	

Explanations for boundary conditions
- - - - - - plate edge free
——— plate edge simply supported
━━━ plate edge clamped

Table 2.13 Curved plate field R/t ≤ 2500 [1]

Load case	Aspect ratio b / R	Buckling factor K	Reduction factor κ
1a 	$\frac{b}{R} \le 1{,}63\sqrt{\frac{R}{t}}$	$K = \frac{b}{\sqrt{R \cdot t}} + 3\,\frac{(R \cdot t)^{0{,}175}}{b^{0{,}35}}$	$\kappa_x = 1$ [2] for $\lambda \le 0{,}4$ $\kappa_x = 1{,}274 - 0{,}686\,\lambda$ for $0{,}4 < \lambda \le 1{,}2$ $\kappa_x = \frac{0{,}65}{\lambda^2}$ for $\lambda > 1{,}2$
1b  p_e = external pressure in [N/mm²]	$\frac{b}{R} > 1{,}63\sqrt{\frac{R}{t}}$	$K = 0{,}3\,\frac{b^2}{R^2} + 2{,}25\left(\frac{R^2}{b \cdot t}\right)^2$	
2 	$\frac{b}{R} \le 0{,}5\sqrt{\frac{R}{t}}$	$K = 1 + \frac{2}{3}\,\frac{b^2}{R \cdot t}$	$\kappa_y = 1$ [2] for $\lambda \le 0{,}25$ $\kappa_y = 1{,}233 - 0{,}933\,\lambda$ for $0{,}25 < \lambda \le 1$ $\kappa_y = 0{,}3 / \lambda^3$ for $1 < \lambda \le 1{,}5$ $\kappa_y = 0{,}2 / \lambda^2$ for $\lambda > 1{,}5$
	$\frac{b}{R} > 0{,}5\sqrt{\frac{R}{t}}$	$K = 0{,}267\,\frac{b^2}{R \cdot t}\left[3 - \frac{b}{R}\sqrt{\frac{t}{R}}\right]$ $\ge 0{,}4\,\frac{b^2}{R \cdot t}$	
3 	$\frac{b}{R} \le \sqrt{\frac{R}{t}}$	$K = \frac{0{,}6 \cdot b}{\sqrt{R \cdot t}} + \frac{\sqrt{R \cdot t}}{b} - 0{,}3\,\frac{R \cdot t}{b^2}$	as in load case 1a
	$\frac{b}{R} > \sqrt{\frac{R}{t}}$	$K = 0{,}3\,\frac{b^2}{R^2} + 0{,}291\left(\frac{R^2}{b \cdot t}\right)^2$	
4 	$\frac{b}{R} \le 8{,}7\sqrt{\frac{R}{t}}$	$K = K_\tau \cdot \sqrt{3}$ $K_\tau = \left[28{,}3 + \frac{0{,}67 \cdot b^3}{R^{1{,}5} \cdot t^{1{,}5}}\right]^{0{,}5}$	$\kappa_\tau = 1$ for $\lambda \le 0{,}4$ $\kappa_\tau = 1{,}274 - 0{,}686\,\lambda$ for $0{,}4 < \lambda \le 1{,}2$ $\kappa_\tau = \frac{0{,}65}{\lambda^2}$ for $\lambda > 1{,}2$
	$\frac{b}{R} > 8{,}7\sqrt{\frac{R}{t}}$	$K_\tau = 0{,}28\,\frac{b^2}{R\sqrt{R \cdot t}}$	

Explanations for boundary conditions:
- - - - - plate edge free
——— plate edge simply supported
▬▬▬ plate edge clamped

1 For curved plate fields with a very large radius the κ-value need not to be taken less than one derived for the expanded plane field.

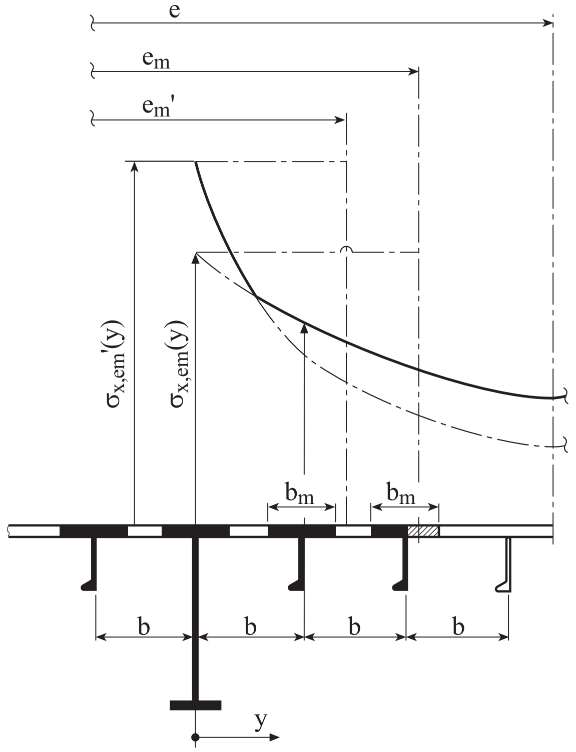
2 For curved single fields. e.g. the bilge strake, which are located within plane partial or total fields, the reduction factor κ may taken as follow:

Load case 1b: $\kappa_x = 0{,}8/\lambda^2 \le 1{,}0$: load case 2: $\kappa_y = 0{,}65/\lambda^2 \le 1{,}0$

Note

The effective width e'_m of stiffened flange plates of girders may be determined as follows:

Stiffening parallel to web of girder:



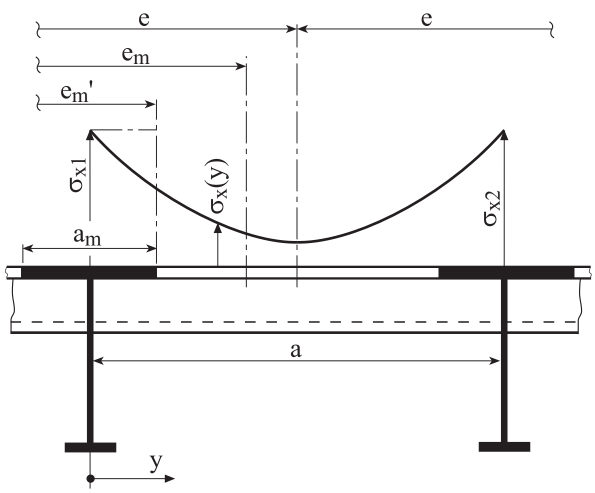
$b < e_m$

$e'_m = n \cdot b_m$

n = *integer number of the stiffener spacing b inside the effective breadth* e_m

$= int\left(\frac{e_m}{b}\right)$

Stiffening perpendicular to web of girder:



$a \geq e_m$

$e'_m = n \cdot a_m < e_m$

$n = 2{,}7 \cdot \frac{e_m}{a} \leq 1$

e = *width of plating supported according to B.4.3 and B.5.2*

For $b \geq e_m$ or $a < e_m$ respectively, b and a have to be exchanged.

a_m and b_m for flange plates are in general to be determined for $\psi = 1$.

Stress distribution between two girders:

$$\sigma_x(y) = \sigma_{x1} \cdot \left\{1 - \frac{y}{e}\left[3 + c_1 - 4 \cdot c_2 - 2\frac{y}{e}\left(1 + c_1 - 2c_2\right)\right]\right\}$$

$c_1 = \frac{\sigma_{x2}}{\sigma_{x1}} \qquad 0 \leq c_1 \leq 1$

$c_2 = \frac{1{,}5}{e} \cdot \left(e''_{m1} + e''_{m2}\right) - 0{,}5$

$e''_{m1} = \frac{e'_{m1}}{e_{m1}}$

$e''_{m2} = \frac{e'_{m2}}{e_{m2}}$

σ_{x1}, σ_{x2} = *normal stresses in flange plates of adjacent girder 1 and 2 with spacing e*

y = *distance of considered location from girder 1*

Scantlings of plates and stiffeners are in general to be determined according to the maximum stresses σ_x(y) at girder webs and stiffeners respectively. For stiffeners under compression arranged parallel to the girder web with spacing b, no lesser value than $0{,}25 \cdot R_{eH}$ shall be inserted for σ_x(y=b).

Shear stress distribution in the flange plates may be assumed linearly.

2.3 Webs and flanges

For non-stiffened webs and flanges of sections and girders, proof of sufficient buckling strength is to be provided as for single plate fields according to 2.1.

Note

Within 0,6 ***L*** *amidships, the following guidance values are recommended for the ratio of web depth to web thickness and/or flange breadth to flange thickness:*

$$\text{flat bars}: \frac{h_w}{t_w} \le 19{,}5\,\sqrt{k}$$

angle, tee and bulb sections:

$$\text{web}: \frac{h_w}{t_w} \le 60{,}0\,\sqrt{k}$$

$$\text{flange}: \frac{b_i}{t_f} \le 19{,}5\,\sqrt{k}$$

b_i = *b_1 or b_2 according to Fig. 2.14, the larger value is to be taken.*

3. Proof of partial and total fields

3.1 Longitudinal and transverse stiffeners

Proof is to be provided that the continuous longitudinal and transverse stiffeners of partial and total plate fields comply with the conditions set out in 3.2 and 3.3.

3.2 Lateral buckling

$$\frac{\sigma_a + \sigma_b}{R_{eH}} S \le 1$$

σ_a = uniformly distributed compressive stress in the direction of the stiffener axis [N/mm²]

= σ_x for longitudinal stiffeners

= σ_y for transverse stiffeners

σ_b = bending stress in the stiffeners

$$= \frac{M_o + M_1}{W_{st} \cdot 10^3} \quad [\mathrm{N/mm^2}]$$

M_o = bending moment due to deformation w of stiffener

$$= F_{Ki} \frac{p_z \cdot w}{c_f - p_z} \quad [\mathrm{N \cdot mm}]$$

$$(c_f - p_z) > 0$$

M_1 = bending moment due to the lateral load p

for continuous longitudinal stiffeners:

$$= \frac{p \cdot b \cdot a^2}{24 \cdot 10^3} \quad [\mathrm{N \cdot mm}]$$

for transverse stiffeners:

$$= \frac{p \cdot a\,(n \cdot b)^2}{c_s \cdot 8 \cdot 10^3} \quad [\mathrm{N \cdot mm}]$$

p = lateral load [kN/m²] according to Section 3

F_{Ki} = ideal buckling force of the stiffener [N]

$$F_{Kix} = \frac{\pi^2}{a^2} E \cdot I_x \cdot 10^4 \quad \text{for long. stiffeners}$$

$$F_{Kiy} = \frac{\pi^2}{(n \cdot b)^2} \cdot E \cdot I_y \cdot 10^4 \quad \text{for transv. stiffeners}$$

I_x, I_y = moments of inertia of the longitudinal or transverse stiffener including effective width of plating according to 2.2 [cm⁴]

$$I_x \ge \frac{b \cdot t^3}{12 \cdot 10^4}$$

$$I_y \ge \frac{a \cdot t^3}{12 \cdot 10^4}$$

p_z = nominal lateral load of the stiffener due to σ_x, σ_y and τ [N/mm²]

for longitudinal stiffeners:

$$p_{zx} = \frac{t_a}{b}\left(\sigma_{x1}\left(\frac{\pi \cdot b}{a}\right)^2 + 2 \cdot c_y \cdot \sigma_y + \sqrt{2}\,\tau_1\right)$$

for transverse stiffeners:

$$p_{zy} = \frac{t_a}{a}\left(2 \cdot c_x \cdot \sigma_{x1} + \sigma_y\left(\frac{\pi \cdot a}{n \cdot b}\right)^2\left(1 + \frac{A_y}{a \cdot t_a}\right) + \sqrt{2}\,\tau_1\right)$$

$$\sigma_{x1} = \sigma_x \left(1 + \frac{A_x}{b \cdot t_a}\right)$$

c_x, c_y = factor taking into account the stresses vertical to the stiffener's axis and distributed variable along the stiffener's length

$$= 0{,}5\,(1 + \psi) \quad \text{for} \quad 0 \le \psi \le 1$$

$$= \frac{0{,}5}{1 - \psi} \quad \text{for} \quad \psi < 0$$

ψ = edge stress ratio according to Table 3.3

A_x, A_y = sectional area of the longitudinal or transverse stiffener respectively [mm²]

$$\tau_1 = \left[\tau - t\sqrt{R_{eH} \cdot E\left(\frac{m_1}{a^2} + \frac{m_2}{b^2}\right)}\right] \ge 0$$

for longitudinal stiffeners:

$$\frac{a}{b} \geq 2,0 \ : \ m_1 = 1,47 \quad m_2 = 0,49$$

$$\frac{a}{b} < 2,0 \ : \ m_1 = 1,96 \quad m_2 = 0,37$$

for transverse stiffeners:

$$\frac{a}{n \cdot b} \geq 0,5 \ : \ m_1 = 0,37 \quad m_2 = \frac{1,96}{n^2}$$

$$\frac{a}{n \cdot b} < 0,5 \ : \ m_1 = 0,49 \quad m_2 = \frac{1,47}{n^2}$$

w = $w_o + w_1$

w_o = assumed imperfection [mm]

$$\frac{a}{250} \geq w_{ox} \leq \frac{b}{250} \quad \text{for long. stiffeners}$$

$$\frac{n \cdot b}{250} \geq w_{oy} \leq \frac{a}{250} \quad \text{for transv. stiffeners}$$

however $w_o \leq 10$ mm

Note

For stiffeners sniped at both ends, w_o shall not be taken less than the distance from the midpoint of plating to the neutral axis of the profile including effective width of plating.

w_1 = deformation of stiffener due to lateral load p at midpoint of stiffener span [mm]

In case of uniformly distributed load, the following values for w_1 may be used:

for longitudinal stiffeners:

$$w_1 = \frac{p \cdot b \cdot a^4}{384 \cdot 10^7 \cdot E \cdot I_x}$$

for transverse stiffeners:

$$w_1 = \frac{5 \cdot a \cdot p\left(n \cdot b\right)^4}{384 \cdot 10^7 \cdot E \cdot I_y \cdot c_s^2}$$

c_f = elastic support provided by the stiffener [N/mm²]

$$c_{fx} = F_{Kix} \cdot \frac{\pi^2}{a^2} \cdot \left(1 + c_{px}\right) \quad \text{for long. stiffeners}$$

$$c_{px} = \frac{1}{1 + \frac{0,91}{c_{x\alpha}} \cdot \left(\frac{12 \cdot 10^4 \cdot I_x}{t^3 \cdot b} - 1\right)}$$

$$c_{x\alpha} = \left[\frac{a}{2\ b} + \frac{2\ b}{a}\right]^2 \quad \text{for} \quad a \geq 2\ b$$

$$= \left[1 + \left(\frac{a}{2\ b}\right)^2\right]^2 \quad \text{for} \quad a < 2\ b$$

$$c_{fy} = c_s \cdot F_{Kiy} \cdot \frac{\pi^2}{\left(n \cdot b\right)^2} \cdot \left(1 + c_{py}\right)$$

for transv. stiffeners

c_s = factor accounting for the boundary conditions of the transverse stiffener

= 1,0 for simply supported stiffeners

= 2,0 for partially constrained stiffeners

$$c_{py} = \frac{1}{1 + \frac{0,91}{c_{y\alpha}} \cdot \left(\frac{12 \cdot 10^4 \cdot I_y}{t^3 \cdot a} - 1\right)}$$

$$c_{y\alpha} = \left[\frac{n \cdot b}{2\ a} + \frac{2\ a}{n \cdot b}\right]^2 \quad \text{for} \quad n \cdot b \geq 2\ a$$

$$= \left[1 + \left(\frac{n \cdot b}{2\ a}\right)^2\right]^2 \quad \text{for} \quad n \cdot b < 2\ a$$

W_{st} = section modulus of stiffener (long. or transverse) [cm³] including effective width of plating according to 2.2

If no lateral load p is acting the bending stress σ_b is to be calculated at the midpoint of the stiffener span for that fibre which results in the largest stress value. If a lateral load p is acting, the stress calculation is to be carried out for both fibres of the stiffener's cross sectional area (if necessary for the biaxial stress field at the plating side).

Note

Longitudinal and transverse stiffeners not subjected to lateral load p have sufficient scantlings if their moments of inertia I_x and I_y are not less than obtained by the following formulae:

$$I_x = \frac{p_{zx} \cdot a^2}{\pi^2 \cdot 10^4}\left(\frac{w_{ox} \cdot h_w}{\frac{R_{eH}}{S} - \sigma_x} + \frac{a^2}{\pi^2 \cdot E}\right) \quad [cm^4]$$

$$I_y = \frac{p_{zy} \cdot \left(n \cdot b\right)^2}{\pi^2 \cdot 10^4}\left(\frac{w_{oy} \cdot h_w}{\frac{R_{eH}}{S} - \sigma_y} + \frac{\left(n \cdot b\right)^2}{\pi^2 \cdot E}\right) \quad [cm^4]$$

3.3 Torsional buckling

3.3.1 Longitudinal stiffeners

$$\frac{\sigma_x \cdot S}{\kappa_T \cdot R_{eH}} \le 1,0$$

κ_T = 1,0 for $\lambda_T \le 0,2$

$$= \frac{1}{\phi + \sqrt{\phi^2 - \lambda_T^2}} \quad \text{for} \quad \lambda_T > 0,2$$

$$\phi = 0,5\left(1 + 0,21\left(\lambda_T - 0,2\right) + \lambda_T^2\right)$$

λ_T = reference degree of slenderness

$$= \sqrt{\frac{R_{eH}}{\sigma_{KiT}}}$$

$$\sigma_{KiT} = \frac{E}{I_P}\left(\frac{\pi^2 \cdot I_\omega \cdot 10^2}{a^2}\varepsilon + 0,385 \cdot I_T\right) \quad [\text{N/mm}^2]$$

For I_P, I_T, I_ω see Fig. 2.14 and Table 2.14.

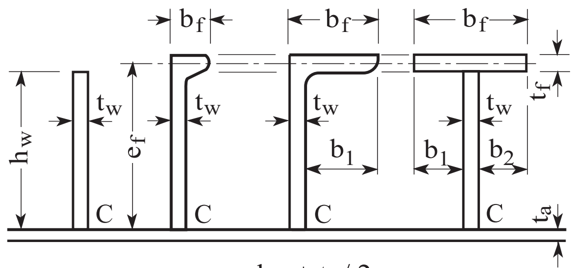


Fig. 2.14 Main dimensions of typical longitudinal stiffeners

I_P = polar moment of inertia of the stiffener related to the point C [cm^4]

I_T = St. Venant's moment of inertia of the stiffener [cm^4]

I_ω = sectorial moment of inertia of the stiffener related to the point C [cm^6]

ε = degree of fixation

$$= 1 + 10^{-4}\sqrt{\frac{a^4}{I_\omega\left(\frac{b}{t^3} + \frac{4\,h_w}{3\,t_w^3}\right)}}$$

h_w = web height [mm]

t_w = web thickness [mm]

b_f = flange breadth [mm]

t_f = flange thickness [mm]

A_w = web area $h_w \cdot t_w$

A_f = flange area $b_f \cdot t_f$

3.3.2 Transverse stiffeners

For transverse stiffeners loaded by compressive stresses and which are not supported by longitudinal stiffeners, proof is to be provided in accordance with 3.3.1 analogously.

Table 2.14 Formulae for the calculation of moments of inertia I_P, I_T and I_ω

Section	I_P	I_T	I_ω
Flat bar	$\frac{h_w^3 \cdot t_w}{3 \cdot 10^4}$	$\frac{h_w \cdot t_w^3}{3 \cdot 10^4}\left(1 - 0,63\frac{t_w}{h_w}\right)$	$\frac{h_w^3 \cdot t_w^3}{36 \cdot 10^6}$
Sections with bulb or flange	$\left(\frac{A_w \cdot h_w^2}{3} + A_f \cdot e_f^2\right)10^{-4}$	$\frac{h_w \cdot t_w^3}{3 \cdot 10^4}\left(1 - 0,63\frac{t_w}{h_w}\right)$ + $\frac{b_f \cdot t_f^3}{3 \cdot 10^4}\left(1 - 0,63\frac{t_f}{b_f}\right)$	for bulb and angle sections: $\frac{A_f \cdot e_f^2 \cdot b_f^2}{12 \cdot 10^6}\left(\frac{A_f + 2,6\,A_w}{A_f + A_w}\right)$ for tee-sections: $\frac{b_f^3 \cdot t_f \cdot e_f^2}{12 \cdot 10^6}$

D. Strength Check in Testing Conditions

1. Symbols

t = net thickness [mm] of plating

w = net section modulus [cm^3] of ordinary stiffeners

A_{sh} = net web sectional area [cm^2]

k = material factor defined in A.2.4 and A.3.2

s = spacing [m] of ordinary stiffeners

S = spacing [m] of primary supporting members

ℓ = span [m] of stiffeners

η = $1 - s / (2 \cdot \ell)$

z = Z co-ordinate [m] of the calculation point

z_{TOP} = Z co-ordinate [m] of the highest point of the tank

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

p_{pv} = setting pressure [kN/m^2] of safety valves or maximum pressure [kN/m^2] in the tank during loading/unloading, whichever is the greater

d_{AP} = distance from the top of air pipe to the top of the compartment [m]

p_{ST} = testing pressure [kN/m^2] defined in 3.

σ_1 = hull girder normal stress [N/mm^2] to be determined in testing conditions.

2. Strength check

2.1 General

The requirements of this Section provide the minimum scantlings of platings and structural members of compartments subjected to testing conditions.

Where the test conditions are subject to induce additional loads, the strength check is to be carried out by direct calculation.

These requirements are not applicable to bottom shell plating and side shell plating.

2.2 Plating

The net thickness [mm] of plating of compartments or structures defined in Table 2.16 is to be not less than:

$$t = s \cdot \sqrt{k \cdot p_{ST}}$$

where the testing pressure p_{ST} is defined in 3.

2.3 Structural members

The net section modulus w [cm^3] and the net shear sectional area A_{sh} [cm^2] of structural members of compartments or structures defined in Table 2.16 are to be not less than the values obtained from the formulae given in Table 2.17.

Table 2.15 Resistance partial safety factors γ_R

Structures	Ordinary stiffeners	Primary supporting members
Fore peak structures	1,25	1,25
Structures located aft of the collision bulkhead	1,02	1,02 [1] 1,15 [2]
[1] in general [2] for bottom and side girders.		

3. Testing pressures

3.1 Still water pressure

The still water pressure to be considered as acting on plates and stiffeners subjected to tank testing is to be obtained, in [kN/m^2], from the formulae in Table 2.16.

The testing conditions of tanks and watertight or weathertight structures are determined by requirements of Section 8, C.

Table 2.16 Testing – Still water pressures

Compartment or structure to be tested	Still water pressure p_{ST} [kN/m^2]
Double bottom tanks	$p_{ST} = 9{,}81 \cdot \left[(Z_{TOP} - Z) + d_{AP}\right]$
Double side tanks Fore peaks used as tank After peaks used as tank	The greater of the following: $p_{ST} = 9{,}81 \cdot \left[(Z_{TOP} - Z) + d_{AP}\right]$ $p_{ST} = 9{,}81 \cdot \left[(Z_{TOP} - Z) + 1\right]$
Cargo tank bulkheads Deep tanks Independent cargo tanks Residual cargo tanks	The greater of the following: $p_{ST} = 9{,}81 \cdot \left[(Z_{TOP} - Z) + d_{AP}\right]$ $p_{ST} = 9{,}81 \cdot \left[(Z_{TOP} - Z) + 1\right]$ $p_{ST} = 9{,}81 \cdot (Z_{TOP} - Z) + 1{,}3 \cdot p_{pv}$
Ballast compartments Fuel oil bunkers Cofferdams	The greater of the following: $p_{ST} = 9{,}81 \cdot \left[(Z_{TOP} - Z) + d_{AP}\right]$ $p_{ST} = 9{,}81 \cdot \left[(Z_{TOP} - Z) + 1\right]$
Double bottom Fore peaks not used as tank After peaks not used as tank	$p_{ST} = 9{,}81 \cdot (Z_{AP} - Z)$
Other independent tanks	The greater of the following: $p_{ST} = 9{,}81 \cdot \left[(Z_{TOP} - Z) + d_{AP}\right]$ $p_{ST} = 9{,}81 \cdot \left[(Z_{TOP} - Z) + 2{,}4\right]$

Table 2.17 Strength check of stiffeners in testing conditions

Stiffener	w	A_{sh}
Vertical stiffeners	$w = \dfrac{4{,}36 \cdot \gamma_R}{m} k \cdot \lambda_b \cdot \beta_b \cdot p_{ST} \cdot \eta_1 \cdot a \cdot \ell^2$	$A_{sh} = 0{,}045 \cdot \gamma_R \cdot k \cdot \lambda_s \cdot \beta_s \cdot \eta_1 \cdot p_{ST} \cdot a \cdot \ell$
Transverse stiffeners Longitudinal stiffeners	$w = \dfrac{4{,}36 \cdot \gamma_R}{m} \cdot k \cdot \beta_b \cdot p_{ST} \cdot \eta_1 \cdot a \cdot \ell^2$	$A_{sh} = 0{,}045 \cdot \gamma_R \cdot k \cdot \beta_s \cdot \eta_1 \cdot p_{ST} \cdot a \cdot \ell$
Longitudinal stiffeners (in case of testing afloat)	$w = \dfrac{1000}{m \cdot \left(\dfrac{230}{\gamma_R} - \sigma_1\right)} \cdot k \cdot \beta_b \cdot \eta_1 \cdot p_{ST} \cdot a \cdot \ell^2$	

a = s for ordinary stiffeners
= S for primary supporting members
η_1 = η for ordinary stiffeners
= 1 for primary supporting members
β_b, β_S = bracket coefficients defined in B.6.2
λ_b, λ_S = coefficients for vertical structural members defined in B.6.3
γ_R = resistance partial safety factor defined in Table 2.15
m = boundary coefficient, to be taken equal to:
= 12 in general, for stiffeners considered as clamped
= 8 for stiffeners considered as simply supported
= 10,6 for stiffeners clamped at one end and simply supported at the other

E. Direct Calculation

1. Symbols

R_{eH} = minimum yielding stress [N/mm^2] of the material

γ_R = partial safety factor covering uncertainties regarding resistance, defined in Table 2.18.

2. General

2.1 Application

2.1.1 The following requirements give direct calculation guidance for the yielding and buckling checks of structural members.

Direct calculation may be adopted instead of Rule scantling formulae or for the analysis of structural members not covered by the Rules.

2.1.2 Yielding check

The yielding check is to be carried out according to:

– 3. for structural members analysed through isolated beam models

– 4. for structural members analysed through three dimensional beam or finite element models

2.1.3 Buckling check

The buckling check is to be carried out according to C. on the basis of the stresses in primary supporting members calculated according to 3. or 4. depending on the structural model adopted.

2.2 Analysis documentation

2.2.1 The following documents are to be submitted to GL for review/approval of the three dimensional beam or finite element structural analyses:

– reference to the calculation program used with identification of the version number and results of the validation test, if the results of the program have not been already submitted to GL approval

– extent of the model, element types and properties, material properties and boundary conditions

– loads given in print-out or suitable electronic format. In particular, the method used to take into account the interaction between the overall, primary and local loadings is to be described. The direction and intensity of pressure loads, concentrated loads, inertia and weight loads are to be provided

– stresses given in print-out or suitable electronic format

– buckling checks

– identification of the critical areas, where the results of the checkings exceed 97,5 % of the permissible Rule criteria in 4.3 and C.

2.2.2 According to the results of the submitted calculations, GL may request additional runs of the model with structural modifications or local mesh refinements in highly stressed areas.

2.3 Net scantlings

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 B.7.

2.4 Resistance partial safety factors

The values of resistance partial safety factor covering uncertainties on resistance to be considered for checking structural members are specified in Table 2.18 for analyses based on different calculation models.

Table 2.18 Resistance partial safety factor γ_R

Calculation model	Yielding check		Buckling check
	General	Watertight bulkhead	
Isolated beam model: – in general – bottom and side girders – collision bulkhead	 1,02 1,15 NA [1]	 1,02 NA [1] 1,25	1,10
Three dimensional beam model	1,20	1,02	1,02
Coarse mesh finite element model	1,20	1,02	1,02
Fine mesh finite element model	1,05	1,02	1,02

[1] NA = not applicable.

3. Yielding check of structural members analysed through an isolated beam structural model

3.1 General

3.1.1 The following requirements apply for the yielding check of structural members subjected to lateral pressure or to wheeled loads and, for those contributing to the hull girder longitudinal strength, to hull girder normal stresses, which may be analysed through an isolated beam model.

3.1.2 The yielding check is also to be carried out for structural members subjected to specific loads, such as concentrated loads.

3.2 Load point

3.2.1 Lateral pressure

Unless otherwise specified, lateral pressure is to be calculated at mid-span of the structural member considered.

3.2.2 Hull girder normal stresses

For longitudinal structural members contributing to the hull girder longitudinal strength, the hull girder normal stresses are to be calculated in way of the neutral axis of the structural member with attached plating.

3.3 Load model

3.3.1 General

The external pressure and the pressures induced by the various types of cargoes and ballast are to be considered, depending on the location of the structural member under consideration and the type of compartments adjacent to it, in accordance with Section 3, C.

3.3.2 Pressure load in service conditions

The pressure load in service conditions is to be determined according to Section 3, C.4. and C.5.

3.3.3 Wheeled loads

For structural members subjected to wheeled loads, the yielding check may be carried out according to 3.4 considering uniform pressures equivalent to the distribution of vertical concentrated forces, when such forces are closely located, taking into account the most unfavourable case.

3.3.4 Hull girder normal stresses

The hull girder normal stresses to be considered for the yielding check of structural members are to be determined according to Section 4, C.3.4.

3.4 Checking criteria

It is to be checked that the normal stress σ and the shear stress τ are in compliance with the following formulae:

$$0{,}98 \cdot \frac{R_{eH}}{\gamma_R} \geq \sigma$$

$$0{,}49 \cdot \frac{R_{eH}}{\gamma_R} \geq \tau$$

4. Yielding check of structural members analysed through a three dimensional structural model

4.1 General

4.1.1 The following requirements apply for the yielding check of structural members subjected to lateral pressure or to wheeled 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.

4.1.2 The yielding check is also to be carried out for structural members subjected to specific loads, such as concentrated loads.

4.2 Analysis criteria

The analysis of structural members based on three dimensional models is to be carried out according to:

– the requirements in G. for structural members subjected to lateral pressure

– the requirements in H. for structural members subjected to wheeled loads.

4.3 Checking criteria

4.3.1 General

For all types of analysis (see G.2.), it is to be checked that the equivalent Von Mises stress σ_{VM}, calculated according to G.5. is in compliance with the following formula:

$$0,98 \cdot \frac{R_{eH}}{\gamma_R} \geq \sigma_{VM}$$

4.3.2 Additional criteria for analyses based on fine mesh finite element models

Fine mesh finite element models are defined with reference to G.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 G.5. are in compliance with the following formulae:

$$0,98 \cdot \frac{R_{eH}}{\gamma_R} \geq MAX(\sigma_1;\sigma_2)$$

$$0,49 \cdot \frac{R_{eH}}{\gamma_R} \geq \tau_{12}$$

4.3.3 Specific case of structural members subjected to wheeled loads

For all types of analysis (see H.), it is to be checked that the equivalent Von Mises stress σ_{VM}, calculated according to H. is in compliance with the following formula:

$$0,98 \cdot \frac{R_{eH}}{\gamma_R} \geq \sigma_{VM}$$

5. Torsion

5.1 Torsion of catamarans

A method for the determination of scantlings of deck beams connecting the hulls of a catamaran subject to torsional moment is given in I.

F. Geometric Properties of Standard Sections

1. Angles, flats and bulb flats

1.1 Notice

1.1.1 Table 2.19 and Tab 2.20 give main characteristics of angles, bulb flats and flats currently used, with an attached plating 500 mm wide having a thickness equal to that of the section web.

1.1.2 The sections are listed in the order of increasing values of the section moduli. For each section, the data are listed in the following order:

– dimensions of the rolled section [mm]

– then, between brackets:

  – the sectional area [cm^2] of the section

  – the section modulus [cm^3] with the attached plating defined in 1.1.1

  – the mean variation of the section modulus [cm^3] for each 10 % variation in sectional area of the attached plating

The values shown in Table 2.19 and Table 2.20 are, as a rule, valid for sectional area of the attached plating variations not exceeding 50 %.

1.1.3 Examples

a) Consider a DIN bulb flat 200 x 9 welded to a 600 x 10 plating. The data shown in Table 2.19 are:

200 x 9 (23,60 209,1 1,98)

23,60 = sectional area [cm^2] of the section

209,1 = section modulus [cm^3] with an attached plating 9 mm thick and 500 mm wide

1,98 = mean increase of the section modulus for each 10 % increase in sectional area of the attached plating.

The section modulus obtained is thus equal to:

209,1 + 1,98·(60 – 45)·10/45 = 215,7 cm^3

b) If the same bulb flat is attached to a 400 x 8 plating, then the section modulus will be:

209,1 + 1,98·(32 – 45)·10/45 = 203,4 cm^3

2. Channels

2.1 Notice

2.1.1 Table 2.21 gives main characteristics of European standard channels currently used, with an attached plating 500 mm wide having a thickness equal to that of the channel web (a).

2.1.2 The channels are listed in the order of increasing values of the section moduli. For each channel, the data are listed in the following order:

– standard designation of the channel section

– dimensions of the channel [mm]

– sectional area [cm^2] of the channel

– section modulus [cm^3] with the attached plating defined in 2.1.1

Table 2.19 Geometric particulars with 500 mm wide attached plating of standard DIN unequal angles and bulb flats

w [cm^3]	Unequal angles	Bulb flats
2	30 x 20 x 3 (1,42 2,5 0,02)	
3	40 x 20 x 3 (1,72 3,7 0,02)	
4	40 x 20 x 4 (2,25 4,8 0,04)	
5	45 x 30 x 3 (2,19 5,7 0,03)	
7	45 x 30 x 4 (2,87 7,5 0,05)	
9	45 x 30 x 5 (3,53 9,1 0,08)	
10	50 x 40 x 4 (3,46 10,5 0,06) 50 x 30 x5 (3,78 10,6 0,08)	
11		60 x 4 (3,58 11,0 0,07)
12	50 x 40 x 5 (4,27 12,8 0,1)	60 x 5 (4,18 12,4 0,09)
13	60 x 30 x 5 (4,29 13,7 0,1)	
14		60 x 6 (4,78 14,0 0,13)
16	60 x 40 x 5 (4,79 16,5 0,11)	
18	60 x 30 x 7 (5,85 18,5 0,18)	
19	60 x 40 x 6 (5,68 19,4 0,15)	
20		80 x 5 (5,4 20,6 0,14)
21	65 x 50 x 5 (5,54 21,4 0,14)	
22	60 x 40 x 7 (6,55 22,4 0,2)	
23		80 x 6 (6,2 23,2 0,18)
25	75 x 50 x 5 (6,04 25,9 0,16)	80 x 7 (7,0 25,7 0,22)
27	75 x 55 x 5 (6,30 27,8 0,17)	
29	80 x 40 x 6 (6,89 29,1 0,2) 65 x 50 x 7 (7,60 29,2 0,24)	
35	75 x 50 x 7 (8,3 35,3 0,27)	100 x 6 (7,74 35,4 0,26)
36	65 x 50 x 9 (9,58 36,5 0,38)	
37	80 x 40 x 8 (9,01 37,7 0,33) 75 x 55 x 7 (8,66 37,7 0,29)	
39		100 x 7 (8,74 39,2 0,31)
40	80 x 65 x 6 (8,41 40,4 0,27)	
43		100 x 8 (9,74 43,0 0,38)
44	75 x 50 x 9 (10,5 44,4 0,43) 90 x 60 x 6 (8,69 44,4 0,29)	
46	100 x 50 x 6 (8,73 46,0 0,31)	
47	75 x 55 x 9 (10,9 47,3 0,44)	
50		120 x 6 (9,31 50,6 0,38)
52	80 x 65 x 8 (11,0 52,4 0,42)	
55		120 x 7 (10,5 55,7 0,44)
57	90 x 60 x 8 (11,4 57,8 0,46)	
59	100 x 50 x 8 (11,5 59,9 0,48)	
60	90 x 75 x 7 (11,1 60,0 0,42)	120 x 8 (11,7 60,9 0,52)
63	100 x 65 x 7 (11,2 63,0 0,45)	
64	80 x 65 x 10 (13,6 64,2 0,63)	
69	100 x 75 x 7 (11,9 69,5 0,49)	
73	100 x 50 x 10 (14,1 73,0 0,67)	
77		140 x 7 (12,6 77,6 0,64)
79	100 x 65 x 9 (14,2 79,1 0,66)	
83		140 x 8 (13,8 83,7 0,71)
87	100 x 75 x 9 (15,1 87,3 0,72)	
90		140 x 9 (15,2 90,8 0,81)
94	100 x 65 x 11 (17,1 94,6 0,91)	
102	130 x 65 x 8 (15,1 102,0 0,79)	
104	100 x 75 x 11 (18,2 104,5 0,99) 120 x 80 x 8 (15,5 104,6 0,79)	160 x 7 (14,6 104,7 0,87)
111	130 x 75 x 8 (15,9 111,3 0,85)	
113		160 x 8 (16,2 113,5 0,98)
122		160 x 9 (17,8 122,5 1,11)
124	130 x 65 x 10 (18,6 124,7 1,07)	
127	120 x 80 x 10 (19,1 127,9 1,08)	
136	130 x 75 x 10 (19,6 136,2 1,16)	
146	130 x 65 x 12 (22,1 146,9 1,41)	
150	150 x 75 x 9 (19,5 150,4 1,23) 120 x 80 x 12 (22,7 150,9 1,43)	
151		180 x 8 (18,9 151,9 1,36)
154	130 x 90 x 10 (21,2 154,9 1,30)	
160	130 x 75 x 12 (23,3 106,8 1,52)	
162		180 x 9 (20,7 162,2 1,51)
173	120 x 80 x14 (26,2 173,1 1,82)	

Table 2.19 Geometric particulars with 500 mm wide attached plating of standard DIN unequal angles and bulb flats *(continued)*

w [cm^3]	Unequal angles	Bulb flats
174		180 x 10 (22,5 174,5 1,67)
180	150 x 75 x 11 (23,6 180,7 1,62)	
182	130 x 90 x 12 (25,1 182,1 1,69)	
186		180 x 11 (24,3 186,4 1,85)
187	150 x 90 x 10 (23,2 187,5 1,59)	
190	160 x 80 x 10 (23,2 190,1 1,65)	
201	150 x 100 x 10 (24,2 201,3 1,70)	
209		200 x 9 (23,6 209,1 1,98)
220	150 x 90 x 12 (27,5 220,8 2,04)	
222		200 x 10 (25,6 222,0 2,17)
224	160 x 80 x 12 (27,5 224 2,10)	
236		200 x 11 (27,6 236,8 2,38)
237	150 x 100 x 12 (28,7 237,2 2,17)	
240	180 x 90 x 10 (26,2 240,8 2,12)	
251		200 x 12 (29,6 251,3 2,61)
257	160 x 80 x 14 (31,8 257,2 2,60)	
272	150 x 100 x 14 (33,2 272,8 2,71)	
283		220 x 10 (29,0 283,8 2,83)
284	180 x 90 x 12 (31,2 284,9 2,68)	
297	200 x 100 x 10 (29,2 297,3 2,66)	
299		220 x 11 (31,2 299,0 3,07)
312		220 x 12 (33,4 312,9 3,32)
327	180 x 90 x 14 (36,1 327,3 3,31)	
344		240 x 10 (32,4 344,9 3,57)
351	200 x 100 x 12 (34,8 351,5 3,36)	
368		240 x 11 (34,9 368,9 3,88)
382	250 x 90 x 10 (33,2 382,0 3,74)	
386		240 x 12 (37,3 386,8 4,17)
404	200 x 100 x 14 (40,3 404,2 4,11)	
447		260 x 11 (38,7 447,0 4,83)
452	250 x 90 x 12 (39,6 452,6 4,65)	
456	200 x 100 x 16 (45,7 456,5 4,90)	
468		260 x 12 (41,3 468,5 5,18)
489		260 x 13 (43,9 489,5 5,52)
521	250 x 90 x 14 (45,9 521,3 5,60)	
532		280 x 11 (42,6 532,8 6,05)
560		280 x 12 (45,5 560,0 6,48)
584		280 x 13 (48,3 584,6 7,02)
588	250 x 90 x 16 (52,1 588,3 6,61)	
634		300 x 11 (46,7 634,4 7,26)
665		300 x 12 (49,7 665,7 7,8)
696		300 x 13 (52,8 696,0 8,45)
724		300 x 14 (55,8 724,5 8,96)
776		320 x 12 (54,2 776,9 9,24)
811		320 x 13 (57,4 811,6 9,88)
845		320 x 14 (60,7 845,6 10,64)
877		320 x 15 (63,9 877,4 11,25)
897		340 x 12 (58,8 897,2 10,08)
937		340 x 13 (62,2 937,7 11,57)
375		340 x 14 (65,5 975,2 12,32)
1012		340 x 15 (68,9 1012,2 13,05)
1153		370 x 13 (69,6 1153,7 14,43)
1192		370 x 14 (73,3 1192,4 15,26)
1238		370 x 15 (77,0 1238,3 16,2)
1310		370 x 16 (80,7 1310,9 1,12)

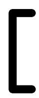
Table 2.20 Geometric particulars with 500 mm wide attached plating of standard DIN flats and equal angles

w [cm^3]	Flats	Equal angles
3	50 x 4 2,0 3,6 0,03)	
4	50 x 5 2,5 4,6 0,05)	
5	50 x 6 3,0 5,7 0,08)	
6	60 x 5 3,0 6,4 0,06) 55 x 6 3,3 6,7 0,08)	
7	60 x 6 3,6 7,8 0,09)	40 x 40 x 4 3,08 7,9 0,06)
9	65 x 6 3,9 9,1 0,1) 60 x 7 5,2 9,4 0,12)	40 x 40 x 5 3,79 9,7 0,09)
10		45 x 45 x 4 3,49 10,1 0,06)
11		40 x 40 x 6 4,48 11,5 0,13)
12	70 x 7 4,9 12,4 0,14) 65 x 8 5,2 12,6 0,17)	45 x 45 x 5 4,3 12,4 0,10)
14	70 x 8 5,6 14,4 0,18)	
16	75 x 8 6,0 16,3 0,20)	
18	80 x x8 6,4 18,3 0,21)	50 x 50 x 6 5,69 18,0 0,15) 55 x 55 x 5 5,32 18,7 0,13)
20		50 x 50 x 7 6,56 20,7 0,21)
21	75 x 10 7,5 21,1 0,31)	
22	90 x 8 7,2 22,8 0,24)	55 x 55 x 6 6,31 22,1 0,17) 60 x 60 x 5 5,82 22,3 0,14)
23	80 x 10 8,0 23,6 0,33)	50 x 50 x 8 7,41 23,5 0,27)
25	90 x 9 8,1 25,9 0,30)	
26		50 x 50 x9 (8,24 26,0 0,34) 60 x 60 x 6 (6,91 26,3 0,19)
27	100 x 8 8,0 27,7 0,28)	
28		55 x 55 x 8 (8,23 28,6 0,30)
29	90 x 10 9,0 29,2 0,37)	
31		65 x 65 x 6 (7,53 31,1 0,22)
34		60 x 60 x 8 (9,03 34,1 0,33)
35	100 x 10 10,0 35,4 0,42)	65 x 65 x 7 (8,7 35,7 0,29)
36		70 x 70 x 6 (8,13 36,1 0,25)
37	110 x 9 9,9 37,5 0,39)	
38	120 x 8 9,6 38,8 2,98)	
40		65 x 65 x 8 (9,85 40,2 0,36)
41		70 x 70 x 7 (9,40 41,5 0,32) 75 x 75 x 6 (8,75 41,7 0,28)
42	110 x 10 11,0 42,1 0,47)	
43	100 x 12 12,0 43,5 0,59)	
44		65 x 65 x 9 (11,0 44,7 0,45)
45	130 x 8 10,4 45,1 0,43)	
46	110 x 11 12,1 46,8 0,56)	70 x 70 x 8 (10,6 46,7 0,40)
47		75 x 75 x 7 (10 ,1 47,8 0,35)
49	120 x 10 12,0 49,5 0,54)	
51	130 x 9 11,7 51,2 0,52) 140 x 8 11,2 51,9 0,50)	
52		70 x 70 x 9 (11,9 52,1 0,49)
54		75 x 75 x 8 (11,5 54,1 0,45) 80 x 80 x 7 (10,8 54,5 0,39)
57	130 x 10 13,0 57,3 0,61)	70 x 70 x 10 (13,1 57,2 0,60)
59	150 x 8 12,0 59,0 0,57)	
60	120 x 12 14,4 60,5 0,74)	
61		80 x 80 x 8 (12,3 61,6 0,49)
62		70 x 70 x 11 (14,3 62,2 0,71)
63	130 x 11 14,3 63,6 0,72)	
65	140 x 10 14,0 65,8 0,70)	
66		75 x 75 x 10 (14,1 66,0 0,65)
70	130 x 12 15,6 70,0 0,83)	
74	150 x 10 15,0 74,8 0,79)	
75		80 x 80 x 10 (15,1 75,1 0,72)
77		75 x 75 x 12 (16,7 77,5 0,91)
78		90 x 90 x 8 (13,9 78,2 0,60)
80	140 x 12 16,8 80,2 0,93)	
87		90 x 90 x 9 (15,5 87,0 0,72)
88		80 x 80 x 12 (17,9 88,7 0,99)
91	150 x 12 18,0 91,1 1,05)	
95		90 x 90 x 10 (17,1 95,7 0,86)
97		100 x 100 x 8 (15,5 97,0 0,73)

Table 2.20 Geometric particulars with 500 mm wide attached plating of standard DIN flats and equal angles *(continued)*

w [cm^3]	Flats	Equal angles
101		80 x 80 x 14 (20,6 101,7 1,31)
104		90 x 90 x 11 (18,7 104,3 1,00)
107	150 x 14 21,0 107,8 1,34)	
112		90 x 90 x 12 (20,3 112,7 1,17)
116	150 x 15 22,5 116,3 1,51)	
119		100 x 100 x 10 (19,2 119,2 1,03)
120		90 x 90 x 13 (21,8 120,7 1,33)
140		100 x 100 x 12 (22,7 140,0 1,37)
145		90 x 90 x 16 (26,4 145,2 1,93)
160		100 x 100 x 14 (26,2 160,5 1,77)
170		100 x 100 x 15 (27,9 170,5 1,99)
180		100 x 100 x 16 (29,6 180,3 2,23)
219		100 x 100 x 20 (36,2 219,3 3,31)
237		130 x 130 x 12 (30,0 237,1 2,76)
244		120 x 120 x 15 (33,9 244,7 3,6)
271		130 x 130 x 14 (34,7 271,8 3,64)
296		140 x 140 x 13 (35,0 296,8 3,51)
305		130 x 130 x 16 (39,3 305,5 4,48)
317		150 x 150 x 12 (34,8 317,6 3,48)
336		140 x 140 x 15 (40,0 336,5 4,5)
364		150 x 150 x 14 (40,3 364,2 4,48)
387		150 x 150 x 15 (43,0 387,3 4,95)
409		150 x 150 x 16 (45,7 409,8 5,6)
442		160 x 160 x 15 (46,1 442,8 5,55)
454		150 x 150 x 18 (51,0 454,8 6,84)
498		150 x 150 x 20 (56,3 498,5 8,2)
544		160 x 160 x 19 (57,5 544,6 8,17)
595		180 x 180 x 16 (55,4 595,8 7,36)
661		180 x 180 x 18 (61,9 661,6 9,0)
725		180 x 180 x 20 (68,4 725,6 10,6)
736		200 x 200 x 16 (61,8 736,7 8,8)
787		180 x 180 x 22 (74,7 787,0 12,54)
818		200 x 200 x 18 (69,1 818,5 10,62)
898		200 x 200 x 20 (76,4 898,9 12,6)

Table 2.21 Geometric particulars with 500 mm wide attached plating of European standard channels

Shape	h x b x a [mm]	A [cm^2]	W [cm^3]	
				
UPN 8	80 x 45 x 6	11,0	35,8	28,4
UPN 10	100 x 50 x 6	13,5	54	38,9
UPN 12	120 x 55 x 7	17,0	80,5	56,1
UPN 14	140 x 60 x 7	20,4	111,9	72,0
UPN 16	160 x 65 x 7,5	24,0	149,0	93,2
UPN 18	180 x 70 x 8	28,0	193,5	118,1
UPN 20	200 x 75 x 8,5	32,2	245,1	147,3
UPN 22	220 x 80 x 9	37,4	311,4	181,2
UPN 24	240 x 85 x 9,5	42,3	380,9	218,1
UPN 26	260 x 90 x 10	48,3	468,4	261,8
UPN 28	280 x 95 x 10	53,4	557,3	300,1
UPN 30	300 x 100 x 10	58,8	656,5	340,7

G. Analyses Based on Three Dimensional Models

1. General

1.1 Application

1.1.1 The following requirements 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 E.

1.1.2 The following 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.

1.1.3 In some specific cases, some of simplifications or assumptions laid down below may not be deemed acceptable by GL in relation to the type of structural model and the analysis performed.

1.1.4 The yielding and buckling checks of primary supporting members are to be carried out according to E.

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 GL 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 The analysis of primary supporting members is to be carried out on fine mesh models, as defined in 3.4.3.

2.2.2 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 3.4.4.

2.3 Beam model analyses

2.3.1 Beam models may be adopted provided that:

– primary supporting members are not so stout that the beam theory is deemed inapplicable by GL

– their behaviour is not substantially influenced by the transmission of shear stresses through the shell plating.

In any case, finite element models are to be adopted when deemed necessary by GL on the basis of the vessel's structural arrangement.

3. Structural modelling of primary supporting members

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 Section 2, F. 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 The model may be limited to one cargo tank/hold length (one half cargo tank/hold length on either side of the transverse bulkhead; see Fig. 2.15).

However, larger models may need to be adopted when deemed necessary by GL on the basis of the vessel's structural arrangement.

3.2.3 In the case of structural symmetry with respect to the vessel's centreline longitudinal plane, the hull structures may be modelled over half the vessel's breadth.

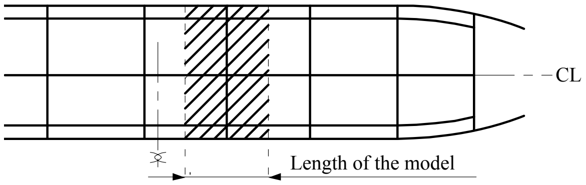


Fig. 2.15 Model longitudinal extension

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. 2.16), 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.

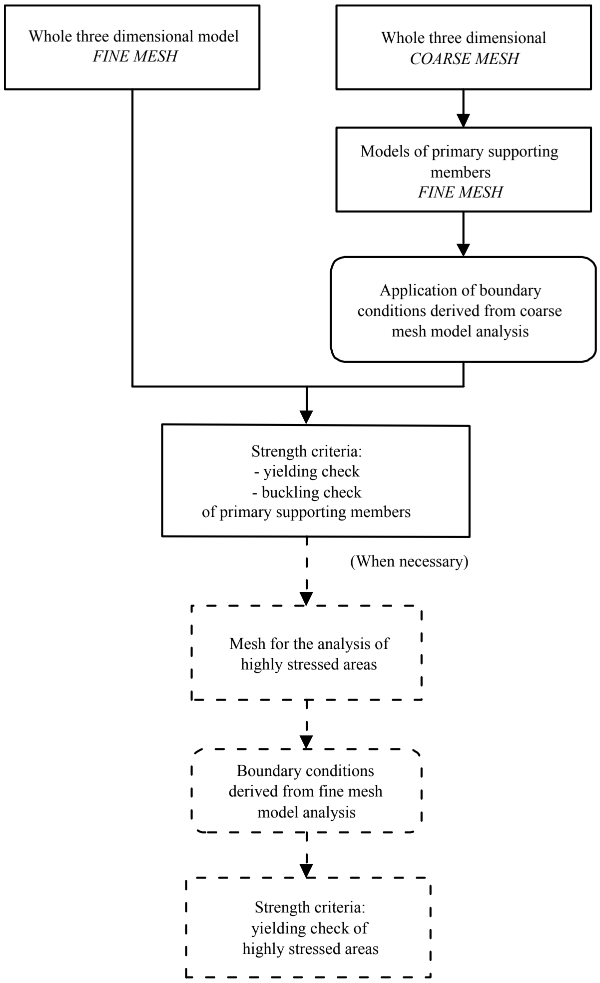


Fig. 2.16 Finite element modelling criteria

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.

3.4.3 Fine mesh

The vessel'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 GL 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.

3.5.2 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.

3.5.3 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

3.5.4 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 one end, while shear forces and bending moments are applied at the other end to ensure equilibrium (see 4.).

At the free 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 vessel's breadth (see 3.2.3), in way of the vessel's centreline longitudinal plane, symmetry or anti-symmetry boundary conditions as specified in Table 2.22 are to be applied, depending on the loads applied to the model (symmetrical or anti-symmetrical, respectively).

Table 2.22 Symmetry and anti-symmetry conditions in way of the vessel'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	free	fixed	free
Anti-symmetry	fixed	free	fixed

1 X, Y and Z directions and axes are defined with respect to the reference co-ordinate system in Section 1, A.1.4

3.6.2 Structural models extended over one cargo tank/hold length

Symmetry conditions are to be applied at the fore and aft ends of the model, as specified in Table 2.23.

When the hull structure is modelled over half the vessel's breadth (see 3.2.3), in way of the vessel's centreline longitudinal plane, symmetry or anti-symmetry boundary conditions as specified in Table 2.22 are to be applied, depending on the loads applied to the model (symmetrical or anti-symmetrical, respectively).

Vertical supports are to be fitted at the nodes positioned in way of the connection of the transverse bulkheads with longitudinal bulkheads, if any, or with sides.

Table 2.23 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 Section 1, A.1.4

4. Primary supporting members load model

4.1 General

4.1.1 Loading conditions and load cases in service conditions

The loads are to be calculated for the most severe loading conditions, 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

4.1.2 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.

4.1.3 Models extended over half vessel's breadth

When the vessel is symmetrical with respect to its centreline longitudinal plane and the hull structure is modelled over half the vessel'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 vessel's centreline longitudinal plane (see 3.6).

4.2 Local loads

4.2.1 General

Still water loads include:

– the still water external pressure, defined in Section 3, C.4.

– the still water internal loads, defined in Section 3, C.5. for the various types of cargoes and for ballast

4.2.2 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.

4.2.3 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 five or more points almost equally spaced inside the same span may be applied as equivalent linearly distributed loads.

4.2.4 Cargo in sacks, bales and similar packages

The vertical loads are comparable to distributed loads. The loads on vertical walls may be disregarded.

4.2.5 Other cargoes

The modelling of cargoes other than those mentioned under 4.2.2 to 4.2.4 will be considered by GL on a case by case basis.

4.3 Hull girder loads

4.3.1 Structural model extended over at least three cargo tank/hold lengths

The hull girder loads are constituted by:

– the still water and wave vertical bending moments

– the still water and wave vertical shear forces

and are to be applied at the model free 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 for the following two conditions:

– maximal bending moments at the middle of the central tank/hold within 0,4·L amidships

– maximal shear forces in way of the aft transverse bulkhead of the central tank/hold

4.3.2 Structural model extended over one cargo tank/hold length

The normal and shear stresses induced by the hull girder loads are to be added to the stresses induced in the primary supporting members by local loads.

4.4 Additional requirements for the load assignment to beam models

Vertical and transverse concentrated loads are to be applied to the model, as shown in Fig. 2.17, to compensate the portion of distributed loads which, due to the positioning of beams on their neutral axes, are not modelled.

In this Figure, F_Y and F_Z represent concentrated loads equivalent to the dashed portion of the distributed loads which is not directly modelled.

5. Stress calculation

5.1 Analyses based on finite element models

5.1.1 Stresses induced by local and hull girder loads

When finite element models extend over at least three cargo tank/hold lengths, both local and hull girder loads are to be directly applied to the model, as specified in 4.3.1. In this case, the stresses calculated by the finite element program include the contribution of both local and hull girder loads.

When finite element models extend over one cargo tank/hold length, only local loads are directly applied to the structural model, as specified in 4.3.2. In this case, the stresses calculated by the finite element 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.

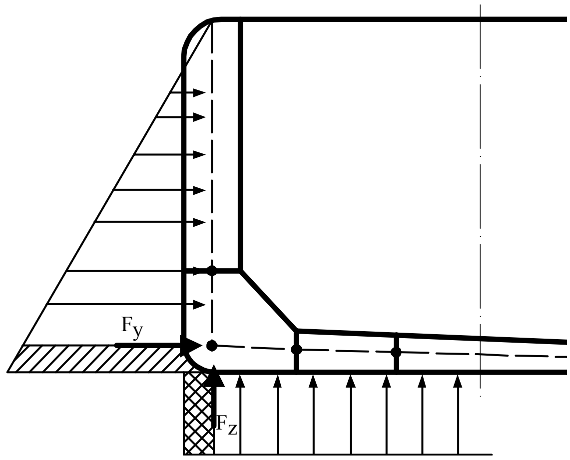


Fig. 2.17 Concentrated loads equivalent to non-modelled distributed loads

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. 2.18. The orientation of the element co-ordinate system may or may not coincide with that of the reference coordinate system in Section 1, A.1.4.

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:

$$\sigma_{VM} = \sqrt{\sigma_1{}^2 + \sigma_2{}^2 - \sigma_1 \cdot \sigma_2 + 3 \cdot \tau_{12}{}^2}$$

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.

5.2 Analyses based on beam models

5.2.1 Stresses induced by local and hull girder loads

Since beam models generally extend over one cargo tank/hold length (see 2.3.1 and 3.2.2), only local loads are directly applied to the structural model, as specified in 4.3.2. 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.

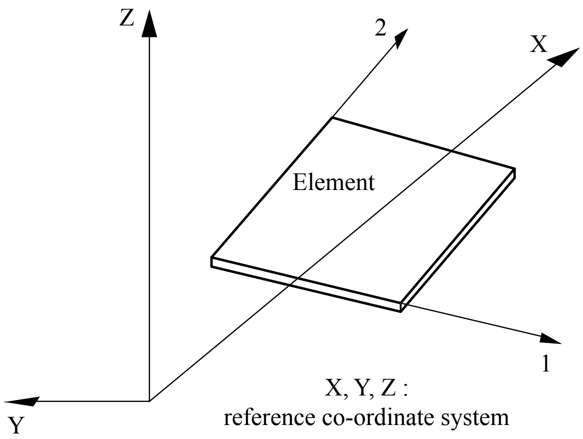


Fig. 2.18 Reference and element co-ordinate systems

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:

$$\sigma_{VM} = \sqrt{\sigma_1{}^2 + 3 \cdot \tau_{12}{}^2}$$

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.

H. Analyses of Primary Supporting Members Subjected to Wheeled Loads

1. General

1.1 Scope

1.1.1 The following requirements apply to 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 E.

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 GL, 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 E.3.3.

1.2 Application

1.2.1 The following requirements apply to vessels 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 vessel ends; their effect on the vessel 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 GL as not being applicable, the analysis criteria are defined on a case by case basis, taking into account the vessel's structural arrangement and loading conditions.

1.3 Information required

To perform these structural analyses, the following characteristics of vehicles loaded are necessary:

– load per axle

– arrangement of wheels on axles

– tyre dimensions

1.4 Lashing of vehicles

The presence of lashing for vehicles is generally to be disregarded, but may be given consideration by GL, on a case by case basis, at the request of the interested parties.

2. Analysis criteria

2.1 Beam model analyses

2.1.1 For inland navigation vessels, beam models, built according to G.3.5, may be adopted in lieu of the finite element models, provided that:

– Primary supporting members are not so stout that the beam theory is deemed inapplicable by GL.

– Their behaviour is not substantially influenced by the transmission of shear stresses through the shell plating.

2.1.2 Finite element models may need to be adopted when deemed necessary by GL on the basis of the vessel'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 B.6.

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 Table 2.24.

Table 2.24 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 Section 1, A.1.4					

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 vessel conditions 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 vessels with a traditional arrangement of fore and aft parts, a simplified approximation may be adopted, when deemed acceptable by GL, 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 (see Fig. 2.19). Each spring, which simulates the effects of the deck in way of which it is modelled, has a stiffness obtained [kN/m] from the following formula:

$$R_D = \frac{24 \cdot E \cdot J_D \cdot s_a \cdot 10^3}{2 \cdot x^4 - 4 \cdot L_D \cdot x^3 + L_D{}^2 \cdot \left(x^2 + 15{,}6 \cdot \frac{J_D}{A_D} \right) + L_D{}^3 \cdot x}$$

J_D = net moment of inertia [m^4] of the average cross-section of the deck, with the attached side shell plating

A_D = net area [m^2] of the average cross-section of deck plating

s_a = spacing of side vertical primary supporting members [m]

x = longitudinal distance [m] measured from the transverse section at mid-length of the model to any deck end

L_D = length of the deck [m] to be taken equal to the vessel's length. Special cases in which such value may be reduced will be considered by GL on a case-by-case basis.

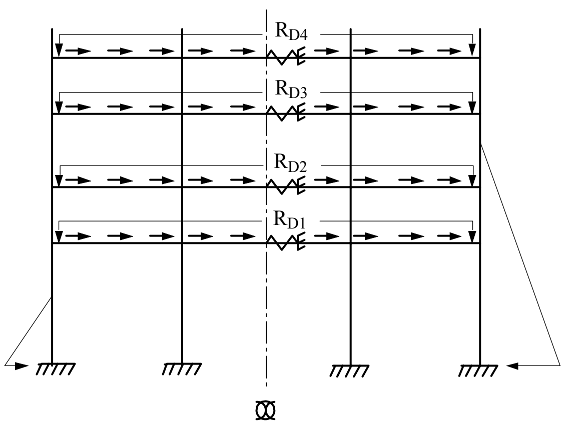


Fig. 2.19 Springs at the fore and aft ends of models subjected to transverse loads

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 loads are to be calculated for the most severe loading conditions, 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 vessel structures.

4.1.3 Loading conditions and load cases: dry uniform cargoes

When the vessel'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.

4.2 Local loads

4.2.1 General

Still water loads include:

– the still water external pressure, defined in Section 3, C.4.

– the still water forces induced by wheeled cargoes, defined in Section 3, C.6.6.

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

The normal stresses induced by the hull girder loads are to be added to the stresses induced in the primary supporting members by local loads.

5. Stress calculation

5.1 Stresses induced by local and hull girder loads

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. 2.20. The orientation of the element co-ordinate system may or may not coincide with that of the reference coordinate system in Section 1, A.1.4.

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:

$$\sigma_{VM} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1 \cdot \sigma_2 + 3 \cdot \tau_{12}^2}$$

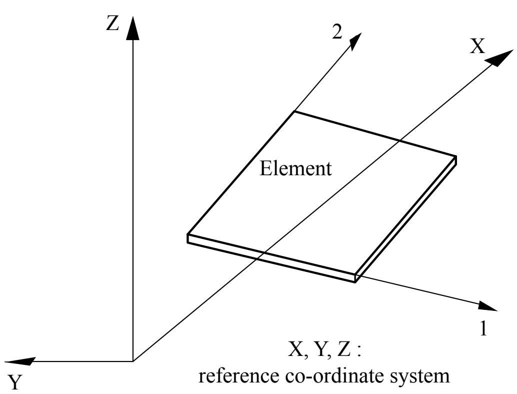


Fig. 2.20 Reference and element co-ordinate systems

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.

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:

$$\sigma_{VM} = \sqrt{\sigma_1^2 + 3 \cdot \tau_{12}^2}$$

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

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 Table 2.23.

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 [kN·m/rad] from the following formulae:

– for intermediate decks:

$$R_F = \frac{3 \cdot E \cdot (J_1 + J_2) \cdot (\ell_1 + \ell_2)}{\ell_1^{\,2} + \ell_2^{\,2} - \ell_1 \cdot \ell_2} \cdot 10^{-5}$$

– for the uppermost deck:

$$R_F = \frac{6 \cdot E \cdot J_1}{\ell_1} \cdot 10^{-5}$$

ℓ_1, ℓ_2 = height [m] of the tween decks, respectively below and above the deck under examination (see Fig. 2.21)

J_1, J_2 = net moments of inertia [cm^4] of side primary supporting members with attached shell plating, relevant to the tween decks, respectively below and above the deck under examination.

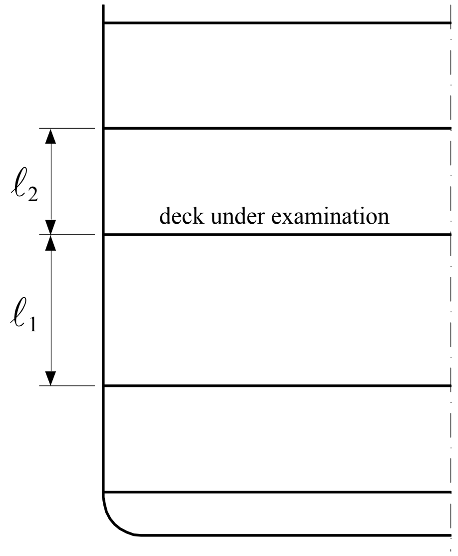


Fig. 2.21 Heights of tween decks for grillage analysis of deck primary supporting members

6.4 Load model

Hull girder and local loads are to be calculated and applied to the model according to 4.

6.5 Stress calculation

Stress components are to be calculated according to 5.1 and 5.3.

I. Torsion of Catamarans

1. Transverse strength in the special case of catamaran craft when the structure connecting both hulls is formed by a deck with single plate stiffened by m reinforced beams over the deck

1.1 Calculation example

1.1.1 General

Deck beams are assumed to be fixed into each hull. Consequently, deck beams are to be extended throughout the breadth of each hull, with the same scantlings all over their span, inside and outside the hulls.

1.1.2 Definitions

Refer to Fig. 2.22.

G = centre of the stiffnesses r_i, of the m deck beams

O = origin of abscissae, arbitrarily chosen

m = number of deck transverses

x_i = abscissa [m] of deck beam i with respect to origin O

S_i = span of deck beam i [m] between the inner faces of the hulls

I_i = bending inertia of deck beam i [m^4]

E_i = Young's modulus of deck beam i, in [N/mm^2]

r_i = stiffness of deck beam i [N/m] equal to:

$$= \frac{12 \cdot E_i \cdot I_i}{S^3_i} \cdot 10^6$$

a = abscissa [m] of the centre G with respect to the origin O

$$= \frac{\Sigma r_i \cdot x_i}{\Sigma r_i}$$

If F_i [N] is the force taken over by the deck beam i, the deflection y_i [m] of the hull in way of the beam i, is:

$$y_i = \frac{F_i \cdot S^3_i \cdot 10^{-6}}{12 \cdot E_i \cdot I_i} = \frac{F_i}{r_i} = d_i \cdot \omega$$

d_i = abscissa [m] of the deck beam i with respect to the origin G:

$= x_i - a$

ω = rotation angle [rad] of one hull in relation to the other around a transverse axis passing through G.

1.1.3 Transverse torsional connecting moment

The catamaran transverse torsional connecting moment [kN·m] about a transverse axis is given by:

$$M_{tt} = 0{,}125 \cdot \Delta \cdot L \cdot a_{CG} \cdot g$$

Δ = vessel displacement [t]

a_{CG} = design vertical acceleration at LCG [m/s^2] to be taken not less than:

$$= 0{,}67 \cdot Soc \cdot \frac{v}{\sqrt{L}}$$

v = vessel speed [m/s]

Soc = coefficient depending on the navigation notation n

$= 0{,}1 \cdot (n + 1{,}1)$

n = navigation coefficient defined in Section 3, B.

H = significant wave height [m]

Moreover, the transverse torsional moment may be expressed as:

$$M_{tt} = F_i \cdot d_i \cdot 10^{-3}$$

1.1.4 Calculation of rotation angle

The rotation angle may be derived from 1.1.3 and is given by the formula:

$$\omega = \frac{M_{tt}}{\Sigma r_i \cdot d_i^2} \cdot 10^3$$

1.1.5 Determination of stresses in deck beams

As M_{tt}, r_i and d_i are known, ω is thus deduced, then F_i [N], the bending moment M_i [N·m] and the corresponding normal and shear stresses can be evaluated in each beam:

$$Fi = \omega \cdot ri \cdot di$$

$$M_i = F_i \cdot S_i / 2$$

1.1.6 Checking criteria

It is to be checked that the normal stress σ and the shear stress are in compliance with the following formulae:

$$\frac{R_{eH}}{\gamma_R \cdot \gamma_m} \geq \sigma$$

$$0{,}5 \cdot \frac{R_{eH}}{\gamma_R \cdot \gamma_m} \geq \tau$$

R_{eH} = minimum yield stress [N/mm^2] of the material, to be taken equal to 235/k, unless otherwise specified

γ_R = partial safety factor covering uncertainties regarding resistance, to be taken equal to 1,10

γ_m = partial safety factor covering uncertainties regarding material, to be taken equal to 1,02.

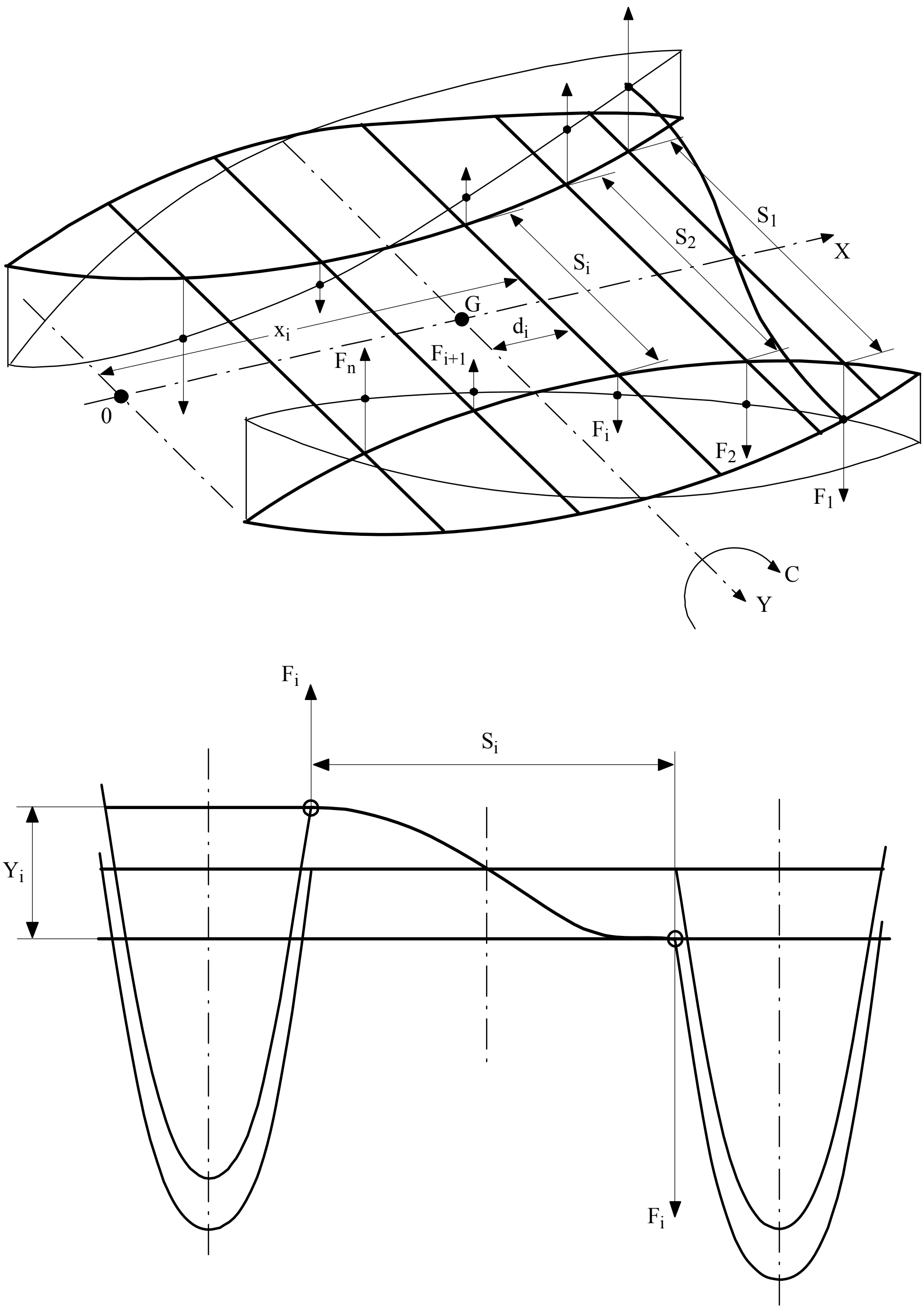


Fig. 2.22 Transverse strength of catamaran

Section 3

Design Load Principles

A. General

1. Definitions

1.1 Local loads

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

1.2 Hull girder loads

Hull girder loads are forces and moments which result as effects of local loads acting on the vessel as a whole and considered as a girder.

1.3 Loading condition

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

2. Application

2.1 Fields of application

2.1.1 The design loads defined in these Rules are to be used for the determination of the hull girder strength and structural scantlings in the central part of vessels.

2.1.2 Load direct calculation

As an alternative to the formulae in Section 4, B., the designer may provide, under his responsibility, the values of hull girder loads. In this case, the justified calculations of these values are to be submitted to GL.

B. Range of Navigation

1. Range of navigation

1.1 General

Each vessel is granted a range of navigation according to its scantlings and other constructional arrangements.

The ranges of navigation considered in these Rules are defined in GL Rules for Classification and Surveys (I-2-1), Section 2, B.10 The significant wave heights corresponding to ranges of navigation are listed in Table 3.1.

1.2 Navigation coefficient

The navigation coefficient to be used for the determination of vessel scantlings is given by the formula:

$$n = 0{,}85 \cdot H$$

H = significant wave height [m]
(wave height measured from crest to trough)

1.3 Length-to-depth ratio

In principle, the length-to-depth ratio is not to exceed the following values:

– for **IN(1,2)** to **IN(2,0)** = L/D = 25

– for **IN(0,6)** = L/D = 35

Vessels having a different ratio are to be considered by GL on a case-by-case basis.

1.4 Ranges of navigation IN(1,2) to IN(2)

On vessels assigned the range of navigation **IN(1,2)** to **IN(2)**, the hatchways are to be fitted with efficient means of closing. The openings of the engine room, if there is an engine room, are to be protected by a superstructure or by a deckhouse.

Table 3.1 Values of significant wave height [m]

Range of navigation	Wave height, H
IN(0)	0
IN(0,6)	0,6
IN(1,2) to IN(2,0)	1,2 to 2,0

C. Local Loads

1. Symbols

L = Rule length [m], defined in Section 1, A.1.

B = breadth [m], defined in Section 1, A.1.

D = depth [m], defined in Section 1, A.1.

T = draught [m], defined in Section 1, A.1.

C_B = block coefficient, defined in Section 1, A.1.

P = design pressure [kN/m^2]

x, y, z = x, y and z co-ordinates [m] of the calculation point with respect to the reference co-ordinate system defined in Section 1, A.1.4

z_L = z co-ordinate [m] of the highest point of the liquid

= $z_{TOP} + d_{AP}$

z_{TOP} = z co-ordinate [m] of the highest point of the tank or compartment

d_{AP} = distance from the top of the air pipe to the top of the tank [m]. For minimum distance for the top of the air pipe above deck, see GL Rules for Machinery, Systems and Electricity (I-2-3), Section 1, C.13.1.1.

p_{pv} = setting pressure [kN/m^2] of safety valves or maximum pressure [kN/m^2] in the tank during loading/unloading, which is the greater

ρ_L = density [t/m^3] of the liquid carried

n = navigation coefficient defined in B..

= 0,85·H

where H is the significant wave height [m]

a_B = motion and acceleration parameter

$$= 0{,}33 \cdot n \cdot \left(0{,}04 \cdot \frac{V}{\sqrt{L}} + 1{,}1 \cdot \frac{h_W}{L}\right)$$

h_W = wave parameter [m]

$$= 11{,}44 - \left|\frac{L-250}{110}\right|^3$$

a_{SU} = surge acceleration [m/s^2] defined in 4.2.1

a_{SW} = sway acceleration [m/s^2] defined in 4.2.2

a_H = heave acceleration [m/s^2] defined in 4.2.3

α_R = roll acceleration [rad/s^2] defined in 4.2.4

α_P = pitch acceleration [rad/s^2] defined in 4.2.5

α_Y = yaw acceleration [rad/s^2] defined in 4.2.6

T_{SW} = sway period [s] defined in 4.2.2

T_R = roll period [s] defined in 4.2.4

T_P = pitch period [s] defined in 4.2.5

A_R = roll amplitude [rad] defined in 4.2.4

A_P = pitch amplitude [rad] defined in 4.2.5

V = maximum ahead service speed [km/h]

2. General

2.1 Application

The following requirements apply for the definition of local loads to be used for the scantling checks of:

– platings

– ordinary stiffeners

– primary supporting members

2.2 Inertial loads

For range of navigation higher than **IN(1,2)**, inertial local loads induced by vessel relative motions and accelerations are to be taken into account.

3. Load definition criteria

3.1 Cargo and ballast 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 external pressures considered as acting alone without any counteraction from the vessel interior

– the differential pressures (internal pressure minus external pressure) considering the compartment adjacent to the outer shell as being loaded.

3.2 Draught associated with each cargo and ballast distribution

Local loads are to be calculated on the basis of the vessel draught T_1 corresponding to the cargo or lightship distribution considered according to the criteria 3.1. The vessel draught is to be taken as the distance measured vertically on the hull transverse section at the middle of the length from the base line to the waterline in:

a) full load condition, when:

- one or more cargo compartments 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 vessel's interior

b) light ballast condition, when one or more ballast tanks are considered as being loaded and the cargo compartments are considered as being empty.

4. Vessel motions and accelerations

4.1 General

4.1.1 Vessels motions and accelerations are defined, with their signs, according to the reference coordinate system in Section 1, A.1.4.

4.1.2 Vessel motions and accelerations are assumed to be periodic. The motion amplitudes are half of the crest to through amplitudes.

4.1.3 As an alternative to the formulae GL may accept the values of vessel motions and accelerations derived from direct calculations or obtained from model tests, when justified on the basis of the vessel's characteristics and intended service.

4.2 Vessel absolute motions and accelerations

4.2.1 Surge

The surge acceleration a_{SU} is to be taken equal to 0,5 m/s^2.

4.2.2 Sway

The sway period and acceleration are obtained from the formulae in Table 3.2.

Table 3.2 Sway period and acceleration

Period T_{SW} [s]	Acceleration a_{SW} [m/s^2]
$\dfrac{0{,}8\cdot\sqrt{L}}{0{,}10\cdot\dfrac{V}{\sqrt{L}}+1}$	$7{,}6\cdot a_B$

4.2.3 Heave

The heave acceleration is obtained [m/s^2] from the following formula:

$$a_H = 9{,}81\cdot a_B$$

4.2.4 Roll

The roll amplitude, period and acceleration are obtained from the formulae in Table 3.3.

4.2.5 Pitch

The pitch amplitude, period and acceleration are obtained from the formulae in Table 3.4.

4.2.6 Yaw

The yaw acceleration is obtained [rad/s^2] from the following formula:

$$\alpha_Y = 15{,}5\cdot\frac{a_B}{L}$$

4.3 Vessel relative accelerations

4.3.1 Definition

At any point, the accelerations in X, Y and Z direction are the acceleration components which result from the vessel motions defined from 4.2.1 to 4.2.6.

4.3.2 Vessel conditions

Vessel relative motions and accelerations are to be calculated considering the vessel in the following conditions:

– upright vessel condition:

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

– inclined vessel condition:

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

Table 3.3 Roll amplitude, period and acceleration

Amplitude A_R [rad]	Period T_R [s]	Acceleration α_R [rad/s^2]
$a_B\cdot\sqrt{E}$ without being taken greater than 0,35	$0{,}77\cdot\dfrac{B}{\sqrt{GM}}$	$\dfrac{40\cdot A_R}{T^2{}_R}$
$E = 11{,}34\cdot\dfrac{GM}{B}\geq 1{,}0$ GM = Distance, in m, from the vessel's centre of gravity to the transverse metacentre, for the loading considered; when GM is not known, the following values may be, in general, assumed: – full load: GM = 0,07·B – lightship: GM = 0,18·B		

Table 3.4 Pitch amplitude, period and acceleration

Amplitude A_P [rad]	Period T_P [s]	Acceleration α_P [rad/s^2]
$0{,}328\cdot a_B\cdot\left(1{,}32-\dfrac{h_W}{L}\right)\cdot\left(\dfrac{0{,}6}{C_B}\right)^{0{,}75}$	$0{,}575\cdot\sqrt{L}$	$\dfrac{40\cdot A_P}{T^2{}_P}$

4.3.3 Accelerations

The reference values of the longitudinal, transverse and vertical accelerations at any point are obtained from the formulae in Table 3.5 for upright and inclined vessel conditions.

Table 3.5 Reference values of the accelerations a_X, a_Y and a_Z

Direction	Upright vessel condition	Inclined vessel condition
X - Longitudinal a_{X1} and a_{X2} [m/s²]	$a_{x1} = \sqrt{a^2_{SU} + \left[9,81 \cdot A_P + \alpha_P \cdot (z - T_1)\right]^2}$	$a_{x2} = 0$
Y - Transverse a_{Y1} and a_{Y2} [m/s²]	$a_{Y1} = 0$	$a_{Y2} = \sqrt{a^2_{SW} + \left[9,81 \cdot A_R + \alpha_R \cdot (z - T_1)\right]^2 + \alpha_Y^2 \cdot K_X \cdot L^2}$
Z - Vertical a_{Z1} and a_{Z2} [m/s²]	$a_{Z1} = \sqrt{a_H^2 + \alpha_P^2 \cdot K_X \cdot L^2}$	$a_{Z2} = \sqrt{0,25 \cdot a_H^2 + \alpha_R^2 \cdot Y^2}$
K_X = coefficient defined as: $= 1,2 \cdot \left(\frac{x}{L}\right)^2 - 1,1 \cdot \frac{x}{L} + 0,2 \geq 0,018$ T_1 = draught [m] defined in 3.2.		

5. External pressure

5.1 Pressure on sides and bottom

The external pressure at any point of the hull, in [kN/m²], is to be obtained from the following formulae:

– for $z \leq T$: $p_E = 9,81\,(T - z + 0,6 \cdot n)$

– for $z > T$: $p_E = \text{MAX}\,(5,9 \cdot n\,;\,3) + p_{WD}$

p_{WD} = specific wind pressure [kN/m²] defined in Table 3.6.

Table 3.6 Specific wind pressure

Navigation Notation	Wind pressure p_{WD} [kN/m²]
IN(1,2), IN(2)	0,4·n
IN(0,6), IN(0)	0,25

5.2 Pressure on exposed decks

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 the values given in Table 3.7.

Table 3.7 Pressure [kN/m²] on exposed decks

Exposed deck location	p_E
Weather deck	3,75·(n + 0,8)
Exposed deck of superstructure or deckhouse:	
– First tier (non public)	2,0
– Upper tiers (non public)	1,5
– Public	4,0

5.3 Pressure on watertight bulkheads

The still water pressure [kN/m²] to be considered as acting on platings and stiffeners of watertight bulkheads of compartments not intended to carry liquids is obtained from the following formula:

$p_{WB} = 9,81 \cdot (z_{TOP} - z)$

6. Internal pressures

6.1 Liquids

6.1.1 General

The pressure transmitted to the hull structure [kN/m²] by liquid cargo (p_C) or ballast (p_B) is the combination of the still water pressure p_S and the inertial pressure p_W.

6.1.2 Still water pressure

– Liquid cargo

the still water pressure is the greater of the values obtained [kN/m²] from the following formulae:

$p_S = 9,81 \cdot \rho_L \cdot (z_L - z)$

$p_S = 9,81 \cdot \rho_L \cdot (z_{TOP} - z) + 1,15 \cdot p_{pv}$

– Ballast

$p_S = 9,81 \cdot (z_L - z + 1)$

6.1.3 Inertial pressure

The inertial pressure is obtained from the formulae in Table 3.8 and is to be taken such that:

$p_S + p_W \geq 0$

6.2 Dry bulk cargoes

6.2.1 General

The pressure transmitted to the hull structure is to be obtained using the formula:

$$p_C = \frac{(D - z)}{D - z_H} p_0$$

Table 3.8 Liquids - inertial pressure

Vessel condition	Inertial pressure p_W [kN/m²] [1]
Upright	$\rho_L \cdot \left[0{,}5 \cdot a_{X1} \cdot \ell_B + a_{Z1} \cdot (Z_{TOP} - Z)\right]$
Inclined	$\rho_L \cdot \left[a_{TY} \cdot (Y - Y_H) - a_{TZ} \cdot (Z - Z_H) + 9{,}81 \cdot (Z - Z_{TOP})\right]$

[1] $p_W = 0$ if $n \le 1{,}02$

ℓ_B = longitudinal distance [m] between the transverse tank boundaries, without taking into account small recesses in the lower part of the tank (see Fig. 3.1)

a_{TY}, a_{TZ} = Y and Z components (negative roll angle) [m/s²] of the total acceleration vector defined as follows:

$a_{TY} = a_{Y2}$

$a_{TZ} = 9{,}81 + a_{Z2}$

Y_H, Z_H = Y and Z co-ordinates [m] of the highest point of the tank in the direction of the total acceleration vector.

p_0 = mean total pressure on the inner bottom (combination of the mean still water pressure p_S defined in 6.2.2 and the mean inertial pressure p_W defined in 6.2.3)

= $p_S + p_W \ge 0$

If $n \le 1{,}02$: $p_W = 0$

z_H = Z co-ordinate [m] of the inner bottom.

6.2.2 Mean still water pressure on the inner bottom

The mean still water pressure on the inner bottom is obtained [kN/m²] from the following formula:

$$p_S = \frac{9{,}81 \cdot m_c}{L_H \cdot B_1}$$

L_H = length [m] of the hold, to be taken as the longitudinal distance between the transverse bulkheads which form boundaries of the hold considered

B_1 = breadth [m] of the hold

m_C = mass of cargo [t] in the hold considered

6.2.3 Mean inertial pressure on the inner bottom

The mean inertial pressure on the inner bottom is obtained [kN/m²] from the following formula:

$$p_W = \frac{a_{Z1} \cdot m_C}{L_H \cdot B_1}$$

where m_C, L_H and B_1 are defined in 6.2.2.

6.3 Dry heavy bulk cargoes

6.3.1 Pressure on side and bulkhead structure

The pressure on side and bulkhead structure is to be determined in compliance with 6.2.

6.3.2 Inner bottom design pressure

The inner bottom design pressure, p_{MS} [kN/m²] is the combination of the still water pressure p_S and the inertial pressure p_W determined in compliance with 6.3.3 and 6.3.4 respectively.

If $n \le 1{,}02$: $p_W = 0$

6.3.3 Inner bottom still water design pressure

The inner bottom still water design pressure p_S is obtained [kN/m²] from the following formula:

$$p_S = k_S \cdot \sqrt{\frac{L \cdot B \cdot T}{L_H} \cdot C_B}$$

k_S = coefficient to be determined using the formula:

= $9{,}81 \cdot \sqrt{0{,}85 \cdot \rho \cdot \tan\varphi}$

L_H = length [m] of the hold, to be taken as the longitudinal distance between the transverse bulkheads which form boundaries of the hold considered

ρ = cargo density [t/m³]

$\rho \ge 2{,}5$

φ = angle of repose of the bulk cargo considered

$\varphi \ge 35°$

6.3.4 Inner bottom inertial design pressure

The inner bottom inertial design pressure p_W is obtained [kN/m²] from the formula given in 6.3.3, using the following value of k_S:

$$k_S = a_{Z1} \cdot \sqrt{0,85 \cdot \rho \cdot \tan \varphi}$$

6.4 Dry uniform cargoes

6.4.1 General

The pressure transmitted to the hull structure, p_C [kN/m²] is the combination of the still water pressure p_S and the inertial pressure p_W.

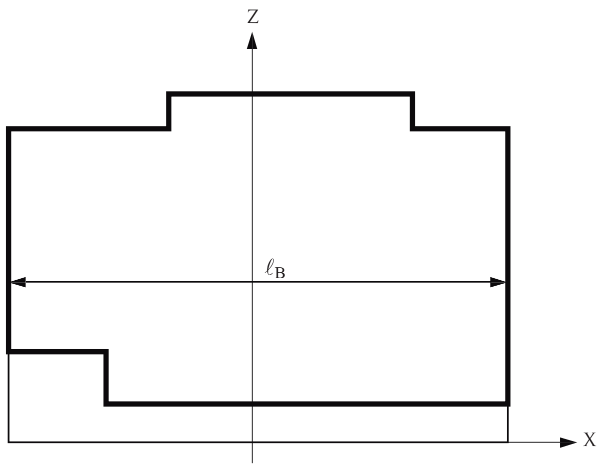


Fig. 3.1 Distance ℓ_B

6.4.2 Still water pressure

The value of the still water pressure p_S is to be specified by the designer.

6.4.3 Inertial pressure

The inertial pressure p_W is obtained [kN/m²] as specified in Table 3.9.

6.5 Dry unit cargoes

6.5.1 General

The force transmitted to the hull structure is the combination of the still water force F_S and the inertial force F_W.

Account is to be taken of the elastic characteristics of the lashing arrangement and/or the structure which contains the cargo.

Table 3.9 Dry uniform cargoes - Inertial pressures

Vessel condition	Inertial pressure p_W [kN/m²] [1]
Upright (positive heave motion)	$p_{W,Z} = p_S \cdot \frac{a_{Z1}}{9,81}$ in z direction
Inclined (negative roll angle)	$p_{W,y} = p_S \cdot \frac{a_{y2}}{9,81}$ in y direction $p_{W,Z} = p_S \cdot \frac{a_{Z2}}{9,81}$ in z direction
[1] $p_W = 0$ if $n \le 1,02$	

6.5.2 Still water force

The still water force transmitted to the hull structure is to be determined on the basis of the force obtained [kN] from the following formula:

$$F_S = 9,81\ m_C$$

Where m_C is the mass [t] of the cargo.

6.5.3 Inertial forces

The inertial forces are obtained [kN/m²] as specified in Table 3.10.

Table 3.10 Dry unit cargoes – Inertial forces

Vessel condition	Inertial force F_W [kN] [1]
Upright (positive heave motion)	$F_{W,X} = m_C \cdot a_{X1}$ in x direction $F_{W,Z} = m_C \cdot a_{Z1}$ in z direction
Inclined (negative roll angle)	$F_{W,Y} = m_C \cdot a_{Y2}$ in y direction $F_{W,Z} = m_C \cdot a_{Z2}$ in z direction
[1] $F_W = 0$ if $n \le 1,02$ ***Note*** *m_C = mass [t] of the cargo.*	

6.6 Wheeled cargoes

6.6.1 Tyred vehicles

The forces transmitted through the tyres are comparable to pressure uniformly distributed 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 axle and the tyre pressures.

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

6.6.2 Non-tyred vehicles

The requirements of 6.6.3 also apply to tracked vehicles; in this case the print to be considered is that below each wheel or wheelwork.

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

6.6.3 Still water force

The still water force transmitted to the hull structure by one wheel is to be determined on the basis of the force obtained [kN] from the formula:

$$F_S = 9{,}81 \cdot m_C$$

$$m_C = Q_A / n_W$$

Q_A = axle load [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

6.6.4 Inertial forces

The inertial forces are obtained [kN] as specified in Table 3.11.

6.7 Accommodation

The still water pressures transmitted to the deck structures are obtained [kN/m^2] as specified in Table 3.12.

6.8 Helicopter loads

6.8.1 Landing load

The landing load transmitted through one tyre to the deck is to be obtained [kN] from the following formula:

$$F_{CR} = 7{,}36 \cdot W_H$$

W_H = maximum weight of the helicopter [t]

Where the upper deck of a superstructure or deck-house is used as a helicopter deck and the spaces below are quarters, bridge, control room or other normally manned service spaces, the value of F_{CR} is to be multiplied by 1,15.

6.8.2 Emergency landing load

The emergency load resulting from the crash of the helicopter is to be obtained [kN] from the following formula:

$$F_{CR} = 29{,}43 \cdot W_H$$

6.8.3 Helicopter having landing devices other than wheels

In the case of a deck intended for the landing of helicopters having landing devices other than wheels (e.g. skates), the landing load and the emergency landing load are to be examined by GL on a case-by-case basis.

7. Testing pressures

7.1 Still water pressures

The still water pressures to be considered as acting on plates and stiffeners subject to tank testing are specified in Section 2, D.3.

Table 3.11 Wheeled cargoes - inertial forces

Vessel condition	Inertial force F_W [kN] [2]
Upright (positive heave motion)	$F_{W,Z} = m_C \cdot a_{Z1}$ in z direction
Inclined (negative roll angle) [1]	$F_{W,Y} = m_C \cdot a_{Y2}$ in y direction $F_{W,Z} = m_C \cdot a_{Z2}$ in z direction

1 This condition is to be considered for the racking analysis of vessels with the type and service Notation **RoRo vessel** or with the additional class Notation **Ferry**, with m_C taken equal to the mass [t] of wheeled loads located on the structural member under consideration.

2 $F_W = 0$ if $n \le 1{,}02$

Table 3.12 Deck pressure in accommodation compartments

Type of accommodation compartment	p [kN/m^2]
– Large spaces (such as: restaurants, halls, cinemas, lounges, kitchen, service spaces, games and hobbies rooms, hospitals)	4,0
– Cabins	3,0
– Other compartments	2,5

D. Hull Girder Loads

1. General

1.1 Definition and convention

1.1.1 Definition

The hull girder loads are forces and moments which result as effects of local loads acting on the vessel as a whole and considered as a girder.

1.1.2 Sign convention

The vertical bending moment is positive when it induces tensile stresses in the deck (hogging bending moment); it is negative in the opposite case (sagging bending moment).

2. Vertical bending moment calculation

2.1 Still water vertical bending moments

2.1.1 The design still water vertical bending moments are the maximum still water bending moments calculated, in hogging and sagging conditions at the midship transverse section for the loading conditions specified in 2.1.2.

2.1.2 Loading conditions

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

- light ship
- fully loaded vessel
- loading and unloading transitory conditions, where applicable

2.1.3 The design still water vertical bending moments are to be obtained from formulae given in Section 4, B.

2.2 Additional bending moments

For vessels assigned the **IN(0,6)** or **IN(1,2)** to **IN(2)** range of navigation defined in the GL Rules for Classification and Surveys (I-2-1), Section 2, B.10., an additional vertical bending moment, calculated according to Section 4, B.7. is to be added to the still water hogging and sagging bending moments, under both loaded and light conditions, for the determination of the hull girder strength and structural scantlings.

Section 4

Hull Girder Strength

A. General

1. Symbols

L = Rule length [m], defined in Section 1, A.1.

B = breadth [m], defined in Section 1, A.1.

D = depth [m], defined in Section 1, A.1.

T = draught [m], defined in Section 1, A.1.

C_B = block coefficient, defined in Section 1, A.1.

R = loaded length ratio

$$= \frac{L - d_{AV} - d_{AR}}{L}$$

where d_{AV} and d_{AR} are parameters defined in B.2.1.1

2. General

2.1 Application

2.1.1 The following requirements apply to vessels with length up to 135 m, of types and characteristics listed hereafter:

– self-propelled cargo carriers with machinery aft

$0,6 \leq R \leq 0,82$

$0,79 \leq C_B < 0,95$

– non-propelled cargo carriers

$0,8 \leq R \leq 0,92$

$C_B \geq 0,92$

– passenger vessels with machinery aft

$0,79 \leq C_B < 0,95$

– service vessels with machinery amidships

2.1.2 For other vessel types or vessels of unusual design or loading sequences, a direct calculation of still water bending moment is to be carried out and submitted to GL.

Direct calculation of still water bending moment is to be performed also if the actual lightship displacement shows at least 20 % deviation from standard value derived from B.6.1.1 or B.6.2.1 as applicable.

2.1.3 For cargo carriers, the cargo is assumed to be homogeneously distributed, and loading and unloading are assumed such as not to create excessive stresses.

3. Standard loading conditions for cargo carriers

3.1 Lightship

For non-propelled cargo type, the vessel is assumed empty, without supplies nor ballast.

For self-propelled cargo type, the light standard loading conditions are:

– supplies: 100 %

– ballast: 50 %

3.2 Fully loaded vessel

For non-propelled cargo type, the vessel is considered to be homogeneously loaded at its maximum draught, without supplies nor ballast.

For self-propelled cargo type, the vessel is considered to be homogeneously loaded at its maximum draught with 10 % of supplies (without ballast).

3.3 Transitory conditions

3.3.1 General

Transitory standard conditions are listed in items 3.3.2 to 3.3.4.

For non-propelled cargo type, the vessel is assumed without supplies nor ballast.

For self-propelled cargo type, the vessel without ballast, is assumed to carry following amount of supplies:

– in hogging condition: 100 % of supplies

– in sagging condition: 10 % of supplies

3.3.2 Loading/unloading in two runs

Loading and unloading are performed uniformly in two runs of almost equal masses.

For self-propelled vessels, the first loading/unloading run is carried out from the aft end of the cargo space, progressing to the fore end, the second run being performed from the fore end towards the aft end.

For non-propelled vessels, the two loading/unloading runs can be carried out from either the aft end or the fore end, progressing towards the opposite end.

3.3.3 Loading/unloading in one run

Loading and unloading are performed uniformly in one run, starting from the aft end of the cargo space, for self-propelled vessels, and from any cargo space end for non-propelled vessels.

3.3.4 Loading/unloading for liquid cargoes

Loading and unloading for liquid cargoes are assumed to be performed in two runs (see 3.3.2), unless otherwise specified.

4. Non-homogeneous loading conditions

4.1 General

If requested, in addition to design bending moments occurring in standard loading conditions described in 2., the hull girder loads may be determined, by direct calculation, in any non-homogeneous loading conditions approved by GL.

B. Design Bending Moments

1. Symbols

L = Rule length [m], defined in Section 1, A.1

B = breadth [m], defined in Section 1, A.1

D = depth [m], defined in Section 1, A.1

T = draught [m], defined in Section 1, A.1

C_B = block coefficient, defined in Section 1, A.1

M_H = design hogging bending moment [kN·m]

M_S = design sagging bending moment [kN·m]

M_{H0} = still water hogging bending moment in light ship conditions [kN·m]

M_{S0} = still water sagging bending moment in fully loaded conditions [kN·m]

M_{H1} = still water hogging bending moment while loading / unloading in one run [kN·m]

M_{H2} = still water hogging bending moment while loading / unloading in two runs [kN·m]

M_{S1} = still water sagging bending moment while loading/unloading in one run [kN·m]

M_{S2} = still water sagging bending moment while loading/unloading in two runs [kN·m]

M_c = correction value [kN·m], given in 7., taking into account the deviation from standard loading conditions, light ship weight and weight distribution

M_{ad} = additional bending moment [kN·m], defined in 6., for **IN(0,6)**, **IN(1,2)** and **IN(2)** ranges of navigation

F = loading factor

= P / P_T

P = actual cargo weight

P_T = cargo weight corresponding to the maximum vessel draught T

2. General

2.1 Definitions

2.1.1 Parameters d_{AV} and d_{AR}

d_{AV}, and d_{AR} are defined as follows (see Fig. 4.1):

d_{AV} = distance between fore cargo hold bulkhead or fore cargo tank bulkhead and fore end (FE) [m]

d_{AR} = distance between aft cargo hold bulkhead or aft cargo tank bulkhead and aft end (AE) [m]

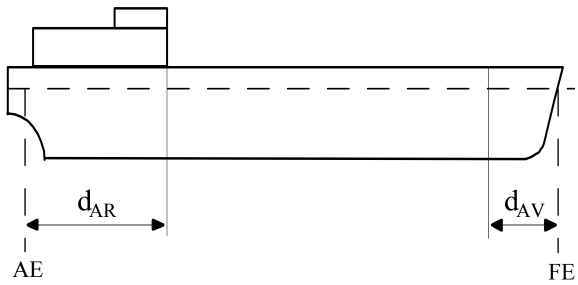


Fig. 4.1 Parameters d_{AV} and d_{AR}

2.1.2 Loaded lengths ℓ_1 and ℓ_2

Loaded lengths ℓ_1 and ℓ_2 are parameters defined as:

$$\ell_1 = \frac{-k_3}{k_2} \cdot L$$

$$\ell_2 = \frac{-k_3}{k_4} \cdot L$$

k_2, k_3, k_4 = coefficients, defined in Table 4.1.

Table 4.1 Coefficients k_i

Vessels	Conditions	k_1	k_2	k_3	k_4
Non-propelled	Hogging	0,063	0,01·L	−0,743	3,479
	Sagging	0	5	−1,213	4,736
Self-propelled	Hogging	–	3,455	−0,780	4,956
	Sagging	–	4,433	−0,870	3,735

2.1.3 Loaded lengths L_1 and L_2

Loaded lengths L_1 and L_2 are parameters defined as:

$$L_1 = 0{,}5 \cdot L - \ell_1 - d_{AV}$$

$$L_2 = 0{,}5 \cdot L - \ell_2 - d_{AR}$$

2.1.4 Loaded length ratios

Following coefficients are required for still water bending moment calculation:

$$R_{11} = \frac{0{,}5 \cdot L - d_{AV} - L_1}{L - d_{AV} - d_{AR}}$$

$$R_{12} = \frac{L_1}{0{,}5 \cdot L - d_{AV} - L_1}$$

$$R_{21} = \frac{0{,}5 \cdot L - d_{AR} - L_2}{L - d_{AV} - d_{AR}}$$

$$R_{22} = \frac{L_2}{0{,}5 \cdot L - d_{AR} - L_2}$$

3. Principle of calculation using formulae

3.1 Dry cargo carriers

3.1.1 Hogging conditions

The design bending moment in hogging conditions is given by the formula:

$$M_H = MAX\ (M_1\ ;\ M_2)$$

M_1 = total hogging bending moment of lightship [kN·m]

= $M_{H0} + M_{ad} + \Sigma M_c$

M_2 = total hogging bending moment in corresponding transitory conditions:

– for loading/unloading in one run

= $M_{H1} + \Sigma M_c$

– for loading/unloading in two runs

= $M_{H2} + \Sigma M_c$

3.1.2 Sagging conditions

The design bending moment in sagging conditions is given by the formula:

$$M_S = MAX\ (M_3\ ;\ M_4)$$

M_3 = total sagging bending moment of loaded vessel [kN·m]

= $M_{S0} + M_{ad} - \Sigma M_c$

M_4 = total sagging bending moment in corresponding transitory conditions:

– for loading/unloading in one run

= $M_{S1} - \Sigma M_c$

– for loading/unloading in two runs

= $M_{S2} - \Sigma M_c$

3.2 Tankers

Where the loading/unloading is carried out according to A.3.3 for liquid cargoes:

– the hogging design bending moment is equal to:

$$M_H = MAX\ (M_1\ ;\ M_2)$$

with $M_2 = M_{H2} + \Sigma M_C$

– the sagging design bending moment is equal to:

$$M_S = MAX\ (M_3\ ;\ M_4)$$

with $M_4 = M_{S2} - \Sigma M_C$,

where M_1 and M_3 are defined in 3.1.

3.3 Other vessels

For vessels other than cargo carriers:

– The hogging design bending moment is equal to:

$$M_H = M_{H0} + M_{ad}$$

– The sagging design bending moment is equal to:

$$M_S = M_{S0} + M_{ad}$$

4. Vertical shear force

4.1 Design shear force

4.1.1 The vertical design shear force [kN] is to be obtained from the following formula:

$$T_s = \frac{\pi \cdot M}{L}$$

M = maximum design bending moment [kN·m]

= MAX (M_H ; M_S)

5. Direct calculation

5.1 Direct calculation

5.1.1 In the case of direct calculation, all calculation documents are to be submitted to GL.

5.1.2 Design still water bending moments

The design still water bending moments are to be determined by direct calculation for:

– vessels of unusual type or design

– unusual loading/unloading sequences

The actual hull lines, lightweight distribution and the characteristics of the intended service are to be taken into account.

5.1.3 Additional bending moment

An additional bending moment taking into account the stream and water conditions in the navigation zone is to be considered.

This additional bending moment may be calculated according to 7. or determined by the designer.

6. Still water bending moments

6.1 Non-propelled cargo carriers

6.1.1 Standard light weights and weight distribution

The hull weight is assumed to be uniformly distributed on the vessel length, and [t] equal to:

– $P_0 = 0{,}12 \cdot L \cdot B \cdot D$ for $D < 3{,}7$ m

– $P_0 = 0{,}10 \cdot L \cdot B \cdot D$ for $D \geq 3{,}7$ m

6.1.2 Standard cargo weight and cargo distribution

The cargo is assumed to be uniformly distributed on the cargo space, and its weight [t] is equal to:

$$P_0 = 0{,}9 \cdot L \cdot B \cdot T \cdot C_B$$

6.1.3 Still water bending moments

The hogging and sagging bending moments in still water conditions are to be obtained from formulae given in Table 4.2.

Where the actual lightship weight or location of the centre of gravity presents a deviation greater than 10 % with respect to the standard value, the still water bending moment is to be corrected using formulae given in Table 4.7.

See also A.2.1.2

6.2 Self-propelled cargo carriers

6.2.1 Standard light weights and weight distribution

The formulae of still water bending moments are based on standard weights and weight distribution defined in Table 4.3.

6.2.2 Standard cargo weight and cargo distribution

The cargo is assumed to be uniformly distributed on the cargo space, and its weight [t] is equal to:

$$P_0 = 0{,}85 \cdot L \cdot B \cdot T \cdot C_B$$

6.2.3 Still water bending moments

The hogging and sagging bending moments in still water conditions are to be obtained from formulae given in Table 4.4.

Where the weight or location of the centre of gravity of a lightship component presents a deviation greater than 10 % with respect to standard value (see Table 4.3), the still water bending moment is to be corrected using formulae given in Table 4.8.

See also A.2.1.2.

6.3 Passenger vessels

The values of the maximum still water bending moments in normal service conditions are to be supplied by the designer.

Where the direct calculation may not be carried out, the still water hogging bending moment [kN·m] for passenger vessels (other than ro-ro vessels) with machinery aft may be determined using the following formula:

$$M_{H0} = 0{,}273 \cdot L^2 \cdot B^{1{,}342} \cdot T^{0{,}172} \cdot (1{,}265 - C_B)$$

6.4 Dredgers

The values of the maximum still water bending moments in normal service conditions are to be supplied by the designer.

Where the direct calculation may not be carried out, the maximum still water bending moment is to be as required in 6.1 or 6.2 for hopper barges and hopper dredgers respectively.

6.5 Tugs and pushers

6.5.1 Application

The following requirements apply to tugs and pushers whose engines are located amidships and whose bunkers are inside the engine room or adjoin it.

6.5.2 Still water bending moments

The values of the maximum hogging and sagging bending moments in normal service conditions are to be supplied by the designer.

Where the direct calculation may not be carried out, the still water bending moments [kN·m] may be determined using the following formulae:

– still water hogging bending moment:

$$M_{H0} = 1{,}96 \cdot L^{1{,}5} \cdot B \cdot D \cdot (1 - 0{,}9 \cdot C_B)$$

– still water sagging bending moment:

$$M_{S0} = 0{,}01 \cdot L^2 \cdot B \cdot T \cdot (\varphi_1 + \varphi_2)$$

$$\varphi_1 = 5{,}5 \cdot \left(0{,}6 \cdot \left(1 + C_B\right) - \frac{X}{L}\right)$$

$$\varphi_2 = 10 \cdot \Phi / L^2 \cdot B$$

X = length [m] of the machinery space increased by the length of adjacent bunkers.

Φ = total brake power of the propelling installation [kW]

Table 4.2 Non-propelled cargo carriers - still water bending moments

Load cases	Hogging moments [kN·m]	Sagging moments [kN·m]
Lightship	$M_{H0} = 0{,}62 \cdot L^2 \cdot B^{0,84} \cdot T^{0,8} \cdot (1 - C_B)$	
Fully loaded vessel		$M_{S0} = 1{,}4 \cdot L^{0,88} \cdot B^{1,17} \cdot T^2 \cdot C_B \cdot [R_{11} \cdot (0{,}52 \cdot L - 1{,}84 \cdot \ell_1) \cdot (1 - R_{12}) + R_{21} \cdot (0{,}5 \cdot L - 1{,}23 \cdot \ell_2) \cdot (1 - R_{22})]$ [1]
Loading and unloading in one run	$M_{H1} = M_{H0} + (M_{S1} - M_{S0})$	$M_{S1} = 0{,}7 \cdot L^{0,88} \cdot B^{1,17} \cdot T^2 \cdot C_B \cdot [R_{11} \cdot (0{,}52 \cdot L - 1{,}84 \cdot \ell_1) \cdot (1 - R_{12}) + 1{,}15 \cdot R_{21} \cdot (0{,}5 \cdot L - 1{,}23 \cdot \ell_2)]$
Loading and unloading in two runs	$M_{H2} = M_{H0} + (M_{S2} - M_{S0})$	$M_{S2} = 0{,}7 \cdot L^{0,88} \cdot B^{1,17} \cdot T^2 \cdot C_B \cdot [R_{11} \cdot (0{,}52 \cdot L - 1{,}84 \cdot \ell_1) \cdot (1 - R_{12}) + R_{21} \cdot (0{,}5 \cdot L - 1{,}23 \cdot \ell_2)]$

ℓ_1, ℓ_2 = parameters defined in 1.1.2

R_{11}, R_{12} = coefficients defined in 1.1.4

R_{21}, R_{22} = coefficients defined in 1.1.4.

[1] In the case of partly filled barge, M_{S0} is to be substituted by M_{SF} given by the formula:
$M_{SF} = F\,(M_{H0} + M_{S0}) - M_{H0}$

Table 4.3 Self-propelled cargo carriers - standard weights and weight distribution

Item	Weight [t] P_0	Centre of gravity from AE [m]	Location [m] X_1	X_2
Hull:				
D ≥ 3,7 m	$0{,}150 \cdot L \cdot B \cdot D$		0	L
D ≥ 3,7 m	$0{,}100 \cdot L \cdot B \cdot D$		0	L
Deckhouse:				
D ≤ 3,7 m	$0{,}010 \cdot L \cdot B \cdot D$		0	d_{AR}
D > 3,7 m	$0{,}006 \cdot L \cdot B \cdot D$		0	d_{AR}
Machinery (main)	$0{,}005 \cdot L \cdot B \cdot T$	$d_{AR} / 2$		
Machinery Installations	$0{,}010 \cdot L \cdot B \cdot T$		0	d_{AR}
Piping [1]	$0{,}005 \cdot L \cdot B \cdot T$		d_{AR}	$L - d_{AV}$
Mooring gear	$0{,}005 \cdot L \cdot B \cdot T$	$L - d_{AV} / 3$		
Supplies (fore)	$0{,}005 \cdot \alpha_1 \cdot L \cdot B \cdot T$	$L - d_{AV} / 2$		
Supplies (aft)	$0{,}005 \cdot \alpha_1 \cdot L \cdot B \cdot T$	$d_{AR} / 2$		
Ballast (fore):				
D ≤ 3,7 m	$0{,}010 \cdot \alpha_2 \cdot L \cdot B \cdot D$	$L - d_{AV} / 2$		
D > 3,7 m	$0{,}003 \cdot \alpha_2 \cdot L \cdot B \cdot D$	$L - d_{AV} / 2$		
Ballast (aft):				
D ≤ 3,7 m	$0{,}010 \cdot \alpha_2 \cdot L \cdot B \cdot D$	$d_{AR} / 2$		
D > 3,7 m	$0{,}003 \cdot \alpha_2 \cdot L \cdot B \cdot D$	$d_{AR} / 2$		

d_{AR}, d_{AV} = parameters defined in A.

α_1, α_2 = coefficients defined in Table 4.5.

[1] for tankers.

Table 4.4 Self-propelled cargo carriers - still water bending moments

Load cases	Hogging moments [kN·m]	Sagging moments [kN·m]
Lightship	$M_{H0} = 0{,}273 \cdot L^2 \cdot B^{1{,}342} \cdot T^{0{,}172} \cdot (1{,}265 - C_B)$ $M_{HH} = 0{,}344 \cdot L^2 \cdot B^{1{,}213} \cdot T^{0{,}352} \cdot (1{,}198 - C_B)$	$M_{HS} = 0{,}417 \cdot L^2 \cdot B^{1{,}464} \cdot (0{,}712 - 0{,}622\ C_B)$
Fully loaded vessel		$M_{S0} = M_{CS} - M_{HS}$ $M_{CS} = 0{,}4 \cdot F \cdot L^{1{,}86} \cdot B^{0{,}8} \cdot T^{0{,}48} \cdot (C_B - 0{,}47)$ $\cdot [3{,}1 + R_{11} \cdot (10{,}68 \cdot L - 53{,}22 \cdot \ell_1) \cdot (1 - R_{12})$ $+ R_{21} \cdot (0{,}17 \cdot L - 0{,}15 \cdot \ell_2) \cdot (1 - R_{22})]$
Loading and unloading in one run	$M_{H1} = M_{HH} + M_L$	$M_{S1} = 0{,}8 \cdot M_{S0} + M_L$
Loading and unloading in two runs	$M_{H2} = M_{HH} + 0{,}5\ M_L$	$M_{S2} = 0{,}8 \cdot M_{S0} + 0{,}5\ M_L$
M_L = parameter defined as: $= P_L \cdot (k_2 \cdot \ell_3 + k_3 \cdot L)$ k_3, k_2 = coefficients defined in Table 4.1 P_L = parameter defined as: $= \dfrac{0{,}77 \cdot L_1}{L - d_{AR} - d_{AV}} F \cdot L \cdot B \cdot T \cdot C_B$		ℓ_1, ℓ_2 = parameters defined in 2.1.2 $\ell_3 = 0{,}5 \cdot L - 0{,}5 \cdot L_1 - d_{AV}$ L_1 = parameter defined in 2.1.3 R_{11}, R_{12} = coefficients defined in 2.1.4 R_{21}, R_{22} = coefficients defined in 2.1.4.

Table 4.5 Values of coefficients α_1 and α_2

Loading conditions	α_1	α_2
Lightship	1	0,5
Fully loaded vessel	0,1	0
Transitory conditions		
– hogging	1	0
– sagging	0,1	0

6.6 Pontoons

The still water bending moments are to be obtained by direct calculation, according to the intended loading conditions.

7. Additional bending moments

7.1 Ranges of navigation IN(1,2) and IN(2)

For ranges of navigation **IN(1,2)** and **IN(2)**, a wave-induced bending moment, taking into account the significant wave height [m] of the navigation area, is to be added to the still water bending moment.

The absolute value of the wave-induced bending moment amidships is to be obtained [kN·m] from the following formula:

$$M_{ad} = 0{,}021 \cdot n \cdot C \cdot L^2 \cdot B \cdot (C_B + 0{,}7)$$

C = parameter, defined in Table 4.6

N = navigation coefficient, defined in Section 3, B.2.2

For intermediate significant wave heights, the value of the wave-induced bending moment may be obtained by interpolation.

7.2 Range of navigation IN(0,6)

For range of navigation **IN(0,6)**, the absolute value of the additional bending moment amidships is to be obtained [kN·m] from the following formula:

$$M_{ad} = 0{,}01 \cdot n \cdot C \cdot L^2 \cdot B \cdot (C_B + 0{,}7)$$

where parameter C is defined in Table 4.6.

8. Correction formulae

8.1 Non-propelled cargo carriers

The correction formulae applicable to non-propelled cargo carriers are given in Table 4.7, where values of coefficients k_1, k_2, k_3, and k_4 are defined in Table 4.1.

8.2 Self-propelled cargo carriers

The correction formulae applicable to self-propelled cargo carriers are given in Table 4.8, where the coefficients k_2, k_3 and k_4 are given in Table 4.1.

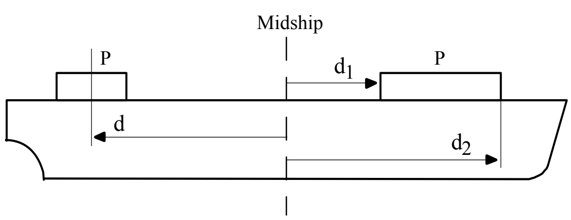


Fig. 4.2 Definition of distances d, d_1, d_2

Table 4.6 Values of parameter C

Significant wave height	C		
	L < 60	60 ≤ L ≤ 90	90 < L
H < 1,2 m	$C = (130 - 0,36 \cdot L) \cdot \frac{L}{1000}$	C = 9,14 – 0,044·L	$C = (90 - 0,36 \cdot L) \cdot \frac{L}{1000}$
H ≥ 1,2 m	$C = (118 - 0,36 \cdot L) \cdot \frac{L}{1000}$		$C = 10,75 - \left(\frac{300 - L}{100}\right)^{1,5}$

Table 4.7 Non-propelled cargo carriers - correction formulae

Item	$X > \frac{L}{2}$	$X \le \frac{L}{2}$
Concentrated weights or loads	$M_C = P \cdot (k_1 \cdot d_2 + k_2 \cdot d + k_3 \cdot L) - P_0 \cdot (k_1 \cdot d_0^2 + k_2 \cdot d_0 + k_3 \cdot L)$	$M_C = P \cdot (k_4 \cdot d + k_3 \cdot L) - P_0 \cdot (k_4 \cdot d_0 + k_3 \cdot L)$
Distributed weights or loads	$M_C = M - M_0$	
Hull weight [1]	$M_C = [0,0416 \cdot k_1 \cdot L^2 + (0,125 \cdot k_2 + k_3 + 0,125 \cdot k_4) \cdot L] \cdot (P - P_0)$	

$M = P \cdot \{0,33 \cdot k_1 \cdot (d_2^2 + d_2 \cdot d_1 + d_1^2) + 0,5 \cdot k_2 \cdot (d_2 + d_1) + k_3 \cdot L\}$

$M_0 = P_0 \cdot \{0,33 \cdot k_1 \cdot (d_{02}^2 + d_{02} \cdot d_{01} + d_{01}^2) + 0,5 \cdot k_2 \cdot (d_{02} + d_{01}) + k_3 \cdot L\}$

P = actual weight or load [t]

P_0 = standard weight or load [t] defined in 6.1
= 0, if not defined in 6.1.

d = actual distance from midship [m] of centre of gravity of concentrated weights (see Fig. 4.2):
= L / 2 – X for X ≤ L / 2
= X – L / 2 for X > L / 2

d_0 = standard distance from midship [m] of centre of gravity of concentrated weights ($d_0 \ge 0$)

d_1, d_2 = distances measured from midship [m] defining the extent of actual distributed weight (see Fig. 4.2)

d_{01}, d_{02} = distances measured from midship [m] defining the extent of standard distributed weight.

[1] Uniform weight distribution

Table 4.8 Self-propelled cargo carriers - correction formulae

Item	$X > \frac{L}{2}$	$X \le \frac{L}{2}$
Concentrated weights or loads Distributed weights or loads	$M_C = P \cdot (k_2 \cdot d + k_3 \cdot L) - P_0 \cdot (k_2 \cdot d_0 + k_3 \cdot L)$	$M_C = P \cdot (k_4 \cdot d + k_3 \cdot L) - P_0 \cdot (k_4 \cdot d_0 + k_3 \cdot L)$
Hull weight [1]	$M_C = (0,125 \cdot k_2 + k_3 + 0,125 \cdot k_4) \cdot (P - P_0) \cdot L$	

P = actual weight or load [t]

P_0 = standard weight or load [t] defined in 6.2
= 0, if not defined in 6.2

d = actual distance from midship [m] of the weight centre of gravity (see Fig. 4.2):
= L / 2 − X for X ≤ L / 2
= X − L / 2 for X > L / 2

d_0 = standard distance from midship [m] of the weight centre of gravity ($d_0 \ge 0$).

[1] Uniform weight distribution

C. Strength Characteristics of the Hull Girder Transverse Sections

1. Symbols

Z = hull girder section modulus [cm^3]

M_H = design hogging bending moment [kN·m]

M_S = design sagging bending moment [kN·m]

2. General

2.1 Application

In the following, the criteria are specified for calculating the hull girder strength characteristics to be used for the checks, in association with the hull girder loads.

3. Characteristics of the hull girder transverse sections

3.1 Hull girder transverse sections

3.1.1 General

The 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 3.2, taking into account the requirements of 3.1.2 to 3.1.5.

3.1.2 Longitudinal bulkheads with vertical corrugations

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

3.1.3 Members in materials other than steel

Where a member is made in material other than steel, its contribution to the longitudinal strength will be determined by GL on case-by-case basis.

3.1.4 Large openings and scallops

Large openings are:

– in the side shell plating: openings having a diameter greater than or equal to 300 mm

– in the strength deck: openings having a diameter greater than or equal to 350 mm

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.

3.1.5 Lightening holes, draining holes and single scallops

Lightening holes, draining holes and single scallops in longitudinals or girders need not be deducted if their height is less than 0,25 h_W, without being greater than 75 mm, where h_W is the web height [mm].

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

3.2 Strength deck

3.2.1 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 deckhouse.

3.2.2 For additional requirements about passenger vessels, see the GL Additional Requirements for Notations (I-2-4), Section 2, D.

3.3 Hull girder section modulus

3.3.1 The section modulus at any point of a hull transverse section is obtained [cm^3] from the following formula:

$$Z = \frac{I_Y}{100 \cdot |z - N|}$$

I_Y = moment of inertia [cm^4] of the hull girder transverse section defined in 3.1, about its horizontal neutral axis

N = Z co-ordinate [m] of the centre of gravity of the hull transverse section

Z = Z co-ordinate [m] of the calculation point of a structural element.

3.4 Hull girder normal stresses

3.4.1 The normal stresses induced by vertical bending moments are obtained [N/mm^2] from the following formulae:

– in hogging conditions:

$$\sigma_1 = \frac{M_H}{Z} \cdot 10^3$$

– in sagging conditions:

$$\sigma_1 = \frac{M_S}{Z} \cdot 10^3$$

Section 5

Hull Scantlings

A. General

1. General

1.1 Application

This Section contains the requirements for the determination of the minimum hull scantlings applicable to the central part (see Section 1, A.1.3.3) of all types of inland waterway vessels.

These requirements are to be integrated with those specified under applicable Sections of the GL Additional Requirements for Notations (I-2-4), depending on the vessel Notations.

1.2 Summary table

The following requirements are to be applied for the scantlings and arrangements of the vessel central part according to Table 5.1.

Table 5.1 Summary table

Main subject	Reference
Bottom scantlings	B.
Side scantlings	C.
Deck scantlings	D.
Bulkhead scantlings	E.
Vessels less than 40 m in length	F.

1.3 Material factor

When aluminium alloys or steels with a minimum guaranteed yield stress R_{eH} other than 235 N/mm^2 are used on a vessel, the scantlings are to be determined by taking into account the material factor defined in Section 2, A.2.4 and Section 2, A.3.2 as follows:

– thickness:

see relevant requirements of the following paragraphs

– section modulus:

$w = k \cdot w_0$

– sectional area:

$A = k \cdot A_0$

w_0, A_0 = scantlings corresponding to a steel with a minimum guaranteed yield stress R_{eH} = 235 N/mm^2

2. Hull arrangements

2.1 Arrangements for hull openings

Arrangements for hull openings are to be in compliance with Section 6, G.

2.2 River chests

2.2.1 Shell plating

The shell plate gross thickness [mm] in way of river chests as well as the gross thickness of all boundary walls of the river chests is not to be less than:

$$t = 1{,}2 \cdot s \cdot k^{0{,}5} \cdot p^{0{,}5} + 1{,}5$$

s = width of the plate panel or stiffener spacing, respectively [m]

p = pressure at the safety relief valve [kN/m^2]:

– in general, $p \geq 196$ kN/m^2

– for river chests without any compressed air connection and which are accessible at any time, $p = 98$ kN/m^2

2.2.2 Stiffeners

The gross section modulus [cm^3] of river chest stiffeners is not to be less than:

$$w = 0{,}58 \cdot s \cdot p \cdot \ell^2$$

s, p = parameters defined in 2.2.1

ℓ = unsupported span of stiffener [m]

2.3 Pipe connections at the shell plating

Scupper pipes and valves are to be connected to the shell by weld flanges. Instead of weld flanges short-flanged sockets with an adequate thickness may be used if they are welded to the shell in an appropriate manner.

B. Bottom Scantlings

1. Symbols

L = Rule length [m], defined in Section 1, A.1.

B = breadth [m], defined in Section 1, A.1.

D = depth [m], defined in Section 1, A.1.

T = draught [m], defined in Section 1, A.1.

t = net thickness [mm] of plating

s = spacing [m] of ordinary stiffeners

S = spacing [m] of primary supporting members

ℓ = span [m] of ordinary stiffeners or primary supporting members

n = navigation coefficient defined in Section 3, B.

= 0,85·H

H = significant wave height [m]

σ_1 = hull girder normal stress [N/mm^2]

β_b, β_s = bracket coefficients defined in Section 2, B. 6.2

η = $1 - s / (2 \cdot \ell)$

w = net section modulus [cm^3] of ordinary stiffeners or primary supporting members

A_{sh} = net web sectional area [cm^2]

k = material factor defined in Section 2, A.2.4 and Section 2, A.3.2

z = Z co-ordinate [m] of the calculation point

B_1 = breadth [m] of the hold

B_2 = breadth [m] of the side tank

M_H = design bending moment [kN·m] in hogging condition

M_S = design bending moment [kN·m] in sagging condition

2. General

2.1 Application

The following requirements apply to longitudinally or transversely framed single and double bottom structures of inland waterway vessels.

The requirements applicable to specific vessel Notations are defined in Chapter 4 .

2.2 General arrangement

2.2.1 The bottom structure is to be checked by the designer to make sure that it withstands the loads resulting from the dry-docking of the vessel.

2.2.2 The bottom is to be locally stiffened where concentrated loads are envisaged.

2.2.3 Girders or floors are to be fitted under each line of pillars, when deemed necessary by GL on the basis of the loads carried by the pillars.

2.2.4 Adequate continuity is to be provided in the case of height variation in the double bottom.

2.2.5 Provision is to be made for the free passage of water from all parts of the bottom to the suctions.

2.3 Keel

Vessels having a rise of floor are to be fitted with a keel plate of about 0,1·B in width, with a thickness equal to 1,15 times the bottom plating thickness.

In the case there is no rise of floor, the keel plate thickness is to be not less than the bottom plating thickness.

2.4 Bilge

2.4.1 Radius

Where the bilge plating is rounded, the radius of curvature is not to be less than 20 times the thickness of the plating.

2.4.2 Extension

The bilge is to extend at least 100 mm on either side of the rounded part and 150 mm above the floor upper edge.

2.4.3 On tank vessels for oil and/or chemicals wear plates in form of doubling plates are not permitted to be attached to the bilge plating within the cargo area, i.e. between the aftmost and the foremost cofferdam bulkhead.

2.5 Drainage and openings for air passage

Holes are to be cut into floors and girders to ensure the free passage of air and liquids from all parts of the double bottom.

3. Scantlings

3.1 Bottom, inner bottom and bilge plating

3.1.1 In the central part, the bottom and inner bottom plating net thickness [mm] are not to be less than the values given in Table 5.2.

3.1.2 Rounded bilge

The bilge plating net thickness [mm] is to be not less than the following values, where t_0 is the bottom plating net thickness [mm]:

– in the case of a bilge radius of curvature practically equal to the floor depth or bottom transverse depth:

  $t = 1{,}15 \cdot t_0$

– in the case of a bilge radius of curvature less than the floor depth or bottom transverse depth but greater than 20 times the bottom plating thickness:

  $t = 1{,}15 \cdot t_0 + 1$

Table 5.2 Bottom and inner bottom plating net thickness [mm]

Item	Transverse framing	Longitudinal framing
Bottom plating	$t = MAX(t_i)$ $t_1 = 1{,}85 + 0{,}03 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$ $t_2 = 1{,}6 \cdot s \cdot (k \cdot p)^{0,5}$ $t_3 = 68 \cdot \frac{s}{k_2} \cdot \sqrt{\frac{M_H}{Z_B}}$ if $t_3 / s > 22 / (k^{0,5} \cdot k_2)$: $t_3 = \frac{7{,}1 \cdot k^{0,5} \cdot s}{k_2 \cdot \sqrt{0{,}21 - \frac{M_H}{Z_B}}}$ see [1]	$t = MAX(t_i)$ $t_1 = 1{,}1 + 0{,}03 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$ $t_2 = 1{,}2 \cdot s \cdot (k \cdot p)^{0,5}$ $t_3 = 39 \cdot s \cdot \sqrt{\frac{M_H}{Z_B}}$ if $t_3 / s > 12{,}5 / k^{0,5}$: $t_3 = \frac{4{,}1 \cdot k^{0,5} \cdot s}{\sqrt{0{,}21 - \frac{M_H}{Z_B}}}$ see [1]
Inner bottom plating	$t = MAX(t_i)$ $t_1 = 1{,}5 + 0{,}016 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$ $t_2 = 1{,}6 \cdot s \cdot (k \cdot p)^{0,5}$ $t_3 = 68 \cdot \frac{s}{k_2} \cdot \sqrt{\frac{M_H}{Z_{DB}}}$ see [1]	$t = MAX(t_i)$ $t_1 = 1{,}5 + 0{,}016 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$ $t_2 = 1{,}2 \cdot s \cdot (k \cdot p)^{0,5}$ $t_3 = 39 \cdot s \cdot \sqrt{\frac{M_H}{Z_{DB}}}$ see [1]

p = design load [kN/m²]:
- in way of ballast tanks:
  $p = MAX(p_E; (p_B - p_M))$ for bottom plating
  $= MAX(p_C; p_B)$ for inner bottom plating
- elsewhere:
  $p = p_E$ for bottom plating
  $= p_C$ for inner bottom plating

p_M = minimum external pressure [kN/m²], $p_M \geq 0$:
= $9{,}81 \cdot (0{,}15 \cdot T - 0{,}6 \cdot n)$

p_E, p_C, p_B = pressures transmitted to the hull structure defined in Section 3, C.4. and Section 3, C.5.

k_2 = $1 + \alpha^2$

α = b_2 / b_1

b_1 = unsupported plate width in y direction [m]

b_2 = unsupported plate width in x direction [m]

Z_B = bottom net hull girder section modulus [cm³]

Z_{DB} = inner bottom net hull girder section modulus [cm³]

[1] A lower value of thickness t_3 may be accepted if in compliance with the buckling analysis carried out according to Section 2, C.

3.1.3 Square bilge

In the case of a square bilge with chine bars (sketches a, b, c of Fig. 5.1), the net scantling of the chine bar is to be determined as follows:

– angle bars

The net thickness of the bars plating [mm] is to be not less than the following formulae, where t_0 is the bottom plating net thickness:

- angle bars inside the hull: $t = t_0 + 2$
- other cases: $t = t_0 + 3$

– round bars and square bars

The diameter of the round bars or the side of the square bars is to be not less than 30 mm.

In the case of a double chine bilge without chine bars (sketch d of Fig. 5.1):

The thickness of the doublers [mm], is to be not less than:

$$t = t_0 + 3$$

where t_0 is the bottom plating thickness.

In the case of a double chine bilge with round chine bars (sketch e of Fig. 5.1):

The diameter of the round bars is to be not less than 30 mm. The thickness of the plating is equal to the bottom plating thickness.

3.1.4 Bilge plate thickness reduction

Forward of the forward shoulder and aft of the aft shoulder, the bilge plate thicknesses according to 3.1.2 and 3.1.3 may be reduced to the bottom plate thickness according to Section 6, A.3, B.3. and C.4. respectively.

3.1.5 Strength check in testing conditions

Plating of compartments or structures to be checked in testing conditions is to comply with Section 2, D.

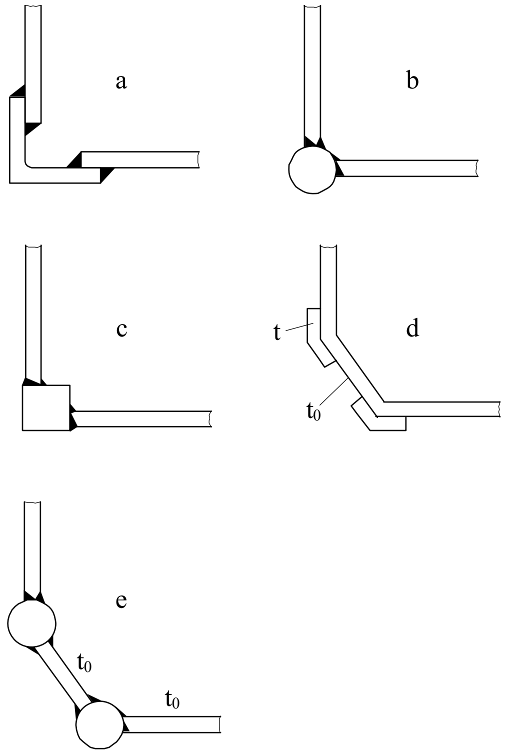


Fig. 5.1 Square bilge

3.2 Bottom and inner bottom structures

3.2.1 Minimum net thickness of web plating

The net thickness [mm] of the web plating of ordinary stiffeners is to be not less than:

$$t = 1{,}63 + 0{,}004 \cdot L \cdot k^{0{,}5} + 4{,}5 \cdot s \quad \text{for } L < 120 \text{ m}$$

$$= 3{,}9 \cdot k^{0{,}5} + s \quad \text{for } L \geq 120 \text{ m}$$

The net thickness [mm] of plating which forms the web of primary supporting members is to be not less than the value obtained from the following formula:

$$t = 3{,}8 + 0{,}016 \cdot L \cdot k^{0{,}5}$$

3.2.2 Net scantlings of bottom and inner bottom structural members in service conditions

The net scantlings of bottom and inner bottom structural members in service conditions are to be obtained from Table 5.3 for single bottom structure and Table 5.4 for double bottom structure.

3.2.3 Net scantlings of bottom and inner bottom structural members in testing conditions

The net scantlings of bottom and inner bottom structural members being part of compartments or structures containing liquid are to comply with Section 2, D.

3.2.4 Buckling check

Bottom and inner bottom structural members are to comply with the requirements stated under Section 2, C.

4. Transversely framed single bottom

4.1 Floors

4.1.1 It is forbidden to connect the floors to the bottom shell plating by means of a flange.

4.1.2 Floors are to be fitted at every frame.

4.1.3 Minimum shear sectional area of floors

In the region where the shear force is maximum, the minimum shear sectional area A_{sh} of floors [cm^2] is to be not less than the value given in Table 5.3.

GL may waive this rule subject to direct calculation of the shearing stresses.

4.1.4 Floor height

The ratio of the floor height to the web net thickness is to be not more than r_T values, given in Table 5.5.

In the case of vessels with considerable rise of floor, this height may be required to be increased so as to assure a satisfactory connection to the frames.

4.2 Girders

4.2.1 Centre girder

All single bottom vessels are to have a centre girder. GL may waive this rule for vessels with breadth B_F measured on the top of floors less than 6 m, where the floor is a rolled section or where the floor stability is covered otherwise.

The web depth of the centre girder has to extend to the floor plate upper edge. The web thickness is not to be less than that of the floor plates.

Centre girder is to be fitted with a face plate, a flat or a flange, the net sectional area of which [cm^2] is not to be less than:

$$A_f = 0{,}764 \cdot B + 3{,}3$$

4.2.2 Side girders

Depending on the breadth B_F measured on the top of floors, side girders are to be fitted in compliance with the following:

– $B_F \leq 6$ m: no side girder

– 6 m < $B_F \leq 9$ m: one side girder at each side

– $B_F > 9$ m: two side girders at each side.

Side girders are to be fitted with a face plate, a flat or a flange, the net sectional area of which is not to be less than that of the floor plate.

Table 5.3 Net scantlings of single bottom structure

Item	w [cm³]	A_{sh} [cm²]
Bottom longitudinals	$w = \frac{83,3}{214 - \sigma_1} \cdot \beta_b \cdot \eta \cdot p_E \cdot s \cdot \ell^2$	$A_{sh} = 0,045 \cdot \beta_s \cdot \eta \cdot p_E \cdot s \cdot \ell$
Floors [1, 2]	$w = 0,58 \cdot \beta_b \cdot p_{\gamma E} \cdot s \cdot \ell^2$	$A_{sh} = 0,045 \cdot \beta_s \cdot p_{\gamma E} \cdot s \cdot \ell$
Bottom transverses [2]	$w = 0,58 \cdot \beta_b \cdot p_{\gamma E} \cdot S \cdot \ell^2$	$A_{sh} = 0,045 \cdot \beta_s \cdot p_{\gamma E} \cdot S \cdot \ell$
Bottom centre and side girders [3]	$w = \frac{125}{197 - \sigma_1} \cdot \beta_b \cdot p_{\gamma E} \cdot S \cdot \ell^2$	$A_{sh} = 0,056 \cdot \beta_s \cdot p_{\gamma E} \cdot S \cdot \ell$

p_E = design load [kN/m²] defined in Section 3, C.5.1
$p_{\gamma E}$ = design load [kN/m²] of bottom primary supporting members
= $9,81\ (\gamma \cdot T + 0,6 \cdot n)$
γ = loading sequence coefficient
= 1 for loading/unloading in one run
= 0,575 for loading/unloading in two runs

1 In way of side ordinary frames: $\beta_b = \beta_S = 1$
2 Scantlings of floors and bottom transverses have to be adequate to those of web frames or side transverses connected to them.
3 The span ℓ is to be taken equal to the web frames / side transverses spacing.

Table 5.4 Net scantlings of double bottom structure

Item	Parameter	Transverse framing	Longitudinal framing
Floors in the hold [1]	section modulus [cm³]	$w = MAX\ (w_1;\ w_2)$ $w_1 = 0,58 \cdot \beta_b \cdot p_1 \cdot s \cdot \ell^2$ $w_2 = 0,58 \cdot \beta_b \cdot p_{\gamma I} \cdot s \cdot (\ell^2 - 4 \cdot B_2^2)$	NA
	thickness [mm]	$t = MAX\ (t_1;\ t_2)$ $t_1 = 3,8 + 0,016 \cdot L \cdot k^{0,5}$ $t_2 = d\ /r_T$	NA
	shear sectional area [cm²]	$A_{sh} = MAX\ (A_1;A_2)$ $A_1 = 0,067 \cdot \beta_s \cdot p_1 \cdot s \cdot \ell$ $A_2 = 0,067 \cdot \beta_s \cdot p_{\gamma I} \cdot s \cdot (\ell - 2 \cdot B_2)$	NA
Floors in the side tank [1]	section modulus [cm³]	$w = MAX\ (w_1;w_2)$ $w_1 = 2,32 \cdot \beta_b \cdot p_1 \cdot s \cdot B_2 \cdot (\ell - B_2)$ $w_2 = 2,32 \cdot \beta_b \cdot p_{\gamma I} \cdot s \cdot B_2 \cdot (\ell - 2 \cdot B_2)$	NA
	shear sectional area [cm²]	$A_{sh} = MAX\ (A_1;A_2)$ $A_1 = 0,067 \cdot \beta_s \cdot p_1 \cdot s \cdot \ell$ $A_2 = 0,067 \cdot \beta_s \cdot p_{\gamma I} \cdot s \cdot (\ell - 2 \cdot B_2)$	NA
Bottom and inner bottom longitudinals	section modulus [cm³]	NA	$w = \frac{83,3}{214 - \sigma_1} \cdot \beta_b \cdot \eta \cdot p_2 \cdot s \cdot \ell^2$
	shear sectional area [cm²]	NA	$A_{sh} = 0,045 \cdot \beta_s \cdot \eta \cdot p_2 \cdot s \cdot \ell$

Table 5.4 Net scantlings of double bottom structure *(continued)*

Item	Parameter	Transverse framing	Longitudinal framing
Bottom transverses in the hold	section modulus [cm^3]	NA	$w = MAX\ (w_1; w_2)$ $w_1 = 0{,}58 \cdot \beta_b \cdot p_1 \cdot S \cdot \ell^2$ $w_2 = 0{,}58 \cdot \beta_b \cdot p_{\gamma I} \cdot S \cdot (\ell^2 - 4 \cdot B_2^2)$
	thickness [mm]	NA	$t = MAX\ (t_1; t_2)$ $t_1 = 3{,}8 + 0{,}016 \cdot L \cdot k^{0,5}$ $t_2 = d / r_L$
	shear sectional area [cm^2]	NA	$A_{sh} = MAX\ (A_1; A_2)$ $A_1 = 0{,}067 \cdot \beta_s \cdot p_1 \cdot S \cdot \ell$ $A_2 = 0{,}067 \cdot \beta_s \cdot p_{\gamma I} \cdot S \cdot (\ell - 2 \cdot B_2)$
Bottom transverses in the side tank	section modulus [cm^3]	NA	$w = MAX\ (w_1; w_2)$ $w_1 = 2{,}32 \cdot \beta_b \cdot p_1 \cdot S \cdot B_2 \cdot (\ell - B_2)$ $w_2 = 2{,}32 \cdot \beta_b \cdot p_{\gamma I} \cdot S \cdot B_2 \cdot (\ell - 2 \cdot B_2)$
	shear sectional area [cm^2]	NA	$A_{sh} = MAX\ (A_1; A_2)$ $A_1 = 0{,}067 \cdot \beta_s \cdot p_1 \cdot S \cdot \ell$ $A_2 = 0{,}067 \cdot \beta_s \cdot p_{\gamma I} \cdot S \cdot (\ell - 2 \cdot B_2)$
Bottom centre and side girders [2]	shear sectional area [cm^2]	$A_{sh} = 0{,}051 \cdot \beta_s \cdot p \cdot S \cdot \ell$	

p = design load of primary supporting members [kN/m^2]
= $MAX\ (p_1; p_{\gamma I})$

p_1 = $p_{\gamma E}$

p_2 = design load of bottom and inner bottom longitudinals [kN/m^2]:

- in way of ballast tanks:
  - for bottom longitudinals: $p_2 = MAX\ [p_E; (p_B - p_M)]$
  - for inner bottom longitudinals: $p_2 = MAX\ (p_C; p_B)$
- elsewhere:
  - for bottom longitudinals: $p_2 = p_E$
  - for inner bottom longitudinals: $p_2 = p_C$

p_M = minimum external pressure [kN/m^2]], $p_M \geq 0$:
= $9{,}81 \cdot (0{,}15 \cdot T - 0{,}6 \cdot n)$

$p_{\gamma E}$ = external pressure [kN/m^2] taking into account the loading sequence:
= $9{,}81 \cdot (\gamma \cdot T + 0{,}6 \cdot n)$

γ = loading sequence coefficient:
= 1 for loading/unloading in one run
= 0,575 for loading/unloading in two runs

$p_{\gamma I}$ = internal load [kN/m^2] taking into account the loading sequence:
= $\gamma_1 \cdot p_C - p_M$

γ_1 = $(\gamma - 0{,}15) / 0{,}85$

d = double bottom height [mm]

r_T, r_L = coefficients defined in Table 5.5

p_E, p_B, p_C = pressures transmitted to the hull structure defined in Section 3, C.5. and Section 3, C.6.

1 In way of side ordinary frames: $\beta_b = \beta_S = 1$

2 The span ℓ is to be taken equal to the web frames or side transverses spacing

NA = not applicable

Table 5.5 Values of coefficients r_T (transverse framing) and r_L (longitudinal framing)

Cargo	r_T	r_L
Uniform	100	90
Non-uniform	90	80

4.2.3 Centre and side girders are to be extended as far aft and forward as practicable. Intercostal web plates are to be aligned and welded to floors.

4.2.4 Where two girders are slightly offset, they are to be shifted over a length at least equal to two frame spacings.

4.2.5 Towards the ends, the thickness of the web plate as well as the sectional area of the top plate may be reduced by 10 %. Lightening holes are to be avoided.

4.2.6 Where side girders are fitted in lieu of the centre girder, the scarfing is to be adequately extended and additional stiffening of the centre bottom may be required.

5. Longitudinally framed single bottom

5.1 Bottom transverses

5.1.1 Spacing

In general, the transverse spacing is to be not greater than 8 frame spacings, nor than 4m, which is the lesser.

5.1.2 Minimum shear sectional area of bottom transverses

In the region where the shear force is maximum and taking into account the possible cuttings provided for the longitudinals, the minimum shear sectional area A_{sh} of bottom transverses [cm^2] is to be not less than the value given in Table 5.3.

GL may waive this rule subject to direct calculation of the shearing stresses.

5.1.3 Bottom transverse height

The ratio of the bottom transverse height to the web net thickness is to be not more than r_L values, given in Table 5.5.

In the case of vessels with considerable rise of floor, this height may be required to be increased so as to assure a satisfactory connection to the side transverses.

5.2 Girders

The requirements in 3.2 apply also to longitudinally framed single bottoms, with transverses instead of floors.

5.3 Bottom longitudinals

5.3.1 General

Longitudinal ordinary stiffeners are generally to be continuous when crossing primary supporting members.

5.3.2 Strengthening

The section modulus of longitudinals located in way of the web frames of transverse bulkheads is to be increased by 10 %.

GL may call for strengthening of the longitudinal located in the centreline of the vessel.

6. Transversely framed double bottom

6.1 Double bottom arrangement

6.1.1 Where it is not possible to visit the double bottoms, they are to be well protected against corrosion.

6.1.2 Where the height of the double bottom varies, the variation is generally to be made gradually and over an adequate length; the knuckles of inner bottom plating are to be located in way of plate floors or girders.

Where this is impossible, suitable structures such as partial girders, brackets, etc., fitted across the knuckle, are to be arranged.

6.1.3 In vessels without a flat bottom, the height of double bottom specified in 6.1.2 may be required to be adequately increased such as to ensure sufficient access to the areas towards the sides.

6.1.4 Strength continuity

Adequate strength continuity of floors is to be ensured in way of the side tank by means of brackets.

6.2 Floors

6.2.1 Spacing

Floors are to be fitted at every frame. Watertight floors are to be fitted:

– in way of transverse watertight bulkheads

– in way of double bottom steps

6.2.2 In general, floors are to be continuous.

6.2.3 Minimum shear sectional area of floors

In the region where the shear force is maximum, the minimum shear sectional area A_{sh} of floors [cm^2] is to be not less than the value given in Table 5.4.

GL may waive this rule subject to direct calculation of the shearing stresses.

6.2.4 Where the double bottom height does not make it possible to connect the floors and girders to the double bottom top by fillet welding, slot welding may be used. In that case, the floors and girders are to be fitted with a face plate or flange.

6.3 Bilge wells

6.3.1 Bilge wells arranged in the double bottom are to be limited in depth and formed by steel plates having a thickness not less than the greater of that required for watertight floors and that required for the inner bottom.

6.3.2 In vessels subject to stability requirements, such bilge wells are to be fitted so that the distance of their bottom from the shell plating is not less than 400 mm.

6.4 Girders

6.4.1 A centre girder is to be fitted on all vessels exceeding 6 m in breadth.

This girder is to be formed by a vertical intercostal plate connected to the bottom plating and fitted with an appropriate face plate.

The intercostal centre girder is to extend over the full length of the vessel or over the greatest length consistent with the lines. It is to have the same thickness as the floors. No manholes are to be provided into the centre girder.

6.4.2 On vessels with ranges of navigation **IN(1,2)** to **IN(2)**, continuous or intercostal girders are to be fitted in the extension of the inner sides. These girders are to have a net thickness equal to that of the inner sides.

On vessels with ranges of navigation **IN(1,2)** to **IN(2)**, built in the transverse system and without web frames, partial intercostal girders are to be fitted in way of the transverse bulkheads of the side tanks. These girders are to be extended at each end by brackets having a length equal to one frame spacing. They are to have a net thickness equal to that of the inner sides.

7. Longitudinally framed double bottom

7.1 General

The requirements in 6.1, 6.3 and 6.4 are also applicable to longitudinally framed double bottoms.

7.2 Transverses

The spacing of transverses [m] is generally to be not greater than 8 frame spacings nor 4 m, whichever is the lesser.

Additional transverses are to be fitted in way of transverse watertight bulkheads.

7.3 Bottom and inner bottom longitudinal ordinary stiffeners

7.3.1 Bottom and inner bottom longitudinal ordinary stiffeners are generally to be continuous through the transverses.

In the case the longitudinals are interrupted in way of a transverse, brackets on both sides of the transverse are to be fitted in perfect alignment.

7.3.2 Struts

Bottom longitudinals may be connected to the inner bottom longitudinals by means of struts having a sectional area not less than those of the connected longitudinals.

Struts are generally to be connected to bottom and inner bottom longitudinals by means of brackets or by appropriate weld sections.

Where struts are fitted between bottom and inner bottom longitudinals at mid-span, the section modulus of bottom longitudinals and inner bottom longitudinals may be reduced by 30 %.

7.4 Brackets to centreline girder

7.4.1 In general, intermediate brackets are to be fitted connecting the centre girder to the nearest bottom and inner bottom ordinary stiffeners.

7.4.2 Such brackets are to be stiffened at the edge with a flange having a width not less than 1/10 of the local double bottom height.

If necessary, GL may require a welded flat bar to be arranged in lieu of the flange.

C. Side Scantlings

1. Symbols

L = Rule length [m] defined in Section 1, A.1.

B = breadth [m] defined in Section 1, A.1.

D = depth [m] defined in Section 1, A.1.

T = draught [m] defined in Section 1, A.1.

B_1 = breadth [m] of the cargo hold

t = net thickness [mm] of plating

s = spacing [m] of ordinary stiffeners

S = spacing [m] of primary supporting members

ℓ = span [m] of ordinary stiffeners or primary supporting members

n = navigation coefficient defined in Section 3, B.

= 0,85·H

H = significant wave height [m]

σ_1 = hull girder normal stress [N/mm²]

β_b, β_s = bracket coefficients defined in Section 2, B.5.2

λ_b, λ_s = coefficients for vertical structural members defined in Section 2, B.5.3

η = $1 - s / (2 \cdot \ell)$

w = net section modulus [cm³] of ordinary stiffeners or primary supporting members

A_{sh} = net web sectional area [cm^2]

k = material factor defined in Section 2, A.2.4 and Section 2, A.3.2

z = Z co-ordinate [m] of the calculation point

H_F = floor height in way of vertical side stiffener [m]

= 0, in way of side web frames and side transverses

2. General

2.1 Application

2.1.1 The following requirements apply to longitudinally or transversely framed single and double side structures of inland waterway vessels.

The requirements applicable to specific vessel Notations are defined in the GL Additional Requirements for Notations (I-2-4).

2.1.2 The transversely framed side structures are built with transverse frames possibly supported by struts, side stringers and web frames.

2.1.3 The longitudinally framed side structures are built with longitudinal ordinary stiffeners supported by side vertical primary supporting members.

3. Scantlings

3.1 Side and inner side plating

3.1.1 In the central part, the side and inner side plating net thickness [mm] is not to be less than the values given in Table 5.6.

3.1.2 Strength check in testing conditions

The plating of compartments or structures to be checked in testing conditions is to comply with Section 2, D.

3.2 Side and inner side structure

3.2.1 Minimum net thickness of web plating

The net thickness of the web plating of ordinary stiffeners is to be not less than:

$$t = 1{,}63 + 0{,}004 \cdot L \cdot k^{0,5} + 4{,}5 \cdot s \qquad \text{for } L < 120 \text{ m}$$

$$t = 3{,}9 \cdot k^{0,5} + s \qquad \text{for } L \geq 120 \text{ m}$$

The minimum net thickness [mm] of plating which forms the web of side and inner side primary supporting members is to be not less than the value obtained from the formula:

$$t = 3{,}8 + 0{,}016 \cdot L \cdot k^{0,5}$$

3.2.2 Net scantlings of side and inner side structural members in service conditions

The net scantlings of side and inner side structural members in service conditions are to comply with Table 5.7 or Table 5.8, as applicable.

3.2.3 Net scantlings of side and inner side structural members in testing conditions

The net section modulus w [cm^3] and the net shear sectional area A_{sh} [cm^2] of side and inner side structural members being part of compartments or structures containing liquid are to comply with Section 2, D.

3.2.4 Buckling check

Side and inner side structural members are to comply with the requirements stated under of Section 2, C.

4. Transversely framed single side

4.1 Side frames

4.1.1 Transverse frames are to be fitted at every frame.

4.1.2 Continuity

Frames are generally to be continuous when crossing primary supporting members.

Otherwise, the detail of the connection is to be examined by GL on a case-by-case basis.

4.1.3 Connection with floors

The frames are to be connected to the floors in accordance with Fig. 5.2, or in an equivalent way.

For overlapping connection as to Fig. 5.2 b) and c), a fillet weld run all around has to be provided.

4.1.4 Connection with deck structure

At the upper end of frames, connecting brackets are to be provided, in compliance with 8.

On single hull open deck vessels, such brackets are to extend to the hatch coaming.

In the case of longitudinally framed deck, connecting brackets are to extend up to the deck longitudinal most at side and even to:

– the hatch coaming, in general

– the side trunk bulkhead, in the case of a trunk vessel.

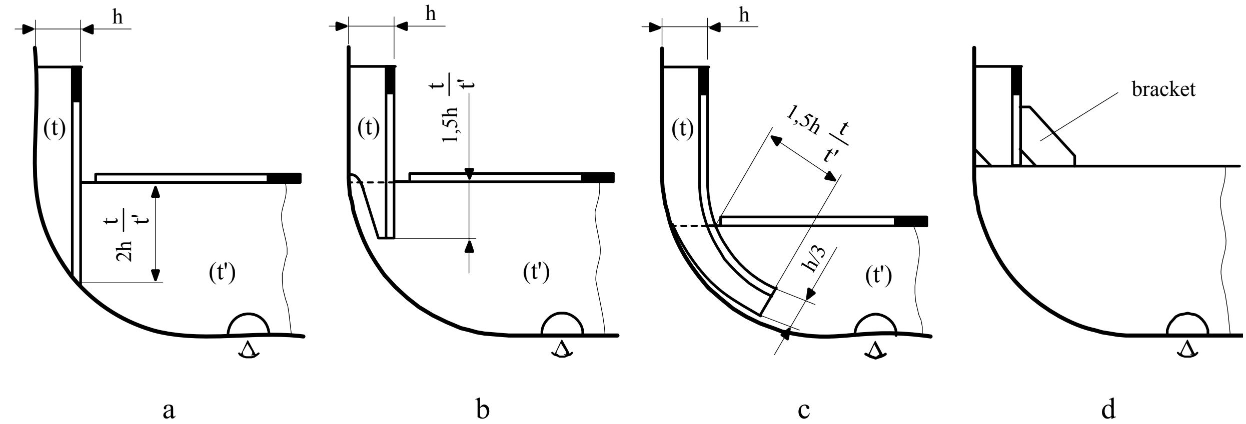


Fig. 5.2 Connection with floors

Table 5.6 Side and inner side plating net thickness [mm]

Item	Transverse framing	Longitudinal framing
Side plating	$t = MAX(t_i)$ $t_1 = 1{,}68 + 0{,}025 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$ $t_2 = 1{,}6 \cdot s \cdot (k \cdot p)^{0,5}$ $t_3 = k_1 \cdot t_0$	$t = MAX(t_i)$ $t_1 = 1{,}25 + 0{,}02 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$ $t_2 = 1{,}2 \cdot s \cdot (k \cdot p)^{0,5}$ $t_3 = k_1 \cdot t_0$
Inner side plating	$t = MAX(t_i)$ $t_1 = 2{,}2 + 0{,}013 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$ $t_2 = 1{,}6 \cdot s \cdot (k \cdot p)^{0,5}$	$t = MAX(t_i)$ $t_1 = 2{,}2 + 0{,}013 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$ $t_2 = 1{,}2 \cdot s \cdot (k \cdot p)^{0,5}$

p = design load [kN/m²]
- in way of ballast tanks:
  - $p = MAX[p_E ; (p_B - p_M)]$ for side plating
  - $= MAX(P_C ; p_B)$ for inner side plating
- elsewhere:
  - $p = p_E$ for side plating
  - $= p_C$ for inner side plating

p_M = minimum external load [kN/m²], $p_M \geq 0$:
for $z \leq 0{,}15 \cdot T$: $p_M = 9{,}81 \cdot (0{,}15 \cdot T - z - 0{,}6 \cdot n)$
for $z > 0{,}15 \cdot T$: $p_M = 0$

$t_0 = t_{bottom}$

k_1 = 0,85 if transversely framed bottom
0,90 if longitudinally framed bottom

p_E, p_B and p_C are parameters defined in Section 3, C.5. and Section 3, C.6.

4.1.5 Reduction of section modulus

When a side stringer is fitted at about mid-span of the frame, the required section modulus of the frame may be reduced by 20 %.

4.1.6 Single bottom: connection of frames to bottom longitudinals

In the case of a longitudinally framed single bottom, the side frames are to be connected to the bottom longitudinal most at side, either directly or by means of a bracket, in accordance with Fig. 5.3.

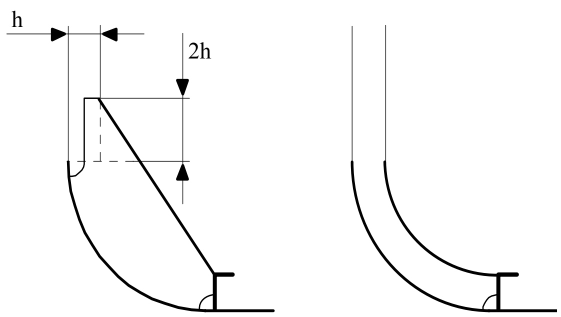


Fig. 5.3 Connection of frames to bottom longitudinals

Table 5.7 Net scantlings of side single hull structure

Item	w	A_{sh}
Side frames	$w = 0{,}58 \cdot \beta_b \cdot \eta \cdot s \cdot (1{,}2 \cdot k_0 \cdot p \cdot \ell_0^2 + \lambda_t \cdot p_{\gamma E} \cdot \ell_F^2)$	$A_{sh} = 0{,}08 \cdot \beta_s \cdot \eta \cdot k_0 \cdot p \cdot s \cdot \ell_0$
Side longitudinals	$w = \dfrac{83{,}3}{214 - \sigma_1} \beta_b \cdot \eta \cdot p \cdot s \cdot \ell^2$	$A_{sh} = 0{,}045 \cdot \beta_s \cdot \eta \cdot p \cdot s \cdot \ell$
Side web frames Side transverses [1]	$w = 1{,}96 \cdot \beta_b \cdot k_0 \cdot p \cdot S \cdot \ell_0^2$	$A_{sh} = 0{,}063 \cdot \beta_s \cdot k_0 \cdot p \cdot S \cdot \ell_0$
Side stringers [2]	$w = \dfrac{125}{197 - \sigma_1} \cdot \beta_b \cdot p \cdot s \cdot \ell^2$	$A_{sh} = 0{,}056 \cdot \beta_s \cdot p \cdot S \cdot \ell$

H_F = floor height or bottom transverse height [m]

p = design load of side structural members [kN/m²]: $p = p_E$

ℓ_F = floor span [m]

$\ell_0 = T - H_F + 0{,}6 \cdot n$

k_0 = coefficient given by the formula:

= $1 + (\ell - \ell_0) / \ell_0$

λ_t = coefficient to be taken equal to:

– in transverse framing:

$$\lambda_t = 0{,}1 \cdot \left(0{,}8 - \frac{\ell^2}{\ell_F^2}\right), \quad \lambda_t \geq 0$$

– in combination framing:

= 0

p_E = external pressure transmitted to the hull structure:

– in general:
p_E is to be determined in compliance with Section 3, C.5.

– for vertical stiffeners:

= $4{,}9 \cdot \ell_0$

$p_{\gamma E}$ = floor external load [kN/m²] taking into account the loading sequence:

= $9{,}81 \cdot (\gamma \cdot T + 0{,}6 \cdot n)$

γ = loading sequence coefficient:

= 1,0 for loading/unloading in one run

= 0,575 for loading/unloading in two runs.

[1] Scantlings of web frames and side transverses at the lower end have to be adequate to those of floors or bottom transverses connected to them.

[2] The span of side stringers is to be taken equal to the side transverses spacing or web frames spacing.

4.2 Side stringers

4.2.1 Arrangement

Side stringers, if fitted, are to be flanged or stiffened by a welded face plate.

The side stringers are to be connected to the frames by welds, either directly or by means of collar plates.

4.3 Web frames

4.3.1 Spacing

Web frames are to be fitted with a spacing [m] not greater than 5 m.

For a construction on the combination system, side web frames are to be provided in way of bottom transverses.

4.3.2 End connections

Where the web frames are connected to the floors or the strong beams, web frame strength continuity is to be ensured, according to Section 2, B.5.5.

4.3.3 End connection in the case of a trunk deck

For vessels fitted with a trunk having a breadth greater than 0,8·B, the web frames determined as laid down before are to extend up to the level of the trunk deck where, as a rule, they are to be connected to strong beams.

Table 5.8 Net scantlings of side double hull structure

Item	w	A_{sh}
Side frames subjected to external load	$w = 0{,}7 \cdot \beta_b \cdot \eta_1 \cdot k_0 \cdot p \cdot s \cdot \ell_0^2$	$A_{sh} = 0{,}08 \cdot \beta_s \cdot \eta_1 \cdot k_0 \cdot p \cdot s \cdot \ell_0$
Side frames and Inner side frames in other loading cases	$w = 0{,}58 \cdot \lambda_b \cdot \beta_b \cdot \eta_1 \cdot p \cdot s \cdot \ell^2$	$A_{sh} = 0{,}058 \cdot \lambda_s \cdot \beta_s \cdot \eta_1 \cdot p \cdot s \cdot \ell$
Side longitudinals and Inner side longitudinals	$w = \dfrac{83{,}3}{214 - \sigma_1} \cdot \beta_b \cdot \eta \cdot p \cdot s \cdot \ell^2$	$A_{sh} = 0{,}045 \cdot \beta_s \cdot \eta \cdot p \cdot s \cdot \ell$
Side web frames and Side transverses subjected to external load	$w = 0{,}7 \cdot \beta_b \cdot k_0 \cdot p \cdot S \cdot \ell_0^2$	$A_{sh} = 0{,}063 \cdot \beta_s \cdot k_0 \cdot p \cdot S \cdot \ell_0$
Side and inner side web frames and Side and inner side transverses in other loading cases	$w = 0{,}58 \cdot \lambda_b \cdot \beta_b \cdot p \cdot S \cdot \ell^2$	$A_{sh} = 0{,}045 \cdot \lambda_s \cdot \beta_s \cdot p \cdot S \cdot \ell$
Plate web frames subjected to external load	$w = 1{,}96 \cdot \beta_b \cdot k_0 \cdot p \cdot S \cdot \ell_0^2$	$A_{sh} = 0{,}063 \cdot \beta_s \cdot k_0 \cdot p \cdot S \cdot \ell_0$
Plate web frames in other loading cases	$w = 1{,}63 \cdot \lambda_b \cdot \beta_b \cdot p \cdot S \cdot \ell^2$	$A_{sh} = 0{,}045 \cdot \lambda_s \cdot \beta_s \cdot p \cdot S \cdot \ell$
Side stringers and Inner side stringers [1]	$w = \dfrac{125}{197 - \sigma_1} \cdot \beta_b \cdot p \cdot S \cdot \ell^2$	$A_{sh} = 0{,}056 \cdot \beta_s \cdot p \cdot S \cdot \ell$

η_1 = 1 if no side web frames are fitted
= η otherwise

p = design load of double side structural members [kN/m²]:
– in way of ballast tanks:
for side structure: $p = \text{MAX}\,[p_E\,;\,(p_B - p_M)]$
for inner side structure: $p = \text{MAX}\,(p_C\,;\,p_B)$
– elsewhere:
for side structure: $p = p_E$
for inner side structure: $p = p_C$

H_F = floor height or bottom transverse height [m]

$\ell_0 = T - H_F + 0{,}6 \cdot n$

k_0 = coefficient given by the formula:
= $1 + (\ell - \ell_0) / \ell_0$

p_E = external pressure transmitted to the hull structure:
– in general:
p_E is to be determined in compliance with Section 3, C.4.
– for vertical stiffeners:
= $4{,}9\ \ell_0$

p_M = minimum external load [kN/m²], $p_M \geq 0$:
for $z \leq 0{,}15 \cdot T$: $p_M = 9{,}81 \cdot (0{,}15 \cdot T - z - 0{,}6 \cdot n)$
for $z > 0{,}15 \cdot T$: $p_M = 0$

p_B, p_C = pressures transmitted to the hull structure defined in Section 3, C.5.

[1] The span of side stringers is to be taken equal to the side transverses spacing or web frames spacing

5. Longitudinally framed single side

5.1 Side transverses

5.1.1 Spacing

Side transverses are to be fitted:

– in general, with a spacing not greater than 8 frame spacings, nor than 4 m

– in way of hatch end beams

5.1.2 The side transverses are generally directly welded to the shell plating.

In the case of a double bottom, the side transverses are to be bracketed to the bottom transverses.

5.1.3 Minimum shear sectional area of transverse web

In the region where the shear force is maximum and taking into account the possible cuttings provided for the longitudinals, the minimum shear sectional area of a transverse web [cm^2] is to be not less than the value given in Table 5.8.

GL may waive this rule subject to direct calculation of the shearing stresses.

5.2 Side longitudinals

Longitudinal ordinary stiffeners are generally to be continuous when crossing primary supporting members.

In the case the longitudinals are interrupted by a primary supporting member, brackets on both sides of the primary supporting member are to be fitted in perfect alignment.

The section modulus of side longitudinals located in way of the stringers of transverse bulkheads is to be increased by 20 %.

6. Transversely framed double side

6.1 General

Adequate continuity of strength is to be ensured in way of breaks or changes in width of the double side. In particular, scarfing of the inner side is to be ensured beyond the cargo hold region.

6.2 Side and inner side frames

6.2.1 Struts

Side frames may be connected to the inner side frames by means of struts having a sectional area not less than those of the connected frames.

Struts are generally to be connected to side and inner side frames by means of vertical brackets or by appropriate weld sections.

Where struts are fitted between side and inner side frames at mid-span, the section modulus of side frames and inner side frames may be reduced by 30 %.

6.3 Side and inner side web frames

6.3.1 It is recommended to provide web frames, fitted every 3 m and in general not more than 6 frame spacings apart.

In any case, web frames are to be fitted in way of strong deck beams.

6.3.2 At their upper end, side and inner side web frames are to be connected by means of a bracket. This bracket can be a section or a flanged plate with a section modulus at least equal to that of the web frames.

At mid-span, the web frames are to be connected by means of struts, the cross sectional area of which is not to be less than those of the connected web frames.

At their lower end, the web frames are to be adequately connected to the floors.

7. Longitudinally framed double side

7.1 General

The requirements in 6.1.1 also apply to longitudinally framed double side.

7.2 Side and inner side longitudinals

7.2.1 Struts

Side longitudinals may be connected to the inner side longitudinals by means of struts having a sectional area not less than those of the connected longitudinals.

Struts are generally to be connected to side and inner side longitudinals by means of brackets or by appropriate weld sections.

Where struts are fitted between side and inner side longitudinals at mid-span, the section modulus of side longitudinals and inner side longitudinals may be reduced by 30 %.

7.3 Side transverses

The requirements in 6.3 also apply to longitudinally framed double side, with side transverses instead of side web frames.

8. Frame connections

8.1 General

8.1.1 End connections

At their lower end, frames are to be connected to floors, by means of lap weld or by means of brackets.

At the upper end of frames, connecting brackets are to be provided, in compliance with 8.2. In the case of open deck vessels, such brackets are to extend to the hatch coaming.

Brackets are normally connected to frames by lap welds. The length of overlap is to be not less than the depth of frames.

8.1.2 Brackets

The same minimum value d is required for both arm lengths of straight brackets. Straight brackets may therefore have equal sides.

A curved bracket is to be considered as the largest equal-sided bracket contained in the curved bracket.

8.2 Upper and lower brackets of frames

8.2.1 Arm length

The arm length of upper brackets, connecting frames to deck beams, and the lower brackets, connecting frames to the inner bottom or to the face plate of floors is to be not less than the value obtained [mm] from the following formula:

$$d = \varphi \cdot \sqrt{\frac{w + 30}{t}}$$

φ = coefficient

= 50 for unflanged brackets

= 45 for flanged brackets

w = required net section modulus of the stiffener [cm^3], given in 8.2.2 and depending on the type of connection

t = bracket net thickness [mm] to be taken not less than the stiffener thickness

8.2.2 Section modulus of connections

For connections of perpendicular stiffeners located in the same plane (see Fig. 5.4) or connections of stiffeners located in perpendicular planes (see Fig. 5.5), the required section modulus is to be taken equal to:

$w = w_2$ if $w_2 \le w_1$

$w = w_1$ if $w_2 > w_1$

where w_1 and w_2 are the required net section moduli of stiffeners, as shown in Fig. 5.4 and Fig. 5.5.

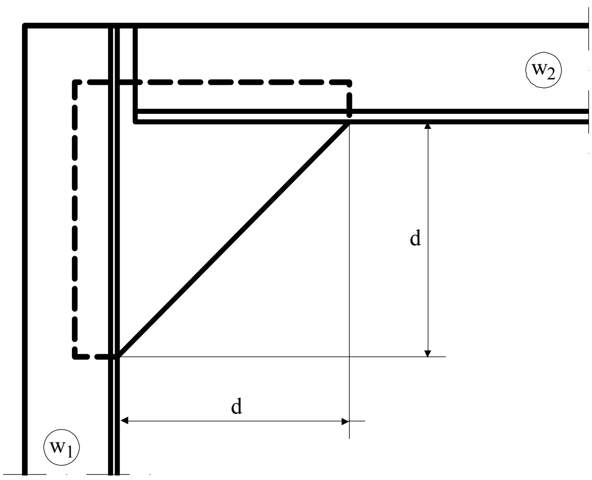


Fig. 5.4 Connections of perpendicular stiffeners in the same plane

8.2.3 All brackets for which:

$$\frac{\ell_b}{t} > 60$$

ℓ_b = length [mm] of the free edge of the bracket

t = bracket net thickness [mm]

are to be flanged or stiffened by a welded face plate.

The sectional area [cm^2] of the flange or the face plate is to be not less than $0{,}01 \cdot \ell_b$.

The width of the face plate is to be not less than 10 t.

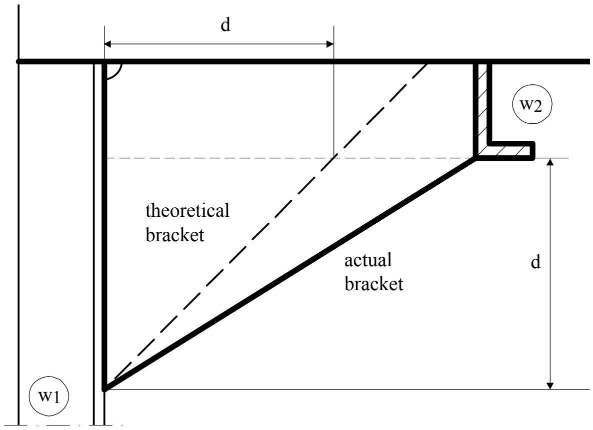


Fig. 5.5 Connections of stiffeners located in perpendicular planes

D. Deck Scantlings

1. Symbols

L = Rule length [m] defined in Section 1, A.1.

B = breadth [m] defined in Section 1, A.1.

D = depth [m] defined in Section 1, A.1.

T = draught [m] defined in Section 1, A.1.

D_1 = unsupported stringer plate length, in [m]

t = net thickness [mm] of plating

s = spacing [m] of ordinary stiffeners

S = spacing [m] of primary supporting members

ℓ = span [m] of ordinary stiffeners or primary supporting members

n = navigation coefficient defined in Section 3, B.

= 0,85·H

H = significant wave height [m]

σ_1 = hull girder normal stress [N/mm^2]

βb, βs = bracket coefficients defined in Section 2, B.5.2

η = $1 - s / (2 \cdot \ell)$

w = net section modulus [cm^3] of ordinary stiffeners or primary supporting members

A_{sh} = net web sectional area [cm^2]

k = material factor defined in Section 2, A.2.4 and Section 2, A.3.2

z = Z co-ordinate [m] of the calculation point

M_H = design bending moment [kN·m] in hogging condition

M_S = design bending moment [kN·m] in sagging condition.

2. General

2.1 Application

2.1.1 The following requirements apply to inland waterway vessels with:

– open decks, consisting of a stringer plate and a longitudinal hatch coaming (Fig. 5.6)

– flush decks, consisting of a deck continuous over the breadth of the vessel (Fig. 5.7 and Fig. 5.8)

– trunk decks, differing from flush decks solely by the presence of a trunk.

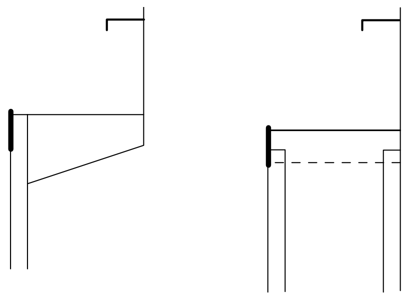


Fig. 5.6 Open deck

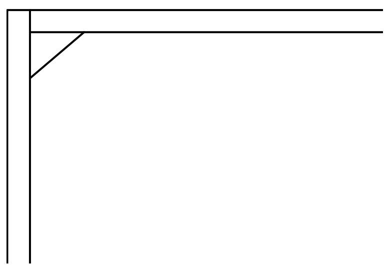


Fig. 5.7 Transversely framed flush deck

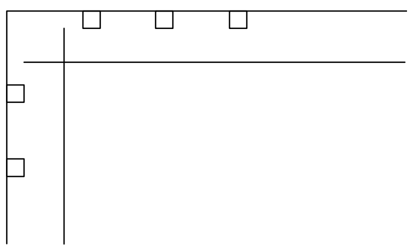


Fig. 5.8 Longitudinally framed flush deck

2.1.2 These decks can be longitudinally or transversely framed and may be sustained by pillars, bulkheads or strong beams.

2.1.3 The requirements applicable to specific vessel Notations are defined in the GL Additional Requirements for Notations (I-2-4).

2.2 General arrangement

2.2.1 It is recommended to avoid breaks in the deck of the cargo hold zone. In any case, the continuity of longitudinal strength is to be ensured at such places.

To ensure continuity in the case of a break, the stringer plate of the lower deck is to:

– extend beyond the break, over a length at least equal to three times its width

– stop at a web frame of sufficient scantlings.

Decks which are interrupted are to be tapered on the side by means of horizontal brackets.

2.2.2 Adequate continuity of strength is also to be ensured in way of changes in the framing system.

Details of structural arrangements are to be submitted to GL for review/approval.

2.2.3 Deck supporting structures under deck machinery, cranes and king posts are to be adequately stiffened.

2.2.4 Where devices for vehicle lashing arrangements and/or corner fittings for containers are directly attached to deck plating, provision is to be made for the fitting of suitable additional reinforcements of the scantlings required by the load carried.

2.2.5 Stiffeners are to be fitted in way of the ends and corners of deckhouses and partial superstructures.

2.2.6 Manholes and flush deck plugs

Manholes and flush deck plugs exposed to the weather are to be fitted with steel covers of efficient construction capable of ensuring tightness. These covers are to be fitted with permanent securing device, unless they are secured with closed spaced bolts.

2.2.7 Freeing ports

Arrangements are to be made to ensure rapid evacuation of water on the decks; in particular, where the bulwarks constitute wells on the weather deck, freeing ports of adequate sectional area are to be provided.

2.2.8 Scuppers

Scuppers on the weather deck and terminating outside the hull are to be made of pipes the thickness of which, as a rule, is not to be less than that of the side plating under the sheerstrake but, however needs not exceed 8 mm.

See also Section 6, G.6.

2.2.9 Stringer plate openings

The openings made in the stringer plate other than scupper openings are to be wholly compensated to the satisfaction of GL.

3. Open deck - Single hull vessels

3.1 Stringer plate

3.1.1 Width

The stringer plate is to extend between the side shell plating and the hatch coaming. In principle its width [m] is to be not less than: $b = 0{,}1 \cdot B$

The stringer plate width and arrangements are to be so that safe movement is possible.

3.1.2 Stringer plate net thickness

The stringer plate is to have a net thickness [mm] not less than the values obtained from Table 5.9.

Table 5.9 Stringer plate net thickness [mm] - Single hull vessels

$\alpha \geq 1$	$\alpha < 1$
$t = MAX\ (t_i)$	$t = MAX\ (t_i)$
$t_1 = 2 + 0{,}02 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$	$t_1 = 2 + 0{,}02 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$
$t_2 = 39 \cdot s \cdot \sqrt{\frac{M_S}{Z_D}}$	$t_2 = 74 \cdot \frac{s}{k_2} \cdot \sqrt{\frac{M_S}{Z_D}}$
if $t_2 / s > 12{,}5 / k^{0,5}$:	if $t_2 / s > 23{,}9 / (k^{0,5} \cdot k_2)$:
$t_2 = \frac{4{,}1 \cdot k^{0,5} \cdot s}{\sqrt{0{,}21 - \frac{M_S}{Z_D}}}$	$t_2 = \frac{7{,}76 \cdot k^{0,5} \cdot s}{k_2 \cdot \sqrt{0{,}21 - \frac{M_S}{Z_D}}}$
see [1]	see [1]

k_2 = coefficient
= $1 + \alpha^2$
$\alpha = b_2 / b_1$
b_1 = unsupported stringer plate width in y direction [m]
b_2 = unsupported stringer plate width in x direction [m]
$s = MIN\ (b_1 ; b_2)$
Z_D = deck net hull girder section modulus [cm^3].

[1] A lower value of thickness t_2 may be accepted if in compliance with the buckling analysis carried out according to Section 2, C.

3.1.3 Stringer angle

If a stringer angle is provided, its thickness is to be at least equal to that of the side shell plating plus 1 mm, being not less than that of the stringer plate. This stringer angle is to be continuous on all the hold length.

3.1.4 In vessels having range of navigation **IN(1,2)** or **IN(2),** GL may require transverse deck plating strips efficiently strengthened and joining the stringer plates of both sides to be fitted.

3.2 Sheerstrake

3.2.1 General

The sheerstrake may be either an inserted side strake welded to the stringer plate or a doubling plate.

3.2.2 Net thickness

The sheerstrake net thickness is not to be less than that of the stringer plate nor than that of the side shell plating.

Moreover, this thickness is not to be less than the minimum value [mm] obtained from following formula:

$$t = 3{,}6 + 0{,}11 \cdot L \cdot k_{0,5} + 3{,}6 \cdot s$$

Where a doubling plate is provided instead of an inserted side strake, its thickness [mm] is not to be less than:

$$t = 2{,}6 + 0{,}076 \cdot L \cdot k_{0,5} + 3{,}6 \cdot s$$

3.2.3 Width

Where the sheerstrake thickness is greater than that of the adjacent side shell plating, the sheerstrake is to extend over a height b, measured from the deckline, in compliance with the following relation:

$$0{,}08 \cdot D \leq b \leq 0{,}15 \cdot D$$

3.3 Hatch coaming

3.3.1 Height

The height of the hatch coaming above the deck [m] is not to be less than the value obtained from the following formula, where b is the stringer plate width defined in 3.1.1:

$$h_C = 0{,}75 \cdot b$$

Furthermore, the height of the hatch coaming above the deck is to comply with the following relation:

$$D + h_C > T + n / 1{,}7 + 0{,}15$$

3.3.2 Expanded depth

The expanded depth of the underdeck portion of the hatch coaming is to be not less than 0,15 m.

3.3.3 Net thickness

The net thickness of the hatch coaming is to be maintained over the length of the hold and is to be determined according to Table 5.10.

3.3.4 Stiffening

The coaming boundaries are to be fitted with an horizontal stiffening member close to the coaming upper edge. In the case the coaming is higher than 750 mm, a second stiffener is to be fitted at about 0,75 times the hatch coaming height.

The hatch coaming longitudinals are to have at least the following characteristics:

– Net cross sectional area [cm²] without attached plating:

  upper stiffener: $A = 2{,}5 \cdot h_C \cdot t$

  additional stiffener: $A = 2{,}5 \cdot h_{AS} \cdot t$

– Radius of gyration [cm] with attached plating:

$$i = 0{,}074 \cdot \ell \cdot \sqrt{\sigma_1}$$

  if $i / \ell > 0{,}76 / k^{0,5}$

$$i = \frac{7{,}79 \cdot k^{0,5} \cdot \ell}{\sqrt{210 - \sigma_1}}$$

t = hatch coaming net thickness [mm] determined according to 3.3.3

h_C = hatch coaming height [m]

h_{AS} = distance of the additional stiffener from the deck [m]

ℓ = span of hatch coaming stiffener [m]

i = radius of gyration [cm]

$$i = \sqrt{\frac{I_e}{A_e}}$$

I_e = net moment of inertia [cm⁴] of the stiffener with attached plating

A_e = net cross sectional area [cm²] of the stiffener with attached plating

σ_1 = compression hull girder normal stress [N/mm²]

The upper strake of the hatch coaming (above the upper stiffener) is to be reinforced in way of the stiffening member where its height [m] exceeds $8 \cdot 10^{-3} \cdot t$, t being the hatch coaming net thickness defined in 3.3.3.

Other cases may be accepted on the basis of buckling strength check (direct calculation).

3.3.5 Stays

The coaming boundaries are to be stiffened with stays, the ends of which are to be connected to the deck and to the stiffeners mentioned in 3.3.4 .

These stays are to be fitted with a spacing of maximum 3 m. In any case, they are to be fitted in way of web frames and bulkheads. They may be:

– sections of net moment of inertia (I_{eS}) with attached plating [cm⁴], in compliance with the following formula:

$$I_{eS} = 13 \cdot \left(\frac{h_c}{\ell}\right)^3 \cdot I_e$$

  I_e = net moment of inertia [cm⁴], of the upper hatch coaming longitudinal stiffener with attached plating

  ℓ = span of hatch coaming longitudinal stiffener [m]

– or brackets with thickness $t = 6 + 0{,}2 \cdot t_0$, (where t_0 is the hatch coaming thickness) and with a flanged edge having a width equal to 10 times the bracket thickness.

Strength continuity of the stays is to be ensured below the deck, as far as practicable, in way of web frames and bulkheads. Stiffeners are to be provided under the deck where necessary, in way of the intermediate stays and of the transverse boundary stays.

3.4 Transverse strength of topside structure

3.4.1 General

The topside structure is to be considered as a girder consisting of the stringer plate, the sheerstrake and the hatch coaming, with scantlings according to 3.1, 3.2 and 3.3.

The distributed transverse load [kN/m] acting on the topside structure is to be taken not less than:

$$q = 0{,}25 \cdot (1{,}2 \cdot k_0 \cdot p_1 \cdot \ell_0 + \lambda_t \cdot p_2 \cdot B)$$

$$\ell_0 = T - H_F + 0{,}6 \cdot n$$

$$k_0 = 1 + (\ell - \ell_0) / \ell_0$$

ℓ = side frame span [m]

H_F = floor height in way of the side frame [m]

p_1 = side frame design load [kN/m²]

  $= 4{,}9 \cdot \ell_0$

p_2 = floor design load [kN/m²]

  $= p_{\gamma E}$

  see B.2.

λ_t = coefficient given by the formula

$$= 0{,}1 \cdot \left(0{,}8 - \frac{\ell_2}{B_2}\right), \ \lambda_t \geq 0$$

  in the case of combination framing system

  = 0

The actual section modulus of the topside structure [cm^3] may be determined by means of the following formula:

$$w = A \cdot b + \frac{t \cdot b^2}{60} \cdot \left(1 + \frac{A_a - A}{A_a + 0,05 \cdot t \cdot b}\right)$$

t = thickness of stringer plate [mm]

b = width of stringer plate [cm]

$A = MIN(A_1 ; A_2)$

$A_a = MAX(A_1 ; A_2)$

A_1 = sheerstrake sectional area [cm^2] including a part of the shell plating extending on 0,15·D

A_2 = hatch coaming sectional area [cm^2] including longitudinal stiffeners. The width [m] of the hatch coaming to be considered is:

$h = h_1 + MIN(0,75 \cdot h_c ; 1)$

h_1 = expanded depth of the underdeck portion of the hatch coaming [m] defined in 3.3.2.

3.4.2 Unsupported stringer plate length

The unsupported stringer plate length D_1 [m] is to be taken as the distance between transverse efficient supports (transverse bulkheads, transverse partial bulkheads, reinforced rings).

3.4.3 Topside structure strength check

The minimum required net section modulus [cm^3] of the topside structure is to be obtained using the formula:

$$Z_{TS} = \frac{83,3}{k_1 \cdot (197 - \sigma_1)} \cdot q \cdot D^2_1$$

D_1 = length not to be taken greater than 33,3 m

k_1 = coefficient

$= 1 + 0,25 \cdot \left(\frac{D_1}{s} - 1\right) \cdot \frac{w}{100 \cdot D}$

w = side frame net section modulus [cm^3]

3.4.4 Strong deck box beams

Where the stringer plate is supported by reinforced rings, the net section modulus of the strong deck box beams is to be not less than:

$$w = \frac{125}{214 - \sigma_A} \cdot p \cdot D_1 \cdot \ell_1^2$$

Table 5.10 Hatch coaming plate net thickness [mm]

α ≥ 1	**α < 1**
$t = MAX(t_i)$ $t_1 = 1,6 + 0,04 \cdot L \cdot k^{0,5} + 3,6 \cdot s$	$t = MAX(t_i)$ $t_1 = 1,6 + 0,04 \cdot L \cdot k^{0,5} + 3,6 \cdot s$
$t_2 = t_0$	$t_2 = t_0$
$t_3 = 26,8 \cdot s \cdot \sqrt{\frac{(1,1 + \Psi) \cdot M_S}{Z_H}}$ if $t_3/s > 8,65 \cdot [(1,1 + \psi) / k]^{0,5}$: $t_3 = \frac{2,86 \cdot s \cdot \sqrt{k \cdot (1,1 + \Psi)}}{\sqrt{0,21 - \frac{M_S}{Z_H}}}$ see [1]	$t_3 = 51 \cdot \frac{s}{k_2} \cdot \sqrt{\frac{(1,1 + \psi) \cdot M_S}{Z_H}}$ if $t_3/s > 16,5 \cdot (1,1 + \psi)^{0,5} / (k^{0,5} \cdot k_2)$: $t_3 = \frac{5,6 \cdot s \cdot \sqrt{k \cdot (1,1 + \Psi)}}{k_2 \cdot \sqrt{0,21 - \frac{M_S}{Z_H}}}$ see [1]
t_0 = stringer plate net thickness k_2 = coefficient $= 1 + \alpha^2$ $\alpha = b_4 / b_3$ b_3 = unsupported hatch coaming height [m] b_4 = unsupported hatch coaming width in x direction [m] $s = MIN(b_3 ; b_4)$ Z_H = net hull girder section modulus in way of the hatch coaming mid-height [cm^3] $\psi = \sigma_{1L} / \sigma_{1U}$ σ_{1L} = compression stress [N/mm^2] on the lower edge of the hatch coaming panel σ_{1U} = compression stress [N/mm^2] on the upper edge of the hatch coaming panel. [1] A lower value of thickness t_3 may be accepted if in compliance with the buckling analysis carried out according to Section 2, C.	

p = deck design load [kN/m²] to be defined by the designer. In any case p is not to be taken less than the value derived from formula given under Section 3, C.4.2

σ_A = deck box beam axial stress [N/mm²]:

$$\sigma_A = \frac{10 \cdot q \cdot D_1}{A}$$

A = deck box beam sectional area [cm²] to be determined in compliance with 10.2.2, where

$P_S = q \cdot D_1$

ℓ_1 = span of strong box beam [m]

4. Open deck - double hull vessels

4.1 Stringer plate

4.1.1 Width

The stringer plate is to extend between the side shell plating and the hatch coaming. In principle, its width b [m] is not to be less than 0,6 m, unless other wise justified.

4.1.2 Stringer plate net thickness

The stringer plate is to have a net thickness [mm] not less than the values obtained from Table 5.11.

Table 5.11 Stringer plate net thickness [mm] Double hull vessels

$\alpha \geq 1$	$\alpha < 1$
$t = MAX\ (t_i)$	$t = MAX\ (t_i)$
$t_1 = 2 + 0{,}02 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$	$t_1 = 2 + 0{,}02 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$
$t_2 = 39 \cdot s \cdot \sqrt{\frac{M_S}{Z_D}}$ if $t_2 / s > 12{,}5 / k^{0,5}$: $t_2 = \frac{4{,}1 \cdot k^{0,5} \cdot s}{\sqrt{0{,}21 - \frac{M_S}{Z_D}}}$ see [1]	$t_2 = 74 \cdot \frac{s}{k_2} \cdot \sqrt{\frac{M_S}{Z_D}}$ if $t_2 / s > 23{,}9 / (k^{0,5} \cdot k_2)$: $t_2 = \frac{7{,}76 \cdot k^{0,5} \cdot s}{k_2 \cdot \sqrt{0{,}21 - \frac{M_S}{Z_D}}}$ see [1]

k_2 = coefficient
= $1 + \alpha_2$

α = b_2 / b_1

b_1 = unsupported stringer plate width in y direction [m]

b_2 = unsupported stringer plate width in x direction [m]

s = MIN (b_1 ; b_2)

Z_D = deck net hull girder section modulus [cm³]

[1] A lower value of thickness t_2 may be accepted if in compliance with the buckling analysis carried out according to Section 2, C.

4.1.3 Stringer angle

If a stringer angle is provided, its thickness is to be at least equal to that of the side shell plating plus 1 mm, being not less than that of the stringer plate. This stringer angle is to be continuous on all the hold length.

4.1.4 In vessels having range of navigation **IN(1,2)** or **IN(2),** GL may require transverse deck plating strips efficiently strengthened and joining the stringer plates of both sides to be fitted.

4.2 Sheerstrake

4.2.1 General

The sheerstrake may be either an inserted side strake welded to the stringer plate or a doubling plate.

4.2.2 Net thickness

The sheerstrake net thickness is not to be less than that of the stringer plate nor than that of the side shell plating.

Moreover, this thickness is not to be less than the minimum value [mm] obtained from the following formula:

$$t = 3{,}6 + 0{,}11 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$$

Where a doubling plate is provided instead of an inserted side strake, its thickness [mm] is not to be less than:

$$t = 2{,}6 + 0{,}076 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$$

4.2.3 Width

Where the sheerstrake thickness is greater than that of the adjacent side shell plating, the sheerstrake is to extend over a height b, measured from the deckline, in compliance with the following relation:

$$0{,}08 \cdot D \leq b \leq 0{,}15 \cdot D$$

4.3 Hatch coaming

4.3.1 Height

The height of the hatch coaming above the deck [m] is not to be less than the value obtained from the following formula, where b is the stringer plate width defined in 4.1.1:

$$h_C = 0{,}75 \cdot b$$

Furthermore, the height of the hatch coaming above the deck is to comply with the following relation:

$$D + h_C > T + n / 1{,}7 + 0{,}15$$

4.3.2 Extension of hatch coaming under the deck

The hatch coaming thickness is to be maintained to a depth under the deck not less than 0,25·b.

4.3.3 Net thickness

The thickness of the hatch coaming is to be maintained over the length of the hold and is to be determined in compliance with 3.3.3.

4.3.4 Stiffening

The coaming boundaries are to be stiffened with an horizontal stiffening member whose scantlings and arrangements are to be in compliance with 3.3.4.

4.3.5 Stays

The coaming boundaries are to be stiffened with stays, the ends of which are to be connected to the deck and to the stiffeners mentioned in 4.3.4.

The scantlings and arrangements of stays are to be in compliance with 3.3.5.

5. Flush deck

5.1 General

In principle, on tankers for oil or chemical cargoes, doubling plates are not allowed to be fitted within the cargo tank area, i.e. from the aftermost to the foremost cofferdam bulkhead.

5.2 Stringer plate

5.2.1 Net thickness

The stringer plate net thickness [mm] is not to be less than that of the adjacent deck plating nor than the value derived from the following formula:

$$t = 2 + 0{,}032 \cdot L \cdot k_{0,5} + 3{,}6 \cdot s$$

5.2.2 Width

Where the stringer plate has a thickness greater than that of the deck plating, its width is to be not less than 50 times its thickness.

5.2.3 Stringer angle

Where a stringer angle is fitted, its thickness is not to be less than that of the side shell plating increased by 1 mm nor, as a rule, when the vessel is built on the transverse system, than that of the stringer plate.

5.2.4 If the stringer plate is rounded at side, it is to extend on the side shell plating over a length at least equal to 25 times its thickness, for vessels built on the transverse system.

5.3 Deck plating

5.3.1 The deck plating net thickness [mm] is to be obtained from Table 5.12.

5.3.2 Deck plating subjected to lateral pressure in testing conditions

Deck plating of compartments or structures to be checked in testing conditions is to comply with Section 2, D.

5.4 Sheerstrake

5.4.1 General

The sheerstrake may be either an inserted side strake welded to the stringer plate or a doubling plate.

5.4.2 Net thickness

The sheerstrake net thickness is not to be less than that of the stringer plate nor than that of the side shell plating.

Moreover, this thickness is not to be less than the minimum value [mm] obtained from following formula:

$$t = 3{,}6 + 0{,}11 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$$

Where a doubling plate is provided instead of an inserted side strake, its thickness [mm] is not to be less than:

$$t = 2{,}6 + 0{,}076 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$$

5.4.3 Rounded sheerstrake

In the case of a rounded sheerstrake connecting the side shell to the deck, the radius of curvature of the strake [mm] is not to be less than 5 times its thickness.

5.4.4 Width

Where the sheerstrake thickness is greater than that of the adjacent side shell plating, the sheerstrake is to extend over a height b, measured from the deckline, in compliance with the following relation:

$$0{,}08 \cdot D \le b \le 0{,}15 \cdot D$$

Where a sheerstrake does not rise above deck, a footguard angle or flat is to be fitted at about 100 mm from the side shell.

The height of the sheerstrake/footguard above the deck is to be at least 50 mm.

5.5 Coamings of separate hatchways

5.5.1 Height

The coaming upper edge is not to be less than 300 mm above the deck.

Furthermore, the height of the hatch coaming, h_C, above the deck is to comply with the following relation:

$$D + h_C > T + n / 1{,}7 + 0{,}15$$

5.5.2 Net thickness

The net thickness of the coaming boundaries is not to be less than:

$t = 0{,}25 \cdot a + 3 \leq 5$ mm,

a being the greater dimension of the hatchway [m].

GL reserves the right to increase the scantlings required herebefore where range of navigation **IN(1,2)** or **IN(2)** is assigned, or to reduce them where range of navigation **IN(0)** is assigned.

5.5.3 Stiffening

The coaming boundaries are to be stiffened with an horizontal stiffening member close to the coaming upper edge. In the case the coaming is higher than 750 mm, a second stiffener is to be fitted at about 0,75 times the hatch coaming height.

The coaming boundaries are to be stiffened with stays, the ends of which are to be connected to the deck and to the upper horizontal stiffeners.

Where necessary, stiffeners are to be provided under deck in way of the stays.

The upper strake of the hatch coaming (above the upper stiffener) is to be reinforced in way of the stiffening member where its height [m] exceeds $8 \cdot 10^{-3} \cdot t$, t being the hatch coaming net thickness defined in 5.5.2.

5.5.4 Strength continuity

Arrangements are to be made to ensure strength continuity of the top structure, at the end of large-size hatchways, mainly by extending the deck girders along the hatchway, beyond the hatchways, up to the end bulkhead or over two frame spacings, whichever is greater.

6. Trunk deck

6.1 Plating net thickness

6.1.1 The trunk sheerstrake, stringer and longitudinal bulkhead plating are to be of the same thickness. That thickness [mm] is not to be less than that of the side shell plating nor than that obtained from following formulae:

– transverse framing:

$t_1 = 0{,}2 + 0{,}04 \cdot L \cdot k^{0{,}5} + 3{,}6 \cdot s$

– longitudinal framing:

$t_2 = t_1 - 0{,}5$

6.1.2 Where the sheerstrake has a thickness greater than that of the adjacent side shell plating, it is to extend to a height at least equal to 25 times its thickness, as measured from the deckline.

6.1.3 The trunk deck plating is to be not less than that obtained from 5.3.

6.1.4 Where the trunk is transversely framed, the thickness of the longitudinal bulkhead of the trunk is to be maintained on the trunk top over a width equal to 25 times its thickness.

7. Deck supporting structure

7.1 General

The deck supporting structure consists of ordinary stiffeners (beams or longitudinals), longitudinally or transversely arranged, supported by primary supporting members which may be sustained by pillars.

7.2 Minimum net thickness of web plating

7.2.1 Deck ordinary stiffeners

The net thickness [mm] of the web plating of ordinary stiffeners is not to be less than:

$t = 1{,}63 + 0{,}004 \cdot L \cdot k^{0{,}5} + 4{,}5 \cdot s$ for $L < 120$ m

$= 3{,}9 \cdot k^{0{,}5} + s$ for $L \geq 120$ m

7.2.2 Deck primary supporting members

The net thickness [mm] of plating which forms the web of primary supporting members is to be not less than the value obtained from the following formula:

$t = 3{,}8 + 0{,}016 \cdot L \cdot k^{0{,}5}$

7.3 Net scantlings in service conditions

7.3.1 The net section modulus w [cm^3] and the net shear sectional area A_{sh} [cm^2] of deck structural members in service conditions are to be obtained from Table 5.13.

7.4 Net scantlings in testing conditions

7.4.1 The net section modulus w [cm^3] and the net shear sectional area A_{sh} [cm^2] of deck structural members being part of compartments or structures containing liquid are to comply with Section 2, D.

7.5 Buckling check

Deck structural members are to comply with the requirements stated under Section 2, C.

Table 5.12 Deck plating net thickness [mm]

Transverse framing	**Longitudinal framing**
$t = MAX(t_i)$ $t_1 = 0{,}9 + 0{,}034 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$ $t_2 = 1{,}6 \cdot s \cdot (k \cdot p)^{0,5}$ $t_3 = 74 \cdot \frac{s}{k_2} \cdot \sqrt{\frac{M_S}{Z_D}}$ if $t_3 / s > 23{,}9 / (k^{0,5} \cdot k_2)$: $t_3 = \frac{7{,}76 \cdot k^{0,5} \cdot s}{k_2 \cdot \sqrt{0{,}21 - \frac{M_S}{Z_D}}}$ see [1]	$t = MAX(t_i)$ $t_1 = 0{,}57 + 0{,}031 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$ $t_2 = 1{,}2 \cdot s \cdot (k \cdot p)^{0,5}$ $t_3 = 39 \cdot s \cdot \sqrt{\frac{M_S}{Z_D}}$ if $t_3 / s > 12{,}5 / k^{0,5}$: $t_3 = \frac{4{,}1 \cdot k^{0,5} \cdot s}{\sqrt{0{,}21 - \frac{M_S}{Z_D}}}$ see [1]

k_2 = coefficient
= $1 + \alpha_2$

$\alpha = b_2 / b_1$

b_1 = unsupported deck width in y direction[m]

b_2 = unsupported deck width in x direction [m]

Z_D = deck net hull girder section modulus [cm^3]

p = deck design load [kN/m^2] to be defined by the designer. In any case p is not to be taken less than the value derived from applicable formulae given under Section 3, C.4.2 and Section 3, C.5.

[1] A lower value of thickness t_3 may be accepted if in compliance with the buckling analysis carried out according to Section 2, C.

Table 5.13 Net scantlings of deck supporting structure

Item	**w**	**A_{sh}**
Deck beams	$w = 0{,}58 \cdot \beta_b \cdot \eta \cdot p \cdot s \cdot \ell^2$	$A_{sh} = 0{,}045 \cdot \beta_s \cdot \eta \cdot p \cdot s \cdot \ell$
Vertical stiffeners on longitudinal trunk bulkheads [1]	$w = 0{,}58 \cdot \lambda_b \cdot \beta_b \cdot \eta \cdot p \cdot s \cdot \ell^2$	$A_{sh} = 0{,}045 \cdot \lambda_s \cdot \beta_s \cdot \eta \cdot p \cdot s \cdot \ell$
Deck longitudinals	$w = \frac{83{,}3}{214 - \sigma_1} \cdot \beta_b \cdot \eta \cdot p \cdot s \cdot \ell^2$	$A_{sh} = 0{,}045 \cdot \beta_s \cdot \eta \cdot p \cdot s \cdot \ell$
Deck transverses	$w = 0{,}58 \cdot \beta_b \cdot p \cdot S \cdot \ell^2$	$A_{sh} = 0{,}045 \cdot \beta_s \cdot p \cdot S \cdot \ell$
Web frames on longitudinal trunk bulkheads [2]	$w = 0{,}58 \cdot \lambda_b \cdot \beta_b \cdot p \cdot S \cdot \ell^2$	$A_{sh} = 0{,}045 \cdot \lambda_s \cdot \beta_s \cdot p \cdot S \cdot \ell$
Deck girders	$w = \frac{1000}{m \cdot (214 - \sigma_1)} \cdot \beta_b \cdot p \cdot S \cdot \ell^2$	$A_{sh} = 0{,}045 \cdot \beta_s \cdot p \cdot S \cdot \ell$

p = deck design load [kN/m^2] to be defined by the designer. In any case p is not to be taken less than the value derived from applicable formulae given under Section 3, C.5.2 and Section 3, C.6.

m = boundary coefficient
= 12,0 in general, for stiffeners considered as clamped
= 8,0 for stiffeners considered as simply supported
= 10,6 for stiffeners clamped at one end and simply supported at the other

[1] Scantlings of vertical stiffeners on longitudinal trunk bulkheads are not to be less than those of deck beams connected to them.

[2] Scantlings of web frames on longitudinal trunk bulkheads are not to be less than those of deck transverses connected to them.

8. Transversely framed deck

8.1 Deck beams

8.1.1 General

In general, deck beams or deck half-beams are to be fitted at each frame.

8.1.2 Open-deck vessels

In the hatchway region, it is recommended to replace the half-beams by brackets, extending to the hatch coaming, as shown on Fig. 5.9.

8.2 Deck girders

8.2.1 Where deck beams are fitted in a hatched deck, they are to be effectively supported by longitudinal girders located in way of hatch side girders to which they are to be connected by brackets and/or clips.

8.2.2 Deck girders subjected to concentrated loads are to be adequately strengthened.

8.2.3 Deck girders are to be fitted with tripping stiffeners or brackets:

– spaced not more than 20 times the girder faceplate width

– in way of concentrated loads and pillars

8.2.4 Where a deck girder comprises several spans and its scantlings vary from one span to another, the connection of two different parts is to be effected gradually by strengthening the weaker part over a length which, as a rule, is to be equal to 25 % of its length.

8.2.5 The connection of girders to the supports is to ensure correct stress transmission. In particular, connection to the bulkheads is to be obtained by means of flanged brackets having a depth equal to twice that of the deck girder and the thickness of the girder, or by any equivalent method.

9. Longitudinally framed deck

9.1 Deck longitudinals

9.1.1 Deck longitudinals are to be continuous, as far as practicable, in way of deck transverses and transverse bulkheads.

Other arrangements may be considered, provided adequate continuity of longitudinal strength is ensured.

The section modulus of deck longitudinals located in way of the web frames of transverse bulkheads is to be increased by 20 %.

9.1.2 Frame brackets, in vessels with transversely framed sides, are generally to have their horizontal arm extended to the adjacent longitudinal ordinary stiffener.

9.2 Deck transverses

9.2.1 Where applicable, deck transverses of reinforced scantlings are to be aligned with floors.

9.2.2 Deck and trunk deck transverses

The section modulus of transverse parts in way of the stringer plate and of the trunk sides is not to be less than the rule value obtained by determining them as deck transverses or as side shell transverses, whichever is greater.

10. Pillars

10.1 General

10.1.1 Pillars or other supporting structures are generally to be fitted under heavy concentrated loads.

10.1.2 Structural members at heads and heels of pillars as well as substructures are to be constructed according to the forces they are subjected to. The connection is to be so dimensioned that at least 1 cm^2 cross sectional area is available for 10 kN of load.

Where pillars are affected by tension loads doublings are not permitted.

10.1.3 Pillars in tanks are to be checked for tension. Tubular pillars are not permitted in tanks for flammable liquids.

10.1.4 Pillars are to be fitted, as far as practicable, in the same vertical line.

10.1.5 The wall thickness [mm] of tubular pillars which may be expected to be damaged during loading and unloading operations is not to be less than:

$$t = 4{,}5 + 0{,}15 \cdot d_a \qquad \text{for } d_a \le 30 \text{ cm}$$

$$t = 0{,}3 \cdot d_a \qquad \text{for } d_a > 30 \text{ cm}$$

where d_a is defined in 10.2.1.

10.2 Scantlings

10.2.1 Definitions

p = deck load [kN/m^2]

P_S = pillar load [kN]:

= $p \cdot A + P_i$

A = load area for one pillar [m^2]

P_i = load from pillars located above the pillar considered [kN]

λ_S = degree of slenderness of the pillar

= ℓ_S / i_S

ℓ_S = length of the pillar [cm]

i_S = radius of gyration of the pillar [cm]:

$$i_S = \sqrt{\frac{I_S}{A_S}}$$

– for solid pillars of circular cross section:

$i_S = 0{,}25\ d_S$

– for tubular pillars:

$$i_S = 0{,}25 \cdot \sqrt{d_a^{\,2} + d_i^{\,2}}$$

I_S = moment of inertia of the pillar [cm^4]

A_S = sectional area of the pillar [cm^2]

d_S = pillar diameter [cm]

d_a = outside diameter of pillar [cm]

d_i = inside diameter of pillar [cm].

10.2.2 The sectional area [cm^2] of pillars is not to be less than:

$$A = 10 \cdot \frac{P_S}{\sigma_P}$$

σ_P = permissible compressive stress according to Table 5.14.

Table 5.14 Permissible compressive stress

Degree of slenderness λ_S	Permissible compressive stress σ_P [N/mm^2]	
	Pillars within accommodation	Elsewhere
$\leq$ 100	$140 - 0{,}0067 \cdot \lambda_S^2$	$117 - 0{,}0056 \cdot \lambda_S^2$
$>$ 100	$7{,}3 \cdot 10^5 \cdot \lambda_S^{-2}$	$6{,}1 \cdot 10^5 \cdot \lambda_S^{-2}$

10.2.3 Where pillars support eccentric loads, they are to be strengthened for the additional bending moment.

10.3 Connections

10.3.1 Pillars are to be attached at their heads and heels by continuous welding.

10.3.2 Pillars working under pressure may be fitted by welds only, in the case the thickness of the attached plating is at least equal to the thickness of the pillar.

Where the thickness of the attached plating is smaller than the thickness of the pillar, a doubling plate is to be fitted.

10.3.3 Heads and heels of pillars which may also work under tension (such as those in tanks) are to be attached to the surrounding structure by means of brackets or insert plates so that the loads are well distributed.

10.3.4 Pillars are to be connected to the inner bottom, where fitted, at the intersection of girders and floors.

Where pillars connected to the inner bottom are not located in way of intersections of floors and girders, partial floors or girders or equivalent structures suitable to support the pillars are to be arranged.

10.3.5 Manholes and lightening holes may not be cut in the girders and floors below the heels of pillars.

11. Bulkheads supporting beams

11.1 Scantlings

Partial or complete bulkheads may be substituted to pillars.

The scantlings of the vertical stiffeners of the bulkheads are to be such as to allow these stiffeners to offer the same compression and buckling strengths as a pillar, taking account of a strip of attached bulkhead plating, whose width is to be determined according to Section 2, C.3.3.

Where a bulkhead supporting beams is part of the watertight subdivision of the vessel or bounds a tank intended to contain liquids, its vertical stiffeners are to be fitted with head and heel brackets and their scantlings are to be increased to the satisfaction of GL, taking account of the additional hydrostatic pressure.

12. Hatch supporting structures

12.1 General

12.1.1 Hatch side girders and hatch end beams of reinforced scantlings are to be fitted in way of cargo hold openings.

In general, hatched end beams and deck transverses are to be in line with bottom and side transverse structures, so as to form a reinforced ring.

12.1.2 Clear of openings, adequate continuity of strength of longitudinal hatch coamings is to be ensured by underdeck girders.

12.1.3 The details of connection of deck transverses to longitudinal girders and web frames are to be submitted to GL.

E. Bulkhead Scantlings

1. Symbols

L = Rule length [m], defined in Section 1, A.1.

B = breadth [m], defined in Section 1, A.1.

D = depth [m], defined in Section 1, A.1.

T = draught [m], defined in Section 1, A.1.

t = net thickness [mm] of plating

s = spacing [m] of ordinary stiffeners

S = spacing [m] of primary supporting members

ℓ = span [m] of ordinary stiffeners or primary supporting members

β_b, β_s = bracket coefficients defined in Section 2, B.5.2

λ_b, λ_s = coefficients for vertical structural members defined in Section 2, B.5.3

η = $1 - s / (2 \cdot \ell)$

w = net section modulus [cm^3] of ordinary stiffeners or primary supporting members

A_{sh} = net web sectional area [cm^2]

k = material factor defined in Section 2, A.2.4 and Section 2, A.3.2

2. General

2.1 Application

2.1.1 The following requirements apply to transverse or longitudinal bulkhead structures which may be plane or corrugated.

In addition to the following rules bulkheads are to comply with specific requirements stated under the GL Additional Requirements for Notations (I-2-4).

2.1.2 Bulkheads may be horizontally or vertically stiffened.

Horizontally framed bulkheads consist of horizontal ordinary stiffeners supported by vertical primary supporting members.

Vertically framed bulkheads consist of vertical ordinary stiffeners which may be supported by horizontal girders.

3. Scantlings

3.1 Bulkhead plating

3.1.1 Minimum net thickness

The minimum bulkhead plating thickness [mm] is to be obtained from Table 5.15.

3.1.2 Strength check of bulkhead plating in service conditions

The bulkhead plating net thickness [mm] in service conditions is to be obtained from Table 5.16.

Table 5.15 Minimum bulkhead plate thickness

Plating	t [mm]
Watertight bulkheads	$t = 0{,}026 \cdot L \cdot k^{0{,}5} + 3{,}6 \cdot s$
Cargo hold bulkhead	$t = 2{,}2 + 0{,}013 \cdot L \cdot k^{0{,}5} + 3{,}6 \cdot s$
Tank and wash bulkhead	$t = 2 + 0{,}0032 \cdot L \cdot k^{0{,}5} + 3{,}6 \cdot s$

Table 5.16 Bulkhead plating thickness

Plating	t [mm]
– Watertight bulkhead – Hold bulkhead – Tank bulkhead	$t = s \cdot (k \cdot p)^{0{,}5}$
Collision bulkhead	$t = 1{,}1 \cdot s \cdot (k \cdot p)^{0{,}5}$
p = p_{WB}, p_B or p_C bulkhead plating design load [kN/m^2] defined in Section 3, C.5. and C.6.	

3.1.3 Strength check of bulkhead plating in testing conditions

Bulkhead plating of compartments or structures to be checked in testing conditions is to comply with Section 2, D.

3.1.4 Buckling check

Bulkhead plating is to comply with requirements stated under Section 2, C.

3.2 Bulkhead ordinary stiffeners

3.2.1 Minimum net thickness of web plating

The net thickness of the web plating of ordinary stiffeners is not to be less than:

$$t = 1{,}1 + 0{,}0048 \cdot L \cdot k^{0{,}5} + 4{,}8 \cdot s$$

3.2.2 Net scantlings of bulkhead ordinary stiffeners in service conditions

The net section modulus w [cm^3] of bulkhead ordinary stiffeners in service conditions is to be obtained from Table 5.17.

The minimum net shear sectional area A_{sh} [cm^2] of the stiffener is not to be less than the value given by the formulae in Table 5.17.

3.2.3 Net scantlings of bulkhead ordinary stiffeners in testing conditions

The net section modulus [cm^3] and the net shear sectional area [cm^2] of bulkhead ordinary stiffeners being part of compartments or structures containing liquid is to comply with Section 2, D.

3.2.4 Buckling check

Ordinary stiffeners of bulkheads are to comply with the requirements stated under Section 2, C.

3.3 Net scantlings of bulkhead primary supporting members

3.3.1 Minimum net thickness of web plating

The net thickness [mm] of the web plating of bulkhead primary supporting members is to be not less than:

– in general: $t = 3{,}8 + 0{,}016 \cdot L \cdot k^{0,5}$

– for collision bulkhead: $t = 4{,}4 + 0{,}018 \cdot L \cdot k^{0,5}$

3.3.2 Net scantlings of bulkhead primary supporting members in service conditions

The net section modulus w [cm^3] and the net shear sectional area A_{sh} [cm^2] of bulkhead primary supporting members in service conditions are to be obtained from Table 5.18.

3.3.3 Net scantlings of bulkhead ordinary stiffeners in testing conditions

The net section modulus [cm^3] and the net shear sectional area [cm^2] of bulkhead primary supporting members being part of compartments or structures containing liquid is to comply with Section 2, D.

3.3.4 Buckling check

Bulkhead primary supporting members are to comply with the requirements stated under Section 2, C.

4. Watertight bulkheads

4.1 Number of watertight bulkheads

4.1.1 General

All vessels, in addition to complying with the requirements of 4.1.2, are to have at least the following transverse watertight bulkheads:

– a collision bulkhead, arranged in compliance with 5.

– an after peak bulkhead, arranged in compliance with 6.

– two bulkheads, complying with 6. forming the boundaries of the machinery space in vessels with machinery amidships, and one bulkhead forward of the machinery space in vessels with machinery aft. In the case of vessels with an electrical propulsion plant, both the generator room and the engine room are to be enclosed by watertight bulkheads.

Table 5.17 Net scantlings of bulkhead ordinary stiffeners

Item	w	A_{sh}
Vertical stiffeners	$w = k_1 \cdot \lambda_b \cdot \beta_b \cdot \eta \cdot p \cdot s \cdot \ell^2$	$A_{sh} = k_2 \cdot \lambda_s \cdot \beta_s \cdot \eta \cdot p \cdot s \cdot \ell$
Transverse stiffeners	$w = k_1 \cdot \beta_b \cdot \eta \cdot p \cdot s \cdot \ell^2$	$A_{sh} = k_2 \cdot \beta_s \cdot \eta \cdot p \cdot s \cdot \ell$
Longitudinal stiffeners	$w = \dfrac{83{,}3}{214 - \sigma_1} \cdot \beta_b \cdot \eta \cdot p \cdot s \cdot \ell^2$	$A_{sh} = 0{,}045 \cdot \beta_s \cdot \eta \cdot p \cdot s \cdot \ell$
p = bulkhead design load [kN/m^2] defined in C.5. k_1 = in general: $k_1 = 4{,}60$ / m for collision bulkhead: $k_1 = 5{,}37$ / m k_2 = in general: $k_2 = 0{,}045$ for collision bulkhead: $k_2 = 0{,}052$ m = boundary coefficient for ordinary stiffeners = 8,0 in the case of primary supporting members simply supported at both ends = 10,6 in the case of primary supporting members simply supported at one end and clamped at the other = 12,0 in the case of primary supporting members clamped at both ends.		

Table 5.18 Net scantlings of bulkhead primary supporting members

Item	w	A_{sh}
Bulkhead web frames, bulkhead transverses	$w = k_1 \cdot \lambda_b \cdot \beta_b \cdot p \cdot S \cdot \ell^2$	$A_{sh} = k_2 \cdot \lambda_s \cdot \beta_s \cdot p \cdot S \cdot \ell$
Stringers on transverse bulkheads	$w = k_1 \cdot \beta_b \cdot p \cdot S \cdot \ell^2$	$A_{sh} = k_2 \cdot \beta_s \cdot p \cdot S \cdot \ell$
Stringers on longitudinal bulkheads	$w = \dfrac{125}{214 - \sigma_1} \cdot \beta_b \cdot p \cdot S \cdot \ell^2$	$A_{sh} = 0{,}045 \cdot \beta_s \cdot p \cdot S \cdot \ell$
p, k_1, k_2 = as defined in Table 5.17.		

4.1.2 Additional bulkheads

In the cargo space of single hull open deck vessels, additional transverse bulkheads may be recommended in order to ensure an efficient support to the topside structure.

Additional bulkheads may be required also for vessels having to comply with stability criteria.

In the cargo space of double hull vessels, transverse bulkheads are to be fitted in the side tanks in way of watertight floors.

4.2 General arrangement

4.2.1 Where an inner bottom terminates on a bulkhead, the lowest strake of the bulkhead forming the watertight floor of the double bottom is to extend at least 300 mm above the inner bottom.

4.2.2 Accommodations, engine rooms and boiler rooms, and the workspaces forming part of these, shall be separated from the holds by watertight transverse bulkheads that extend up to the deck.

4.2.3 Longitudinal bulkheads are to terminate at transverse bulkheads and are to be effectively tapered to the adjoining structure at the ends and adequately extended in the machinery space, where applicable.

4.2.4 The structural continuity of the bulkhead vertical and horizontal primary supporting members with the surrounding supporting structures is to be carefully ensured.

4.2.5 The height of vertical primary supporting members of longitudinal bulkheads may be gradually tapered from bottom to deck.

Requirements in C.6.3 or C.7.3 are to be complied with too.

4.3 Height of transverse watertight bulkheads

4.3.1 Transverse watertight bulkheads other than the collision bulkhead and the after peak bulkhead are to extend up to the upper deck.

4.3.2 Where it is not practicable to arrange a watertight bulkhead in one plane, a stepped bulkhead may be fitted. In this case, the part of the deck which forms the step is to be watertight and equivalent in strength to the bulkhead.

4.4 Openings in watertight bulkheads

4.4.1 Certain openings below the main deck are permitted in bulkheads other than the collision bulkhead, but these are to be kept to a minimum compatible with the design and proper working of the vessel and to be provided with watertight doors having strength such as to withstand the head of water to which they may be subjected.

4.5 Watertight doors

4.5.1 Doors cut out in watertight bulkheads are to be fitted with watertight closing appliances. The arrangements to be made concerning these appliances are to be approved by GL.

4.5.2 The thickness of watertight doors is to be not less than that of the adjacent bulkhead plating, taking account of their actual spacing.

4.5.3 Where vertical stiffeners are cut in way of watertight doors, reinforced stiffeners are to be fitted on each side of the door and suitably overlapped; cross-bars are to be provided to support the interrupted stiffeners.

4.5.4 Watertight doors required to be open during navigation are to be of the sliding type and capable of being operated both at the door itself, on both sides, and from an accessible position above the bulkhead deck.

Means are to be provided at the latter position to indicate whether the door is open or closed, as well as arrows indicating the direction in which the operating gear is to be operated.

4.5.5 Watertight doors may be of the hinged type if they are always intended to be closed during navigation.

Such doors are to be framed and capable of being secured watertight by handle-operated wedges which are suitably spaced and operable at both sides.

4.6 Cofferdams

4.6.1 As a general rule, adequately ventilated cofferdams are to be provided between compartments intended for the carriage of different liquids where, on the basis of information supplied by the owner, there exists a risk of pollution of one product by another.

In particular, cofferdams are to be provided between fuel bunkers and fresh water tanks.

5. Collision bulkhead

5.1 Arrangement of collision bulkhead

5.1.1 The collision bulkhead is to be positioned aft of the fore perpendicular at a distance d_C [m] such that:

$$0{,}04 \cdot L_H \le d_c \le 0{,}04 \cdot L_H + 2$$

L_H = length of the vessel's hull [m], excluding rudder and bowsprit

5.1.2 GL may, on a case-by-case basis, accept a greater distance from the collision bulkhead to the forward perpendicular to that specified in 5.1.1, on basis of calculations which show that the buoyancy of the fully loaded vessel is ensured and the residual safety clearance is at least 100 mm when the compartment ahead of the collision bulkhead is flooded.

5.1.3 GL may, on a case-by-case basis, accept a reduction of the distance in 5.1.1 up to at least 0,03 L_H, on the basis of calculations which show that the buoyancy of the fully loaded vessel is ensured and the residual safety clearance is at least 100 mm when the compartment ahead of and behind the collision bulkhead is flooded.

5.1.4 The increase/reduction of distances according to 5.1.2 and 5.1.3 is subject to approval to be granted by the competent authority.

5.1.5 The collision bulkhead is to extend to the uppermost deck in the fore part of the vessel.

5.2 Openings in the collision bulkhead

5.2.1 General

Openings may not be cut in the collision bulkhead below the main deck.

The number of openings in the collision bulkhead above the main deck is to be kept to the minimum compatible with the design and proper working of the vessel.

All such openings are to be fitted with means of closing to weathertight standards.

5.2.2 Doors and manholes

No doors or manholes are permitted in the collision bulkhead below the bulkhead deck.

5.2.3 Passage of piping

No bilge cock or similar device is to be fitted on the collision bulkhead.

A maximum of two pipes may pass through the collision bulkhead below the main deck, unless otherwise justified. Such pipes are to be fitted with suitable valves operable from above the main deck. The valve chest is to be secured at the bulkhead inside the fore peak. Such valves may be fitted on the after side of the collision bulkhead provided that they are easily accessible and the space in which they are fitted is not a cargo space.

6. After peak, machinery space bulkheads and stern tubes

6.1 Extension

These bulkheads are to extend to the uppermost continuous deck.

6.2 Stern tubes

The after peak bulkhead is to enclose the stern tube and the rudder trunk in a watertight compartment. Other measures to minimize the danger of water penetrating into the vessel in case of damage to stern tube arrangements may be taken at the discretion of GL.

For vessels less than 65 m, where the after peak bulkhead is not provided in way of the stern tube stuffing box, the stern tubes are to be enclosed in watertight spaces of moderate volume.

7. Tank bulkheads

7.1 Number and arrangement of tank bulkheads

7.1.1 The number and location of transverse and longitudinal watertight bulkheads in vessels intended for the carriage of liquid cargoes (tankers and similar) are to comply with the stability requirements to which the vessel is subject.

7.1.2 In general, liquid compartments extending over the full breadth of the vessel are to be fitted with at least one longitudinal bulkhead, whether watertight or not, where the mean compartment breadth is at least equal to $2 \cdot B/3$.

As a rule, where the bulkhead is perforated, the total area of the holes is generally to be about 5 % of the total area of the bulkhead.

8. Tanks

8.1 Arrangements

8.1.1 Liquid fuel or lubrication oil shall be carried in oiltight tanks which shall either form part of the hull or shall be solidly connected with the vessel's hull.

8.1.2 Fuel oil, lubrication oil and hydraulic oil tanks provided in the machinery space are not to be located above the boilers nor in places where they are likely to reach a high temperature, unless special arrangements are provided with the agreement of GL.

8.1.3 Where a cargo space is adjacent to a fuel bunker which is provided with a heating system, the fuel bunker boundaries are to be adequately heat insulated.

8.1.4 Arrangements are to be made to restrict leaks through the bulkheads of liquid fuel tanks adjacent to the cargo space.

8.1.5 Gutterways are to be fitted at the foot of bunker bulkheads, in the cargo space and in the machinery space in order to facilitate the flow of liquid due to eventual leaks towards the bilge suctions.

The gutterways may however be dispensed with if the bulkheads are entirely welded.

8.1.6 Where ceilings are fitted on the tank top or on the top of deep tanks intended for the carriage of fuel oil, they are to rest on grounds 30 mm in depth so arranged as to facilitate the flow of liquid due to eventual leaks towards the bilge suctions.

The ceilings may be positioned directly on the plating in the case of welded top platings.

8.1.7 Fuel tanks formed by the vessel's hull shall not have a common wall with cargo tanks, lubricating oil tanks, fresh water tanks or drinking water tanks.

Upon special approval on small vessels the arrangement of cofferdams between fuel oil and lubricating oil tanks may be dispensed with provided that the common boundary is continuous, i.e. it does not abut at the adjacent tank boundaries, see Fig. 5.9.

8.1.8 Fuel tanks or lubrication oil tanks which are in normal service under static pressure of the liquid shall not have any common surfaces with passenger areas and accommodations.

8.1.9 Fuel tanks, lubrication oil and hydraulic oil tanks shall not be located forward of the collision bulkhead.

8.2 Scantlings

Scantlings of fuel tanks are to be in compliance with 2.

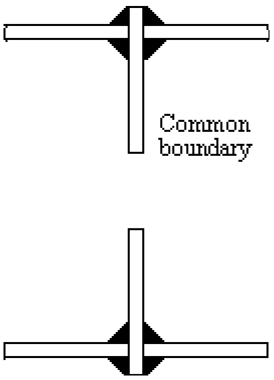


Fig. 5.9 Continuous common boundary

9. Plane bulkheads

9.1 General

9.1.1 Where a bulkhead does not extend up to the uppermost continuous deck (such as the after peak bulkhead), suitable strengthening is to be provided in the extension of the bulkhead.

9.1.2 Bulkheads are generally stiffened in way of deck girders.

9.1.3 The stiffener webs of side tank watertight bulkheads are generally to be aligned with the webs of inner hull longitudinal stiffeners.

9.1.4 Floors are to be fitted in the double bottom in way of plane transverse bulkheads.

9.1.5 In way of the sterntube, the thickness of the after peak bulkhead plating is to be increased by 60 %.

Instead of the thickness increase required herebefore, a doubling plate of the same thickness as the bulkhead plating may be fitted.

9.2 Bulkhead stiffeners

9.2.1 As a rule, stiffeners are to be fitted in way of structural components likely to exert concentrated loads, such as deck girders and pillars, and for engine room end bulkheads, at the ends of the engine seatings.

9.2.2 On vertically framed watertight bulkheads, where stiffeners are interrupted in way of the watertight doors, stanchions are to be fitted on either side of the door, carlings are to be fitted to support the interrupted stiffeners.

9.3 End connections

9.3.1 In general, end connections of ordinary stiffeners are to be welded directly to the plating or bracketed. However, stiffeners may be sniped, provided the scantlings of such stiffeners are modified accordingly.

Sniped ends may be accepted where the hull lines make it mandatory in the following cases:

– liquid compartment boundaries

– collision bulkhead.

9.3.2 Where sniped ordinary stiffeners are fitted, the snipe angle is to be not greater than 30° and their ends are to be extended, as far as practicable, to the boundary of the bulkhead.

Moreover, the thickness of the bulkhead plating supported by the stiffener is to be in compliance with Section 2, B.4.6.3

10. Corrugated bulkheads

10.1 General

10.1.1 The main dimensions a, b, c and d of corrugated bulkheads are defined in Fig. 5.10.

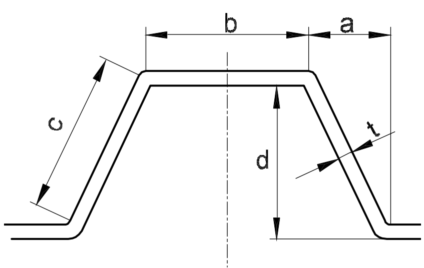


Fig. 5.10 Corrugated bulkhead

10.1.2 Unless otherwise specified, the following requirement is to be complied with:

$$a \le d$$

Moreover, in some cases, GL may prescribe an upper limit for the ratio b / t.

10.1.3 In general, the bending internal radius R_i is to be not less than the following values [mm]:

– for normal strength steel:

$R_i = 2,5\ t$

– for high tensile steel:

$R_i = 3,0\ t$

where t is the thickness [mm] of the corrugated plate.

10.1.4 When butt welds in a direction parallel to the bend axis are provided in the zone of the bend, the welding procedures are to be submitted to GL for approval, as a function of the importance of the structural element.

10.1.5 Transverse corrugated bulkheads having horizontal corrugations are to be fitted with vertical primary supporting members of number and size sufficient to ensure the required vertical stiffness of the bulkhead.

10.1.6 In general, where girders or vertical primary supporting members are fitted on corrugated bulkheads, they are to be arranged symmetrically.

10.2 Bulkhead scantlings

10.2.1 Bulkhead plating

The bulkhead plating net thickness is to be determined as specified in 3.1, substituting the stiffener spacing by the greater of the two values b and c [m] as per 10.1.1.

10.2.2 Corrugations

The section modulus of a corrugation is to be not less than that of the equivalent stiffener having the same span as the corrugation and an attached plating width equal to (b + a).

The actual section modulus of a corrugation is to be obtained [cm^3] from following formula:

$$w = \frac{t \cdot d}{6} \cdot \left(3 \cdot b + c\right) \cdot 10^{-3}$$

t = net thickness of the plating of the corrugation [mm]

d, b, c = dimensions of the corrugation [mm] shown in Fig. 5.11

Moreover, where the ratio b / t ≥ 46, the net section modulus required for a bulkhead is to be in accordance with the following formula, where the coefficient c_k is defined in Table 5.19.

$$w = c_k \cdot \left(b + a\right) \cdot p \cdot \left(\frac{\ell \cdot b}{80 \cdot t}\right)^2 \cdot 10^{-3}$$

10.2.3 Stringers and web frames

It is recommended to fit stringers or web frames symmetrically with respect to the bulkhead. In all cases, their section modulus is to be determined in the same way as for a plane bulkhead stringer or web frame.

Table 5.19 Values of coefficient c_k

Boundary conditions	Collision bulkhead	Watertight bulkhead	Cargo hold Bulkhead
Simply supported	1,73	1,38	1,04
Simply supported (at one end)	1,53	1,20	0,92
Clamped	1,15	0,92	0,69

10.3 Structural arrangement

10.3.1 The strength continuity of corrugated bulkheads is to be ensured at ends of corrugations.

10.3.2 Where corrugated bulkheads are cut in way of primary members, attention is to be paid to ensure correct alignment of corrugations on each side of the primary member.

10.3.3 In general, where vertically corrugated transverse bulkheads are welded on the inner bottom, floors are to be fitted in way of the flanges of corrugations.

However, other arrangements ensuring adequate structural continuity may be accepted by GL.

10.3.4 Where stools are fitted at the lower part of transverse bulkheads, the thickness of adjacent plate floors is to be not less than that of the stool plating.

10.3.5 In general, where vertically corrugated longitudinal bulkheads are welded on the inner bottom, girders are to be fitted in double bottom in way of the flanges of corrugations.

However, other arrangements ensuring adequate structural continuity may be accepted by GL.

10.3.6 In general, the upper and lower parts of horizontally corrugated bulkheads are to be flat over a depth equal to 0,1 · D.

10.4 Bulkhead stool

10.4.1 In general, plate diaphragms or web frames are to be fitted in bottom stools in way of the double bottom longitudinal girders or plate floors, as the case may be.

10.4.2 Brackets or deep webs are to be fitted to connect the upper stool to the deck transverses or hatch end beams, as the case may be.

10.4.3 The continuity of the corrugated bulkhead with the stool plating is to be adequately ensured. In particular, the upper strake of the lower stool is to be of the same thickness and yield stress as those of the lower strake of the bulkhead.

11. Hold bulkheads of open deck vessels

11.1 Special arrangements

11.1.1 The upper end of vertical stiffeners is to be connected either to a box beam or a stringer located at the stringer plate level or above.

11.1.2 As far as practicable, the bottom of the box beam or the bulkhead end stringer is to be located in the same plane as the stringer plate.

Where this is not the case, the bulkhead plating or the box beam sides are to be fitted with an efficient horizontal framing at that level.

11.1.3 The upper part of horizontally framed bulkheads are to be subject to a special review by GL.

12. Non-tight bulkheads

12.1 Definition

A bulkhead is considered to be acting as a pillar when besides the lateral loads, axial loads are added.

12.2 Non-tight bulkheads not acting as pillars

12.2.1 Non-tight bulkheads not acting as pillars are to be provided with vertical stiffeners with a maximum spacing equal to:

– 0,9 m, for transverse bulkheads

– two frame spacings, with a maximum of 1,5 m, for longitudinal bulkheads.

12.3 Non-tight bulkheads acting as pillars

12.3.1 Non-tight bulkheads acting as pillars are to be provided with vertical stiffeners with a maximum spacing equal to:

– two frame spacings, when the frame spacing does not exceed 0,75 m,

– one frame spacing, when the frame spacing is greater than 0,75 m.

12.3.2 Each vertical stiffener, in association with a width of plating equal to 35 times the plating thickness, is to comply with the applicable requirements for pillars in D.9., the load supported being determined in accordance with the same requirements.

12.3.3 In the case of non-tight bulkheads supporting longitudinally framed decks, web frames are to be provided in way of deck transverses.

13. Wash bulkheads

13.1 General

13.1.1 The requirements in 12.2 apply to transverse and longitudinal wash bulkheads whose main purpose is to reduce the liquid motions in partly filled tanks.

13.2 Openings

13.2.1 The total area of openings in a transverse wash bulkhead is generally to be between 10 % and 30 % of the total bulkhead area.

In the upper, central and lower portions of the bulkhead (the depth of each portion being 1/3 of the bulkhead height), the areas of openings, expressed as percentages of the corresponding areas of these portions, are to be within the limits given in Table 5.20.

13.2.2 In any case, the distribution of openings is to fulfill the strength requirements specified in 12.3.

13.2.3 In general, large openings may not be cut within 0,15·D from bottom and from deck.

Table 5.20 Areas of openings in transverse wash bulkheads

Bulkhead portion	Lower limit	Upper limit
Upper	10 %	15 %
Central	10 %	50 %
Lower	2 %	10 %

F. Vessels less than 40 m in Length

1. Symbols

L = Rule length [m] defined in Section 1, A.1.

B = breadth [m] defined in Section 1, A.1.

D = depth [m] defined in Section 1, A.1.

T = draught [m] defined in Section 1, A.1.

t = net thickness [mm] of plating

s = spacing [m] of ordinary stiffeners

S = spacing [m] of primary supporting members

ℓ = span [m] of ordinary stiffeners or primary supporting members

n = navigation coefficient defined in Section 3, B.

= 0,85·H

H = significant wave height [m]

β_b, β_s = bracket coefficients defined in Section 2, B.5.2

η = $1 - s / (2 \cdot \ell)$

w = net section modulus [cm^3] of ordinary stiffeners or primary supporting members

A_{sh} = net web sectional area [cm^2]

k = material factor defined in Section 2, A.2.4 and Section 2, A.3.2

z = Z co-ordinate [m] of the calculation point

2. General

2.1 Application

2.1.1 As an alternative to requirements of B. to D., the following contains the prescriptions for the determination of the minimum hull scantlings applicable to the central part of all types of single hull inland waterway vessels less than 40 m in length, of normal design and dimensions.

Cargo carriers covered by these requirements have their machinery aft and are assumed to be loaded and unloaded in two runs.

2.1.2 Arrangement and scantlings not covered in the following are to be as specified in B. to E.

2.2 Definition

In the following requirements, the coefficient K_{MZ} to be used for the scantling of small vessels is to be derived from the formula:

$$K_{MZ} = \sqrt{\frac{K_M}{K_Z}}$$

where the coefficients K_M and K_Z are given in Table 5.21 and Table 5.22.

3. Bottom scantlings

3.1 Bottom and bilge plating

3.1.1 The bottom plating net thickness [mm] is not to be less than the values derived from Table 5.23.

3.1.2 The bilge plating scantling is to comply with B.3.1.2 or B.3.1.3, as applicable.

3.1.3 Strength check of bottom plating in testing conditions

Bottom plating of compartments or structures to be checked in testing conditions is to comply with Section 2, D.

Table 5.21 Values of coefficient K_M

Range of navigation	Vessel type	K_M		
		Bottom plating	Top plating	Stiffeners
IN(0)	All	1,0	1,0	1,0
IN(0,6)	Self-propelled cargo carriers and passenger vessels Non-propelled cargo carriers Other vessels	1,08 1,0 1,2	1,056 1,0 1,5	1,08 1,0 1,5
IN(1,2) to IN(2)	Self-propelled cargo carriers and passenger vessels Non-propelled cargo carriers Other vessels	$0,83 + 0,98 \cdot n$ $0,385 + 2,08 \cdot n$ $1 + n$	$0,88 + 0,69 \cdot n$ $0,75 + 0,75 \cdot n$ $1 + 2,1 \cdot n$	$0,83 + 0,98 \cdot n$ $0,385 + 2,08 \cdot n$ $1 + 2,1 \cdot n$

Table 5.22 Values of coefficient K_Z

Range of navigation	K_Z	Range of navigation	K_Z
IN(0) IN(0,6)	1,0	IN(1,2) to IN(2)	$1 + 0,158 \cdot n$

Table 5.23 Bottom plating net thickness [mm]

Transverse framing	Longitudinal framing
$t = MAX (t_i)$ $t_1 = 1,85 + 0,03 \cdot L \cdot k^{0,5} + 3,6 \cdot s$ $t_2 = 1,6 \cdot s \cdot (k \cdot p)^{0,5}$ $t_3 = 1,5 \cdot s \cdot K_{MZ} \cdot (k \cdot L)^{0,5}$	$MAX (t_i)$ $t_1 = 1,1 + 0,03 \cdot L \cdot k^{0,5} + 3,6 \cdot s$ $t_2 = 1,2 \cdot s \cdot (k \cdot p)^{0,5}$ $t_3 = 0,86 \cdot s \cdot K_{MZ} \cdot (k \cdot L)^{0,5}$
p = design load [kN/m^2] = $9,81 \cdot (T + 0,6 \cdot n)$	

3.2 Bottom structure

3.2.1 Minimum net thickness of web plating

The net thickness [mm] of the web plating of ordinary stiffeners is to be not less than:

$$t = 1{,}63 + 0{,}004 \cdot L \cdot k^{0,5} + 4{,}5 \cdot s$$

The net thickness [mm] of plating which forms the web of primary supporting members is to be not less than the value obtained from the following formula:

$$t = 3{,}8 + 0{,}016 \cdot L \cdot k^{0,5}$$

3.2.2 Net scantlings of bottom structural members in service conditions

The net scantlings of bottom structural members in service conditions are to be obtained from Table 5.24.

3.2.3 Net scantlings of bottom structural members in testing conditions

The net section modulus w [cm^3] and the net shear sectional area A_{sh} [cm^2] of bottom structural members being part of compartments or structures containing liquid are to comply with Section 2, D.

4. Side scantlings

4.1 Side plating

4.1.1 The side plating net thickness [mm] is not to be less than the values given in Table 5.25.

4.1.2 Strength check of side plating in testing conditions

The side plating of compartments or structures to be checked in testing conditions is to comply with Section 2, D.

Table 5.24 Net scantlings of bottom structure

Item	w	A_{sh}
Bottom longitudinals	$w = \dfrac{0{,}4 \cdot \beta_b \cdot \eta \cdot p_E \cdot s \cdot \ell^2}{1 - 0{,}18 \cdot K_{MZ}}$	$A_{sh} = 0{,}045 \cdot \beta_s \cdot \eta \cdot p_E \cdot s \cdot \ell$
Floors [1, 2]	$w = 0{,}58 \cdot \beta_b \cdot p \cdot s \cdot B^2$	$A_{sh} = 0{,}045 \cdot \beta_s \cdot p \cdot s \cdot B$
Bottom transverses [2]	$w = 0{,}58 \cdot \beta_b \cdot p \cdot S \cdot B^2$	$A_{sh} = 0{,}045 \cdot \beta_s \cdot p \cdot S \cdot B$
Bottom centre and side girders [3]	$w = 0{,}63 \cdot \beta_b \cdot p \cdot S \cdot \ell^2 \geq w_0$	$A_{sh} = 0{,}056 \cdot \beta_s \cdot p \cdot S \cdot \ell$

p_E = design load of bottom longitudinals [kN/m^2] defined in Section 3, C.5.1
p = design load [kN/m^2] of bottom primary supporting members
= $9{,}81 \cdot (\gamma \cdot T + 0{,}6 \cdot n)$
γ = 0,575 for cargo carriers
= 1,0 for other vessels
w_0 = section modulus of floors or bottom transverses

1 In way of side ordinary frames: $\beta_b = \beta_S = 1$
2 Scantlings of floors and bottom transverses have to be adequate to those of web frames or side transverses connected to them.
3 The span ℓ is to be taken equal to the web frame spacing.

Table 5.25 Side plating net thickness [mm]

Transverse framing	Longitudinal framing
$t = MAX(t_i)$	$t = MAX(t_i)$
$t_1 = 1{,}68 + 0{,}025 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$	$t_1 = 1{,}25 + 0{,}02 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$
$t_2 = 1{,}6 \cdot s \cdot (k \cdot p)^{0,5}$	$t_2 = 1{,}2 \cdot s \cdot (k \cdot p)^{0,5}$
$t_3 = k_1 \cdot t_0$	$t_3 = k_1 \cdot t_0$

p = design load [kN/m^2]
= $9{,}81 \cdot (T + 0{,}6 \cdot n)$
t_0 = t_{bottom}
k_1 = 0,85 if transversely framed bottom
= 0,90 if longitudinally framed bottom.

4.2 Side structure

4.2.1 Minimum net thickness of web plating

The net thickness of the web plating of ordinary stiffeners is to be not less than:

$$= 1{,}63 + 0{,}004 \cdot L \cdot k^{0{,}5} + 4{,}5 \cdot s$$

The thickness [mm] of plating which forms the web of primary supporting members is to be not less than the value obtained from the formula:

$$= 3{,}8 + 0{,}016 \cdot L \cdot k^{0{,}5}$$

4.2.2 Net scantlings of side structural members in service conditions

The net scantlings of side structural members in service conditions are to be obtained from Table 5.26.

4.2.3 Net scantlings of side structural members in testing conditions

The net section modulus w [cm^3] and the net shear sectional area A_{sh} [cm^2] of side structural members being part of compartments or structures containing liquid are to comply with Section 2, D.

5. Deck scantlings

5.1 Open deck vessels

5.1.1 General

The arrangement and stiffening of the topside structure are to be as specified in D.2.

5.1.2 Topside structure scantlings

The topside structure scantlings are to be derived from Table 5.27.

5.2 Flush deck and trunk deck

5.2.1 General

Scantlings of the topside strakes are to comply with D.5. and D.6.

5.2.2 The deck plating net thickness [mm] is to be obtained from Table 5.28.

Within the midship region, the sectional area [cm^2] of the deck structure in way of the hatchways, including the side and top of trunk, is not to be less than:

$$A = 6 \cdot B \cdot s \cdot K_{MZ} \cdot L^{0{,}5}$$

Table 5.26 Net scantlings of side structure

Primary supporting members	w	A_{sh}
Side frames	$w = 0{,}58 \cdot s \cdot \beta_b \cdot \eta \cdot (1{,}2 \cdot k_0 \cdot p \cdot \ell_0^2 + \lambda_t \cdot p_F \cdot B^2)$	$A_{sh} = 0{,}08 \cdot \beta_s \cdot \eta \cdot k_0 \cdot p \cdot s \cdot \ell_0$
Side longitudinals	$w = 0{,}40 \cdot \beta_b \cdot \eta \cdot p \cdot s \cdot \ell^2$	$A_{sh} = 0{,}045 \cdot \beta_s \cdot \eta \cdot p \cdot s \cdot \ell$
Side webs, side transverses [1]	$w = 1{,}96 \cdot \beta_b \cdot k_0 \cdot p \cdot S \cdot \ell_0^2$	$A_{sh} = 0{,}063 \cdot \beta_s \cdot k_0 \cdot p \cdot S \cdot \ell_0$
Side stringers [2]	$w = 0{,}63 \cdot \beta_b \cdot p \cdot S \cdot \ell^2$	$A_{sh} = 0{,}056 \cdot \beta_s \cdot p \cdot S \cdot \ell$

p = design load of side structural members [kN/m^2]:
= $4{,}9 \cdot \ell_0$ for vertical stiffeners
= p_E for longitudinal stiffeners
where p_E is defined in Section 3, C.5.1

ℓ_0 = $T - H_F + 0{,}6 \cdot n$

H_F = floor height or bottom transverse height [m]

p_F = floor design load [kN/m^2] to be obtained from the following formula:
= $9{,}81 \cdot (\gamma \cdot T + 0{,}6 \cdot n)$
$\gamma = 0{,}575$ for cargo carriers
$= 1{,}0$ for other vessels

k_0 = coefficient given by the formula:
= $\ell + (\ell - \ell_0) / \ell_0$

λ_t = coefficient
$$= 0{,}1 \cdot \left(0{,}8 - \frac{\ell^2}{B^2}\right), \lambda_t \geq 0$$
In combination framing: $\lambda_t = 0$

1 Scantlings of web frames and side transverses have to be adequate to those of floors or bottom transverses connected to them.
2 The span of side stringers is to be taken equal to the side transverses spacing or web frames spacing [m].

Table 5.27 Topside structure net scantlings

Item	Thickness [mm]		Minimum width / Height [m]
	$\alpha \geq 1$	$\alpha < 1$	
Stringer plate	$t = MAX\ (t_i)$ $t_1 = 2 + 0{,}02 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s_1$ $t_2 = 1{,}24 \cdot s_1 \cdot K_{MZ} \cdot (k \cdot L)^{0,5}$	$t = MAX\ (t_i)$ $t_1 = 2 + 0{,}02 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s_1$ $t_2 = 1{,}33 \cdot s_1 \cdot K_{MZ} \cdot (k \cdot L)^{0,5}$	$b = 0{,}1 \cdot B$
Sheerstrake	$t = 2{,}6 + 0{,}076 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s_2$		$b = 0{,}08 \cdot D$
Hatch coaming	$t = MAX\ (t_i)$ $t_1 = 1{,}6 + 0{,}04 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s_3$ $t_2 = (1 + h / D) \cdot t_0$	$t = MAX\ (t_i)$ $t_1 = 1{,}6 + 0{,}04 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s_3$ $t_2 = (1 + h / D) \cdot t_0$	See D.3.3.1
α = b_2 / b_1 s_1 = MIN (b_1; b_2) b_1 = unsupported stringer plate width in y direction [m] b_2 = unsupported stringer plate width in x direction [m] s_2 = side ordinary stiffener spacing [m] s_3 = MIN (b_3; b_4) b_3 = unsupported hatch coaming height [m] b_4 = unsupported hatch coaming width in x direction [m] t_0 = stringer plate thickness [mm]. h = actual hatch coaming height above the deck [m]			

Table 5.28 Flush deck net scantlings [mm]

Transverse framing	Longitudinal framing
Deck plating: $t = MAX\ (t_i)$ $t_1 = 0{,}9 + 0{,}034 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$ $t_2 = 1{,}6 \cdot s \cdot (k \cdot p)^{0,5}$ $t_3 = 1{,}33 \cdot s \cdot K_{MZ} \cdot (k \cdot L)^{0,5}$	Deck plating: $t = MAX\ (t_i)$ $t_1 = 0{,}57 + 0{,}031 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$ $t_2 = 1{,}20 \cdot s \cdot (k \cdot p)^{0,5}$ $t_3 = 1{,}24 \cdot s \cdot K_{MZ} \cdot (k \cdot L)^{0,5}$
p = deck design load [kN/m²] to be defined by the designer. In any case p is not to be taken less than: = $3{,}75 \cdot (n + 0{,}8)$	

5.2.3 Deck plating subjected to lateral pressure in testing conditions

Deck plating of compartments or structures to be checked in testing conditions is to comply with Section 2, D.

5.3 Deck structure

5.3.1 Minimum net thickness of web plating

The net thickness [mm] of the web plating of ordinary stiffeners is to be not less than:

$$t = 1{,}63 + 0{,}004 \cdot L \cdot k^{0,5} + 4{,}5 \cdot s$$

The net thickness [mm] of plating which forms the web of primary supporting members is to be not less than the value obtained from the following formula:

$$t = 3{,}8 + 0{,}016 \cdot L \cdot k^{0,5}$$

5.3.2 Net scantlings of deck structural members in service conditions

The net scantlings of deck structural members in service conditions are to be obtained from Table 5.29.

5.3.3 Net scantlings of deck structural members in testing conditions

The net section modulus w [cm³] and the shear sectional area [cm²] of deck structural members being part of compartments or structures containing liquid are to comply with Section 2, D.

6. Subdivision

The arrangement and scantlings of bulkheads are to be as specified in E.

Table 5.29 Net scantlings of deck structure

Item	w [cm³]	A_{sh} [cm²]
Deck beams	$w = 0{,}58 \cdot \beta_b \cdot \eta \cdot p \cdot s \cdot \ell^2$	$A_{sh} = 0{,}045 \cdot \beta_s \cdot \eta \cdot p \cdot s \cdot \ell$
Vertical stiffeners on longitudinal trunk bulkheads [1]	$w = 0{,}58 \cdot \lambda_b \cdot \beta_b \cdot \eta \cdot p \cdot s \cdot \ell^2$	$A_{sh} = 0{,}045 \cdot \lambda_s \cdot \beta_s \cdot \eta \cdot p \cdot s \cdot \ell$
Deck longitudinals	$w = \dfrac{0{,}4 \cdot \beta_b \cdot \eta \cdot p \cdot s \cdot \ell^2}{1 - 0{,}18 \cdot K_{MZ}}$	$A_{sh} = 0{,}045 \cdot \beta_s \cdot \eta \cdot p \cdot s \cdot \ell$
Deck transverses	$w = 0{,}58 \cdot \beta_b \cdot p \cdot S \cdot \ell^2$	$A_{sh} = 0{,}045 \cdot \beta_s \cdot p \cdot S \cdot \ell$
Vertical primary supporting members on longitudinal trunk bulkheads [1]	$w = 0{,}58 \cdot \lambda_b \cdot \beta_b \cdot p \cdot S \cdot \ell^2$	$A_{sh} = 0{,}045 \cdot \lambda_s \cdot \beta_s \cdot p \cdot S \cdot \ell$
Deck girders	$w = 0{,}63 \cdot \beta_b \cdot p \cdot S \cdot \ell^2$	$A_{sh} = 0{,}056 \cdot \beta_s \cdot p \cdot S \cdot \ell$

p = deck design load [kN/m²] to be defined by the designer. In any case p is not to be taken less than:
= $3{,}75 \cdot (n + 0{,}8)$

[1] Scantlings of vertical structural members on longitudinal trunk bulkheads are not to be less than those of deck stiffeners connected to them.

Section 6

Other Structures

A. Fore Part

1. Symbols

L = Rule length [m] defined in Section 1, A.1.

B = breadth [m] defined in Section 1, A.1.

D = depth [m] defined in Section 1, A.1.

T = draught [m] defined in Section 1, A.1.

t = thickness [mm] of plating

p = design load [kN/m^2] according to 2.6

s = spacing [m] of ordinary stiffeners

S = spacing [m] of primary supporting members

ℓ = span [m] of ordinary stiffeners or primary supporting members

n = navigation coefficient defined in Section 3, B.

= 0,85·H

H = significant wave height [m]

β_b, β_s = bracket coefficients defined in Section 2, B.5.2

η = $1 - s / (2 \cdot \ell)$

w = net section modulus, in [cm^3], of ordinary stiffeners or primary supporting members

A_{sh} = net web sectional area, in [cm^2]

k = material factor defined in Section 2, A.2.4 and Section 2, A.3.2

z = Z co-ordinate [m] of the calculation point

m = boundary coefficient, to be taken equal to:

= 12,0 in general, for stiffeners considered as clamped

= 8,0 for stiffeners considered as simply supported

= 10,6 for stiffeners clamped at one end and simply supported at the other

f = coefficient defined as follows:

= 1,0 in case of **IN(1,2)** and **IN(2)**

= 0,9 in case of **IN(0,6)**

= 0,8 in case of **IN(0)**

2. General

2.1 Application

2.1.1 The following requirements apply to all vessels for the scantling of the fore part structures as defined in Section 1, A.1.3.

As to the requirements which are not explicitly dealt with in the following, refer to the previous Chapters.

2.2 Net scantlings

2.2.1 As specified in Section 2, B.6., all scantlings referred to in this Section, with the exception of those indicated in 7., are net scantlings, i.e. they do not include any margin for corrosion.

2.3 Resistance partial safety factors

2.3.1 The resistance partial safety factors to be considered for the checking of the fore part structures are as specified in Table 6.1.

Table 6.1 Resistance partial safety factors γ_R

Structures	Ordinary stiffeners	Primary supporting members
Fore peak structures	1,40	1,60
Structures located aft of the collision bulkhead	1,02	1,20

2.4 Material factor

2.4.1 When steels with a minimum guaranteed yield stress R_{eH} other than 235 N/mm^2 are used on a vessel, the scantlings are to be determined by taking into account the material factor as follows:

– thickness: see relevant requirements in the following paragraphs

– section modulus:

$$w = k \cdot w_0$$

– sectional area:

$$A = k \cdot A_0$$

w_0, A_0 = scantlings corresponding to a steel with a minimum guaranteed yield stress R_{eH} = 235 N/mm^2.

2.5 Connections of the fore peak with structures located aft of the collision bulkhead

2.5.1 Tapering

Adequate tapering is to be ensured between the scantlings in the fore peak and those aft of the collision bulkhead. The tapering is to be such that the scantling requirements for both areas are fulfilled.

2.6 Design loads

2.6.1 Pressure on sides and bottom

The design pressure [kN/m^2] on sides and bottom is to be derived from the following formulae:

$$p_E = 9{,}81 \cdot (T - z + 0{,}6 \cdot n) \qquad \text{for } z \le T$$

$$= \text{MAX}\,(5{,}9 \cdot n;\ 3) + p_{WD} \qquad \text{for } z > T$$

p_{WD} = specific wind pressure [kN/m^2]

= 0,25 for **IN(0)** and **IN(0,6)**

= 0,4·n for **IN(1,2)** to **IN(2)**.

2.6.2 Pressure on exposed deck

The external pressure on exposed decks is to be defined by the designer and, in general, may not be taken less than:

$$p = 3{,}75 \cdot (n + 0{,}8)\ \ [kN/m^2]$$

2.6.3 Pressure on tween deck

The external pressure on tween decks is to be defined by the designer and, in general, may not be taken less than:

$$p = 4{,}0\ kN/m^2$$

3. Bottom scantlings and arrangements

3.1 Longitudinally framed bottom

3.1.1 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 Table 6.2.

3.1.2 For bilge plating, see Section 5, B.3.

3.1.3 Bottom transverses

Bottom transverses are to be fitted at every 8 frame spacings and generally spaced no more than 4 m apart.

The arrangements of bottom transverses are to be as required in the midship region.

Their scantlings are neither to be less than required in Table 6.2 nor lower than those of the corresponding side transverses, as defined in 4.2.2.

3.1.4 Fore peak arrangement

Where no centreline bulkhead is to be fitted, a centre bottom girder having the same dimensions and scantlings as required for bottom transverses is to be provided.

The centre bottom girder is to be connected to the collision bulkhead by means of a large end bracket.

Side girders, having the same dimensions and scantlings as required for bottom transverses, 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.

3.2 Transversely framed bottom

3.2.1 Plating

The scantling of plating is to be not less than the value obtained from the formulae in Table 6.2.

3.2.2 Floors

Floors are to be fitted at every frame spacing.

The floor net scantlings are to be not less than those derived from Table 6.2.

A relaxation from the Rules of dimensions and scantlings may be granted by GL for very low draught vessels.

3.2.3 Where no centreline bulkhead is to be fitted, a centre bottom girder is to be provided according to 3.1.4.

3.3 Keel plate

3.3.1 The thickness of the keel plate is to be not less than that of the adjacent bottom plating.

Adequate tapering is to be ensured between the bottom and keel plating in the central part and the stem.

4. Side scantlings and arrangements

4.1 Arrangement

4.1.1 In way of the anchors, the side plating net thickness is to be increased by 50 %, or a doubling plate is to be provided.

Where a break is located in the fore part deck, the net thickness of the sheerstrake is to be increased by 40 % in the region of the break.

4.2 Longitudinally framed side

4.2.1 Plating and ordinary stiffeners

The scantlings of plating and ordinary stiffeners are to be not less than the values obtained from the formulae in Table 6.3.

Table 6.2 Net scantlings of bottom plating and structural members

Item	Scantlings	Minimum web thickness [mm]
Plating	Net thickness [mm]: $t = MAX (t_1 ; t_2)$ – longitudinal framing: $t_1 = 1{,}1 + 0{,}03 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$ – transverse framing: $t_1 = 1{,}85 + 0{,}03 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$ $t_2 = 1{,}1 \cdot s \cdot \sqrt{k \cdot p}$	
Inner bottom plating	Net thickness [mm]: $t = MAX (t_1 ; t_2)$ $t_1 = 1{,}5 + 0{,}016 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$ $t_2 = 1{,}1 \cdot s \cdot \sqrt{k \cdot p}$	
Bottom longitudinals Inner bottom longitudinals	Net section modulus [cm^3]: $w = \frac{4{,}36 \cdot \gamma_R}{m} \cdot \beta_b \cdot \eta \cdot p \cdot s \cdot \ell^2$ Net shear sectional area [cm^2]: $A_{sh} = 0{,}045 \cdot \gamma_R \cdot \beta_s \cdot \eta \cdot p \cdot s \cdot \ell$	$t = 1{,}63 + 0{,}004 \cdot L \cdot k^{0,5} + 4{,}5 \cdot s$
Floors Bottom transverses	Net section modulus [cm^3]: $w = 0{,}54 \cdot \gamma_R \cdot \beta_b \cdot p \cdot a \cdot \ell^2$ Net shear sectional area [cm^2]: $A_{sh} = 0{,}045 \cdot \gamma_R \cdot \beta_s \cdot p \cdot a \cdot \ell$	$t = 3{,}8 + 0{,}016 \cdot L \cdot k^{0,5}$

p = design load according to 2.6 and Section 3, C.6.
a = spacing [m] of floors (s) or bottom transverses (S)
m = boundary coefficient defined in 1.
γ_R = resistance partial safety factor defined in Table 6.1.

4.2.2 Side transverses

Side transverses are to be located in way of bottom transverses 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 [cm^3] and net shear sectional area A_{sh} [cm^2] are to be not less than the values derived from Table 6.3.

4.3 Transversely framed side

4.3.1 Plating and ordinary stiffeners (side frames)

Side frames fitted at every frame space are to have the same vertical extension as the collision bulkhead.

Where, due to the hull design, the actual spacing between transverse stiffeners, measured on the plating, is quite greater than the frame spacing, this later should be reduced, or intermediate frames with scantlings in compliance with Table 6.3, are to be provided.

The net scantlings of plating and side stiffeners are to be not less than the values obtained from the formulae in Table 6.3.

The value of the side frame section modulus is generally to be maintained for the full extension of the side frame.

4.3.2 Web frames

The web frames in a transverse framing system are to be spaced not more than 4 m apart.

The web frame section modulus is to be equal to the section modulus of the floor connected to it.

4.3.3 Fore peak arrangement

Depending on the hull body shape and structure aft of the collision bulkhead, one or more adequately spaced side stringers per side are to be fitted. In particular, it is recommended to provide a side stringer where intermediate frames are fitted over a distance equal to the breadth B of the vessels.

The side stringer net section modulus w [cm^3] and shear sectional area A_{sh} [cm^2] are to be not less than the values obtained from Table 6.3.

Table 6.3 Net scantlings of side plating and structural members

Item	Scantlings	Minimum web thickness [mm]
Plating	Net thickness [mm]: $t = MAX\,(t_1\,;\,t_2)$ – longitudinal framing: $t_1 = 1{,}25 + 0{,}025 \cdot L \cdot k^{0{,}5} + 3{,}6 \cdot s$ – transverse framing: $t_1 = 1{,}68 + 0{,}02 \cdot L \cdot k^{0{,}5} + 3{,}6 \cdot s$ $t_2 = 1{,}1 \cdot s \cdot \sqrt{k \cdot p}$	
Side longitudinals	Net section modulus [cm³]: $w = \frac{4{,}36 \cdot \gamma_R}{m} \cdot \beta_b \cdot \eta \cdot p \cdot s \cdot \ell^2$ Net shear sectional area [cm²]: $A_{sh} = 0{,}045 \cdot \gamma_R \cdot \beta_s \cdot \eta \cdot p \cdot s \cdot \ell$	$t = 1{,}63 + 0{,}004 \cdot L \cdot k^{0{,}5} + 4{,}5 \cdot s$
Side frames	Net section modulus [cm³]: $w = \frac{4{,}36 \cdot \gamma_R}{m} \cdot \beta_b \cdot \eta \cdot \left(1{,}2 \cdot k_0 \cdot p_0 \cdot \ell_0{}^2 + \lambda_t \cdot p_F \cdot \ell_F{}^2\right)$ Net shear sectional area [cm²]: $A_{sh} = 0{,}045 \cdot \gamma_R \cdot \beta_s \cdot \eta \cdot k_0 \cdot p_0 \cdot s \cdot \ell_0$	
Intermediate side frames	Net section modulus [cm³]: $w = \frac{5{,}23 \cdot \gamma_R}{m} \cdot \beta_b \cdot \eta \cdot k_0 \cdot p_0 \cdot s \cdot \ell_0{}^2$ Net shear sectional area [cm²]: $A_{sh} = 0{,}045 \cdot \gamma_R \cdot \beta_s \cdot \eta \cdot k_0 \cdot p_0 \cdot s \cdot \ell_0$	
Side transverses Side web frames	Net section modulus [cm³]: $w = 0{,}54 \cdot \gamma_R \cdot \beta_b \cdot k_0 \cdot p_0 \cdot S \cdot \ell_0{}^2$ Net shear sectional area [cm²]: $A_{sh} = 0{,}045 \cdot \gamma_R \cdot \beta_s \cdot k_0 \cdot p_0 \cdot S \cdot \ell_0$	$t = 3{,}8 + 0{,}016 \cdot L \cdot k^{0{,}5}$
Side stringers	Net section modulus [cm³]: $w = 0{,}54 \cdot \gamma_R \cdot \beta_b \cdot p \cdot S \cdot \ell^2$ Net shear sectional area [cm²]: $A_{sh} = 0{,}045 \cdot \gamma_R \cdot \beta_s \cdot p \cdot S \cdot \ell$	

m = boundary coefficient defined in 1.

γ_R = resistance partial safety factor defined in Table 6.1

ℓ_0 = $T - H_F + 0{,}6 \cdot n$

p_0 = $4{,}6 \cdot \ell_0$

p = design load according to 2.6

k_0 = $1 + (\ell - \ell_0) / \ell_0$

ℓ_F = floor span [m]

H_F = floor height or bottom transverse height [m]

p_F = floor design load [kN/m²], defined in 2.6.1

λ_t = coefficient, $\lambda_t \geq 0$

= $0{,}1 \cdot \left(0{,}8 - \frac{\ell^2}{\ell_F{}^2}\right)$

= 0 in combination framing system

Non-tight platforms may be fitted in lieu of side girders. Their openings and scantlings are to be in accordance with 6.1 and their spacing is to be not greater than 2,5 m.

4.3.4 Access to fore peak

Manholes may be cut in the structural members to provide convenient access to all parts of the fore peak.

These manholes are to be cut smooth along a well rounded design and are not to be greater than that strictly necessary to provide the man access. Where manholes of greater sizes are needed, edge reinforcement by means of flat bar rings or other suitable stiffeners may be required.

5. Decks

5.1 Deck scantlings and arrangements

5.1.1 The scantlings of deck plating and structural members are to be not less than the values obtained from the formulae in Table 6.4.

5.1.2 Where the hatchways form corners, the deck plating is to have the same thickness as the stringer plate.

The deck plating is to be reinforced in way of the anchor windlass and other deck machinery, bollards, cranes, masts and derrick posts.

5.1.3 Supporting structure of windlasses and chain stoppers

For the supporting structure under windlasses and chain stoppers the permissible stresses as stated in Section 2, E.3.4 are to be observed.

The acting forces are to be calculated for 80 % or 45 % of the rated breaking load of the chain cable as follows:

a) For chain stoppers: 80 %

b) For windlasses:

– 80 % when no chain stopper is fitted

– 45 % when a chain stopper is fitted

Table 6.4 Net scantlings of deck plating and structural members

Item	Scantlings	Minimum web thickness [mm]
Plating	Net thickness [mm]: $t = MAX(t_1; t_2)$ – longitudinal framing: $t_1 = 0{,}57 + 0{,}031 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$ – transverse framing: $t_1 = 0{,}9 + 0{,}034 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$ $t_2 = 1{,}1 \cdot s \cdot \sqrt{k \cdot p}$	
Plating of tween decks	Net thickness [mm]: $t = MAX(t_1; t_2)$ $t_1 = 3{,}5 + 0{,}01 \cdot L \cdot k^{0,5}$ $t_2 = 1{,}1 \cdot s \cdot \sqrt{k \cdot p}$	
Deck ordinary stiffeners	Net section modulus [cm³]: $w = \frac{4{,}36 \cdot \gamma_R}{m} \cdot \beta_b \cdot \eta \cdot p \cdot s \cdot \ell^2$ Net shear sectional area [cm²]: $A_{sh} = 0{,}045 \cdot \gamma_R \cdot \beta_s \cdot \eta \cdot p \cdot s \cdot \ell$	$t = 1{,}6 + 0{,}004 \cdot L \cdot k^{0,5} + 4{,}5 \cdot s$
Deck transverses	Net section modulus [cm³]: $w = 0{,}54 \cdot \gamma_R \cdot \beta_b \cdot p \cdot S \cdot \ell^2$ Net shear sectional area [cm²]: $A_{sh} = 0{,}045 \cdot \gamma_R \cdot \beta_s \cdot p \cdot S \cdot \ell$	$t = 3{,}8 + 0{,}016 \cdot L \cdot k^{0,5}$
Deck girders	Net section modulus [cm³]: $w = \frac{4{,}36 \cdot \gamma_R}{m} \cdot \beta_b \cdot p \cdot S \cdot \ell^2$ Net shear sectional area [cm²]: $A_{sh} = 0{,}045 \cdot \gamma_R \cdot \beta_s \cdot \eta \cdot p \cdot S \cdot \ell$	$t = 3{,}8 + 0{,}016 \cdot L \cdot k^{0,5}$
p = deck design load according to 2.6 m = boundary coefficient defined in 1. γ_R = resistance partial safety factor defined in Table 6.1.		

5.2 Stringer plate

5.2.1 The net thickness of stringer plate [mm], is to be not less than the greater of:

– $t = 2 + 0{,}032 \cdot L \cdot k^{0{,}5} + 3{,}6 \cdot s$

– $t = t_0$

t_0 = is the deck plating net thickness

6. Non-tight bulkheads and platforms

6.1 Arrangements and scantlings

6.1.1 Non-tight platforms or bulkheads located inside the peak are to be provided with openings having a total area not less than 10 % of that of the platforms or bulkheads.

The scantlings of bulkheads and platforms are to comply with the requirements of non-tight bulkheads (see Section 5, E.12.).

The number and depth of non-tight platforms within the peak is considered by GL on a case-by-case basis.

The platforms may be replaced by equivalent horizontal structures whose scantlings are to be supported by direct calculations.

7. Stems

7.1 General

7.1.1 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.

7.2 Plate stems

7.2.1 Thickness

The gross thickness [mm] of the plate stem is to be not less than the value obtained [mm] from the following formula:

$$t = 1{,}37 \cdot \left(0{,}95 + \sqrt{L}\right) \leq 15$$

For non-propelled vessels, this value may be reduced by 20 %.

This thickness is to be maintained from 0,1 m at least aft of the forefoot till the load waterline. Above the load waterline, this thickness may be gradually tapered towards the stem head, where it is to be not less than the local value required for the side plating or, in case of pontoon-shaped foreship, the local value required for the bottom plating.

7.2.2 Centreline stiffener

If considered necessary, and particularly where the stem radius is large, a centreline stiffener or web of suitable scantlings is to be fitted.

Where the stem plating is reinforced by a centreline stiffener or web, its thickness may be reduced by 10 %.

7.2.3 Horizontal diaphragms

The plating forming the stems is to be supported by horizontal diaphragms spaced not more than 500 mm apart and connected, as far as practicable, to the adjacent frames and side stringers.

The diaphragm plate is to be at least 500 mm deep and its thickness is to be not less than 0,7 times that of the stem.

7.2.4 Pushing transom

Where self-propelled vessels are equipped for pushing other vessels in case of pontoon-shaped foreship, a pushing transom is to be fitted in compliance with Section 7, F.2.2

7.3 Bar stems

7.3.1 Sectional area

The sectional area of bar stems constructed of forged or rolled steel is to be not less than the value obtained [cm^2], from the following formulae:

$$A_p = f \cdot (0{,}006 \cdot L_2 + 12)$$

7.3.2 Thickness

The gross thickness of the bar stems constructed of forged or rolled steel, is to be not less than the value obtained [mm] from the following formula:

$$t = 0{,}33 \cdot L + 10$$

7.3.3 Extension

The bar stem is to extend beyond the forefoot by about 1 m.

Its cross sectional area may be gradually tapered from the load waterline to the upper end.

7.3.4 Stiffened bar stem

Where the bar stem is reinforced by a flanged plate or a bulb flat stiffener, its sectional area may be reduced according to Table 6.5.

Table 6.5 Stiffened bar stem

Sectional area [cm^2]	Reduction on sectional area of the bar stem
> 0,95 t	10 %
> 1,50 t	15 %
t = web thickness [mm] of the plate stiffener	

8. Thruster tunnel

8.1 Scantlings of the thruster tunnel and connection with the hull

8.1.1 Net thickness of tunnel plating

The net thickness [mm] of the tunnel plating is to be neither less than the thickness of the adjacent bottom plating, increased by 2 mm, nor than that obtained from following formula:

$$t = 4{,}4 + 0{,}024 \cdot L \cdot k_{0,5}$$

8.1.2 Connection with the hull

The tunnel is to be fully integrated in the bottom structure.

Adequate continuity with the adjacent bottom structure is to be ensured.

B. Aft Part

1. Symbols

L = Rule length [m] defined in Section 1, A.1.

B = breadth [m] defined in Section 1, A.1.

D = depth [m] defined in Section 1, A.1.

T = draught [m] defined in Section 1, A.1.

t = thickness [mm] of plating

p = design load [kN/m^2]

s = spacing [m] of ordinary stiffeners

S = spacing [m] of primary supporting members

ℓ = span [m] of ordinary stiffeners or primary supporting members

n = navigation coefficient defined in Section 3, B.

= $0{,}85 \cdot H$

H = significant wave height [m]

β_b, β_s = bracket coefficients defined in Section 2, B.5.2

η = $1 - s / (2 \cdot \ell)$

w = net section modulus [cm^3] of ordinary stiffeners or primary supporting members

A_{sh} = net web sectional area [cm^2]

k = material factor defined in Section 2, A.2.4 and Section 2, A.3.2

z = Z co-ordinate [m] of the calculation point

m = boundary coefficient

= 12 in general, for stiffeners considered as clamped

= 8 for stiffeners considered as simply supported

= 10,6 for stiffeners clamped at one end and simply supported at the other

f = coefficient defined as follows:

= 1,0 for **IN(1,2)** and **IN(2)**

= 0,9 for **IN(0,6)**

= 0,8 for **IN(0)**.

2. General

2.1 Application

The following requirements apply for the scantling of structures located aft of the after peak bulkhead.

As to the requirements which are not explicitly dealt with in the following, refer to the previous Sections.

2.2 Net scantlings

As specified in Section 2, B.6., all scantlings referred to in the following, with the exception of those indicated in 4., are net scantlings, i.e. they do not include any margin for corrosion.

2.3 Material factor

When steels with a minimum guaranteed yield stress R_{eH} other than 235 N/mm^2 are used on a vessel, the scantlings are to be determined by taking into account the material factor as follows:

– thickness:

see relevant requirements in the following

– section modulus:

$w = k \cdot w_0$

– sectional area:

$A = k \cdot A_0$

w_0, A_0 = Scantlings corresponding to a steel with a minimum guaranteed yield stress R_{eH} = 235 N/mm^2

2.4 Design loads

2.4.1 Pressure on sides and bottom

The design pressure on sides and bottom is to be derived from following formulae:

$$p_E = 9{,}81 \cdot (T - z + 0{,}6 \cdot n) \qquad \text{for } z \le T$$

$$p_E = \text{MAX}\,(5{,}9 \cdot n;\ 3) + p_{WD} \qquad \text{for } z > T$$

p_{WD} = specific wind pressure [kN/m²]

= 0,25 for **IN(0)** and **IN(0,6)**

= 0,4·n for **IN(1,2)** and **IN(2)**.

2.4.2 Pressure on exposed deck

The external pressure on exposed decks is to be defined by the designer and, in general, may not be taken less than:

$$p = 3{,}75 \cdot (n + 0{,}8)$$

2.4.3 Pressure on tween deck

The external pressure on tween decks is to be defined by the designer and, in general, may not be taken less than:

$$p = 4{,}0 \text{ kN/m}^2$$

2.5 Connections of the aft part with structures located fore of the after bulkhead

2.5.1 Tapering

Adequate tapering is to be ensured between the scantlings in the aft part and those fore of the after bulkhead. The tapering is to be such that the scantling requirements for both areas are fulfilled.

3. After peak

3.1 Arrangement

3.1.1 General

The after peak is, in general, to be transversely framed.

3.1.2 Floors

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.

In way of and near the rudder post and propeller post, higher floors of increased thickness are to be fitted. The increase will be considered by GL on a case-by-case basis, depending on the arrangement proposed.

3.1.3 Side frames

Side frames are to be extended up to the deck.

Where, due to the hull design, the actual spacing between transverse stiffeners, measured on the plating, is significantly larger than the frame spacing, the latter should be reduced, or intermediate frames with scantlings in compliance with Table 6.6, are to be provided.

Table 6.6 Net scantlings of bottom plating and structural members

Item	Scantlings	Minimum web thickness [mm]
Bottom plating	Net thickness [mm]: $t = MAX(t_1; t_2)$ – longitudinal framing: $t_1 = 1{,}1 + 0{,}03 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$ – transverse framing: $t_1 = 1{,}85 + 0{,}03 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$ $t_2 = 1{,}1 \cdot s \cdot \sqrt{k \cdot p}$	
Inner bottom plating	Net thickness [mm]: $t = MAX(t_1; t_2)$ $t_1 = 1{,}5 + 0{,}016 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$ $t_2 = 1{,}1 \cdot s \cdot \sqrt{k \cdot p}$	
Bottom longitudinals Inner bottom longitudinals	Net section modulus [cm³]: $w = \frac{6{,}1}{m} \cdot \beta_b \cdot \eta \cdot p \cdot s \cdot \ell^2$ Net shear sectional area [cm²]: $A_{sh} = 0{,}06 \cdot \beta_s \cdot \eta \cdot p \cdot s \cdot \ell$	$t = 1{,}63 + 0{,}004 \cdot L \cdot k^{0,5} + 4{,}5 \cdot s$
Floors Bottom transverses	Net section modulus [cm³]: $w = 0{,}87 \cdot \beta_b \cdot p \cdot a \cdot \ell^2$ Net shear sectional area [cm²]: $A_{sh} = 0{,}069 \cdot \beta_s \cdot p \cdot a \cdot \ell$	$t = 3{,}8 + 0{,}016 \cdot L \cdot k^{0,5}$
a = spacing [m] of floors (s) or bottom transverses (S) m = boundary coefficient defined in 1. p = design load [kN/m²] defined in 2.4.1 and Section 3, C.6.		

3.1.4 Platforms and side girders

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.

3.1.5 Longitudinal bulkheads

A longitudinal non-tight bulkhead is to be fitted on the centreline of the vessel, in general in the upper part of the peak, and stiffened at each frame spacing.

Where no longitudinal bulkhead is to be fitted, centre line bottom and deck girders having the same dimensions and scantlings as required respectively for bottom and deck transverses are to be provided.

3.1.6 Local reinforcement

The deck plating is to be reinforced in way of the anchor windlass, steering gear and other deck machinery, bollards, cranes, masts and derrick posts.

3.2 Bottom scantlings

3.2.1 Bottom plating and structural members

The net scantlings of bottom plating and structural members are to be not less than those obtained from formulae in Table 6.6.

For bilge plating see Section 5, B.3.

The floor scantlings are to be increased satisfactorily in way of the rudder stock.

3.3 Side scantlings

3.3.1 Plating and structural members

The net scantlings of plating and structural members are to be not less than those obtained from formulae in Table 6.7.

3.3.2 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.

3.3.3 Side stringers

Where the vessel depth exceeds 2 m, a side stringer is to be fitted at about mid-depth.

3.4 Deck scantlings and arrangements

3.4.1 Plating and ordinary stiffeners

The net scantlings of deck plating and structural members are not to be less than those obtained from the formulae in Table 6.8.

Where a break is located in the after part deck, the thickness of the sheerstrake is to be increased by 40 % in the region of the break.

3.4.2 The deck plating is to be reinforced in way of the anchor windlass and other deck machinery, bollards, cranes, masts and derrick posts.

The supporting structure of windlasses and chain stoppers is to be in compliance with A.5.1.3

3.4.3 Stringer plate

The net thickness of stringer plate [mm] is to be not less than the greater of:

– $t = 2 + 0{,}032 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$

– $t = t_0$

t_0 = deck plating net thickness

4. Sternframes

4.1 General

Sternframes may be made of cast or forged steel, with a hollow section, or fabricated from plate.

4.2 Connections

4.2.1 Heel

Sternframes are to be effectively attached to the aft structure. The propeller post heel is to extend forward over a length [m] including the scarf, at least equal to:

$$d = 0{,}01 \cdot L + 0{,}6 \text{ with } \quad 1{,}2 \le d \le 1{,}8$$

in order to provide an effective connection with the keel. However, the sternframe need not extend beyond the after peak bulkhead.

The value of d may however be reduced to 1m where no centreline propeller is fitted.

4.2.2 Connection with hull structure

The thickness of shell plating connected with the sternframe is to be not less than the rule thickness of the bottom plating amidships.

4.2.3 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.

4.2.4 Connection with transom floors

Propeller post and rudder post should in their upper part be led and connected in suited and safe manner to the vessel structure. In range where the forces of the rudder post are led into the vessel structure the shell plating has to be strengthened.

Table 6.7 Net scantlings of shell plating and structural members

Item	Scantlings	Minimum web thickness [mm]
Side plating Transom plating	Net thickness [mm]: $t = MAX\ (t_1; t_2)$ – longitudinal framing: $t_1 = 1{,}25 + 0{,}025 \cdot L \cdot k^{0{,}5} + 3{,}6 \cdot s$ – transverse framing: $t_1 = 1{,}68 + 0{,}02 \cdot L \cdot k^{0{,}5} + 3{,}6 \cdot s$ $t_2 = 1{,}1 \cdot s \cdot \sqrt{k \cdot p}$	
Side longitudinals	Net section modulus [cm³]: $w = \frac{6{,}1}{m} \cdot \beta_b \cdot \eta \cdot p \cdot s \cdot \ell^2$ Net shear sectional area [cm²]: $A_{sh} = 0{,}063 \cdot \beta_s \cdot \eta \cdot p \cdot s \cdot \ell$	$t = 1{,}63 + 0{,}004 \cdot L \cdot k^{0{,}5} + 4{,}5 \cdot s$
Side frames	Net section modulus [cm³]: $w = \frac{6{,}1}{m} \cdot \beta_b \cdot \eta \cdot s \cdot \left(1{,}2 \cdot k_0 \cdot p_0 \cdot \ell_0^2 + \lambda_t \cdot p_F \cdot \ell_F^2\right)$ Net shear sectional area [cm²]: $A_{sh} = 0{,}063 \cdot \beta_s \cdot \eta \cdot k_0 \cdot p_0 \cdot s \cdot \ell_0$	
Intermediate side frames	Net section modulus [cm³]: $w = \frac{6{,}1}{m} \cdot \beta_b \cdot \eta \cdot s \cdot k_0 \cdot p_0 \cdot \ell_0^2$ Net shear sectional area [cm²]: $A_{sh} = 0{,}063 \cdot \beta_s \cdot \eta \cdot k_0 \cdot p_0 \cdot s \cdot \ell_0$	
Side transverses Side web frames	Net section modulus [cm³]: $w = 0{,}87 \cdot \beta_b \cdot k_0 \cdot p_0 \cdot S \cdot \ell_0^2$ Net shear sectional area [cm²]: $A_{sh} = 0{,}072 \cdot \beta_s \cdot k_0 \cdot p_0 \cdot S \cdot \ell_0$	$t = 3{,}8 + 0{,}016 \cdot L \cdot k^{0{,}5}$
Side stringers	Net section modulus [cm³]: $w = 0{,}87 \cdot \beta_b \cdot p \cdot S \cdot \ell^2$ Net shear sectional area [cm²]: $A_{sh} = 0{,}072 \cdot \beta_s \cdot p \cdot S \cdot \ell$	

m = boundary coefficient defined in 1.

p = design load according to 2.4

ℓ_0 = $T - H_F + 0{,}6 \cdot n$

p_0 = $4{,}9 \cdot \ell_0$

k_0 = $1 + (\ell - \ell_0) / \ell_0$

ℓ_F = floor span [m]

H_F = floor height or bottom transverse height [m]

p_F = floor design load [kN/m²] defined in 2.4.1

λ_t = coefficient, $\lambda_t \geq 0$

= $0{,}1 \cdot \left(0{,}8 - \frac{\ell^2}{\ell_F^2}\right)$

= 0 in combination framing system

Table 6.8 Net scantlings of deck plating and structural members

Item	Scantlings	Minimum web thickness [mm]
Deck plating	Net thickness [mm]: $t = MAX\ (t_1\ ;\ t_2)$ – longitudinal framing: $t_1 = 0{,}57 + 0{,}031 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$ – transverse framing: $t_1 = 0{,}90 + 0{,}034 \cdot L \cdot k^{0,5} + 3{,}6 \cdot s$ $t_2 = 1{,}1 \cdot s \cdot \sqrt{k \cdot p}$	
Plating of tween decks	Net thickness [mm]: $t = MAX\ (t_1\ ;\ t_2)$ $t_1 = 3{,}5 + 0{,}01 \cdot L \cdot k^{0,5}$ $t_2 = 1{,}1 \cdot s \cdot \sqrt{k \cdot p}$	
Deck longitudinals Deck beams	Net section modulus [cm^3]: $w = \frac{6{,}1}{m} \cdot \beta_b \cdot \eta \cdot p \cdot s \cdot \ell^2$ Net shear sectional area [cm^2]: $A_{sh} = 0{,}063 \cdot \beta_s \cdot \eta \cdot p \cdot s \cdot \ell$	$t = 1{,}63 + 0{,}004 \cdot L \cdot k^{0,5} + 4{,}5 \cdot s$
Deck transverses	Net section modulus [cm^3]: $w = 0{,}87 \cdot \beta_b \cdot p \cdot S \cdot \ell^2$ Net shear sectional area [cm^2]: $A_{sh} = 0{,}072 \cdot \beta_s \cdot p \cdot S \cdot \ell$	$t = 3{,}8 + 0{,}016 \cdot L \cdot k^{0,5}$
Deck girders	Net section modulus [cm^3]: $w = \frac{4{,}36 \cdot \gamma_R}{m} \cdot \beta_b \cdot p \cdot S \cdot \ell^2$ Net shear sectional area [cm^2]: $A_{sh} = 0{,}045 \cdot \gamma_R \cdot \beta_s \cdot p \cdot S \cdot \ell$	$t = 3{,}8 + 0{,}016 \cdot L \cdot k^{0,5}$
m = boundary coefficient defined in 1. p = design load [kN/m^2], defined in 2.4 γ_R = resistance partial safety factor defined in Table 6.1.		

The shape of the vessel's stern, the thickness of the rudder and of the propeller well should be such that forces coming from the propeller are as small as possible.

In vessel's transverse direction, the propeller post has to be fastened to strengthened and higher floor plates, which are connected by a longitudinal girder in plane of the propeller post over a range of several frames. With the propeller post directly connected, floorplates or plates of longitudinal webs should have a thickness of 0,30 times the thickness of the bar propeller post according to 4.3.1.

4.2.5 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.

4.3 Propeller posts

4.3.1 Scantlings of propeller posts

The gross scantlings of propeller posts are to be not less than those obtained from the formulae in Table 6.9 for single and twin screw vessels.

These scantlings are to be maintained from the bottom to above the propeller boss. At the upper part, the scantlings may be reduced gradually to those of the rudder post, where the latter joins the propeller post.

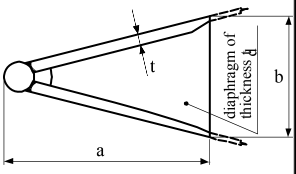
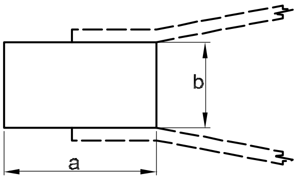
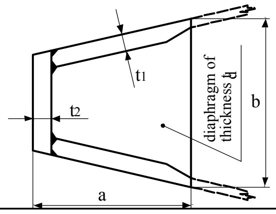
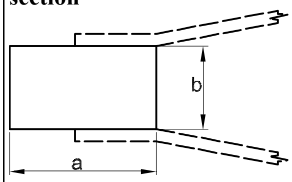
In vessels having a high engine power with respect to their size, or subjected to abnormal stresses, strengthening of the propeller post may be called for by GL.

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 Table 6.9.

4.3.2 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 Section 8, A.3.3

Table 6.9 Gross scantlings of propeller posts

Single screw vessels		Twin screw vessels	
Fabricated propeller post	**Bar propeller post, cast or forged, having rectangular section**	**Fabricated propeller post**	**Bar propeller post, cast or forged, having rectangular section**
			
a [mm] = $29 \cdot L^{1/2}$	a [mm] = $14{,}1 \cdot A^{0{,}5}$	a [mm] = $29 \cdot L^{1/2}$	a [mm] = $14{,}1 \cdot A^{0{,}5}$
b/a = 0,7	b/a = 0,5	b/a = 0,7	b/a = 0,5
t [mm] = $2{,}5 \cdot L^{1/2}$ with $t \geq 1{,}3 \cdot t_{bottom\ midship}$	thickness: NA	t_1 [mm] = $2{,}5 \cdot L^{1/2}$ with $t_1 \geq 1{,}3 \cdot t_{bottom\ midship}$ t_2 [mm] = $3{,}2 \cdot L^{1/2}$ with $t_2 \geq 1{,}3 \cdot t_{bottom\ midship}$	thickness: NA
Sectional area: NA	for $L \leq 40$: A [cm²] = $f \cdot (1{,}4 \cdot L + 12)$ for $L > 40$: A [cm²] = $f \cdot (2 \cdot L - 12)$	Sectional area: NA	A [cm²] = $f \cdot (0{,}005 \cdot L^2 + 20)$
t_d [mm] = $1{,}3 \cdot L^{1/2}$	t_d : NA	t_d [mm] = $1{,}3\ L^{1/2}$	t_d : NA
f = coefficient defined in 1. A = sectional area [cm²], of the propeller post. NA = not applicable.			

4.4 Propeller shaft bossing

4.4.1 Thickness

In single screw vessels, the thickness of the propeller shaft bossing, included in the propeller post [mm] is to be not less than:

$$t = 6 \cdot \sqrt{f \cdot (0{,}7 \cdot L + 6)} \qquad \text{for } L \leq 40$$

$$t = 6 \cdot \sqrt{f \cdot (L - 6)} \qquad \text{for } L > 40$$

f = coefficient defined in 1.

4.5 Stern tubes

4.5.1 The stern tube thickness is to be considered by GL 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 stern tube and the plating adjacent to the sternframe are different, the stern tube thickness is to be at least equivalent to that of the plating.

C. Machinery Space

1. Symbols

L = Rule length [m] defined in Section 1, A.1.

B = breadth [m] defined in Section 1, A.1.

D = depth [m] defined in Section 1, A.1.

T = draught [m] defined in Section 1, A.1.

t = thickness [mm] of plating

p = design load [kN/m²]

s = spacing [m] of ordinary stiffeners

S = spacing [m] of primary supporting members

ℓ = span [m] of ordinary stiffeners or primary supporting members

n = navigation coefficient defined in Section 3, B.

= $0{,}85 \cdot H$

H = significant wave height [m]

β_b, β_s = bracket coefficients defined in Section 2, B.6.2

η = $1 - s / (2 \cdot \ell)$

w = net section modulus [cm³] of ordinary stiffeners or primary supporting members

A_{sh} = net web sectional area [cm²]

k = material factor defined in Section 2, A.2.4 and Section 2, A.3.2

z = Z co-ordinate [m] of the calculation point

P = maximum power [kW] of the engine

n_R = number of revolutions per minute of the engine shaft at power equal to P

M_H = design bending moment [kNm] in hogging condition

M_S = design bending moment [kNm] in sagging condition

2. General

2.1 Application

2.1.1 The following Rules apply for the arrangement and scantling of the machinery space structures. They are to be considered as recommendations.

As to the requirements which are not explicitly dealt with in the following, refer to the previous Sections.

2.1.2 Alternative arrangements and scantlings on the basis of direct calculations are to be submitted to GL on a case-by-case basis.

2.2 Connections of the machinery space with the structures located aft and forward

2.2.1 Tapering

Adequate tapering is to be ensured between the scantlings in the machinery space and those located aft and forward. The tapering is to be such that the scantling requirements for all areas are fulfilled.

2.2.2 Hull girder strength check

On vessels with machinery space aft, the hull girder strength in way of the connection of the machinery space with the central part is to be assessed.

The following indicated value may be used for the design bending moment:

$$M_D = 2 \cdot \frac{d_{AR} \cdot M}{L}$$

M = design bending moment [kN·m] M_H or M_S

= M_H in hogging condition according to Section 4, B.3.

= M_S in sagging condition according to Section 4, B.3.

d_{AR} = length of aft deck beyond the cargo space [m] (see Section 4, B.2.1.1).

2.2.3 Deck discontinuities

a) Decks which are interrupted in the machinery space are to be tapered on the side by means of horizontal brackets.

Where the deck is inclined, the angle of inclination is to be limited. The end of slope is to be located in way of reinforced ring.

b) Where the inclination of deck is limited by transverse bulkheads, the continuity of the longitudinal members is to be ensured.

In way of breaks in the deck, the continuity of longitudinal strength is to be ensured. To that effect, the stringer of the lower deck is to:

- extend beyond the break, over a length at least equal to three times its width
- stop at a web frame of sufficient scantlings

c) At the ends of the sloped part of the deck, suitable arrangements are required to take into account the vertical component of the force generated in the deck.

2.3 Arrangements

Every engine room shall normally have two exits. The second exit may be an emergency exit. If a skylight is permitted as an escape, it shall be possible to open it from the inside. See also GL Rules for Machinery, Systems and Electricity (I-2-3), Section 1, H.2.5 and Additional Requirements for Notations (I-2-4), Section 3, A.2.7.3.

For the height of entrances to machinery space, see G.9.4

2.4 Material factor

When steels with a minimum guaranteed yield stress R_{eH} other than 235 N/mm^2 are used on a vessel, the scantlings are to be determined by taking into account the material factor as follows:

- thickness:

  see relevant requirements in the following

- section modulus:

  $w = k \cdot w_0$

- sectional area:

  $A = k \cdot A_0$

w_0, A_0 = scantlings corresponding to a steel with a minimum guaranteed yield stress R_{eH} = 235 N/mm^2

3. Design loads

3.1 Local loads

3.1.1 Pressure on sides and bottom

The design pressure on sides and bottom is to be derived from following formulae:

$$p_E = 9{,}81 \cdot (T - z + 0{,}6 \cdot n) \qquad \text{for } z \le T$$

$$p_E = \text{MAX}\,(5{,}9 \cdot n\ ;\ 3) + p_{WD} \qquad \text{for } z > T$$

p_{WD} = specific wind pressure [kN/m^2]:

= 0,25 for **IN(0)** and **IN(0,6)**

= 0,4·n for **IN(1,2)** and **IN(2)**.

3.1.2 Pressure on deck

The external pressure on deck is to be defined by the designer and, in general, may not be taken less than:

$$p = 3{,}75 \cdot (n + 0{,}8)$$

3.2 Hull girder loads

3.2.1 The normal stress, σ_1 induced by hull girder loads is to be neglected if the fore bulkhead of the machinery space is located at a distance less than 0,2·L from the aft end defined in Section 1, A.1.2.5.

4. Hull scantlings

4.1 Shell plating

4.1.1 Where the machinery space is located aft, the shell plating thickness is to be determined as specified in Table 6.10. Otherwise, requirements of Section 5, B., Section 5, C. and Section 5, D. are to be complied with.

4.1.2 For bilge plating see Section 5, B.3.

4.2 Shell structure

4.2.1 Where the machinery space is located aft, the scantlings of ordinary stiffeners and primary supporting members are to be as required by Table 6.11. Otherwise, requirements of Section 5, B., Section 5, C. and Section 5, D. are to be complied with.

4.3 Topside structure

4.3.1 The scantlings and arrangement of the topside structure are to be in compliance with Section 5, D.5.2 and Section 5, D.5.4.

5. Bottom structure

5.1 General

Where the hull is shaped, the bottom is to be transversely framed. In all other cases it may be transversely or longitudinally framed.

5.2 Transversely framed bottom

5.2.1 Arrangement of floors

Where the bottom in the machinery space is transversely framed, floors are to be arranged at every frame. Furthermore, reinforced floors are to be fitted in way of important machinery and at the end of keelsons not extending up to the transverse bulkhead.

The floors are to be fitted with welded face plates, which are preferably to be symmetrical. Flanges are forbidden.

5.3 Longitudinally framed bottom

5.3.1 Transverses

Where the bottom is longitudinally framed, transverses are to be arranged every 4 frame spacings. Additional transverses are to be fitted in way of important machinery.

6. Side structure

6.1 General

The type of side framing in machinery spaces is generally to be the same as that adopted in the adjacent areas. In any case, it is to be continuous over the full length of the machinery space.

6.2 Transversely framed side

6.2.1 Web frames

In vessels built on transverse system, web frames 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.

The mean web frame spacing in the machinery space is in general not more than 5 frame spacings.

Table 6.10 Shell plating net scantlings

Item	Transverse framing	Longitudinal framing
Bottom plating	$t = MAX(t_i)$ $t_1 = 1{,}85 + 0{,}03 \cdot L \cdot k^{0{,}5} + 3{,}6 \cdot s$ $t_2 = 1{,}6 \cdot s \cdot (k \cdot p)^{0{,}5}$	$t = MAX(t_i)$ $t_1 = 1{,}1 + 0{,}03 \cdot L \cdot k^{0{,}5} + 3{,}6 \cdot s$ $t_2 = 1{,}2 \cdot s \cdot (k \cdot p)^{0{,}5}$
Side plating	$t = MAX(t_i)$ $t_1 = 1{,}68 + 0{,}025 \cdot L \cdot k^{0{,}5} + 3{,}6 \cdot s$ $t_2 = 1{,}6 \cdot s \cdot (k \cdot p)^{0{,}5}$	$t = MAX(t_i)$ $t_1 = 1{,}25 + 0{,}02 \cdot L \cdot k^{0{,}5} + 3{,}6 \cdot s$ $t_2 = 1{,}2 \cdot s \cdot (k \cdot p)^{0{,}5}$
Deck plating	$t = MAX(t_i)$ $t_1 = 0{,}9 + 0{,}034 \cdot L \cdot k^{0{,}5} + 3{,}6 \cdot s$ $t_2 = 1{,}6 \cdot s \cdot (k \cdot p)^{0{,}5}$	$t = MAX(t_i)$ $t_1 = 0{,}57 + 0{,}031 \cdot L \cdot k^{0{,}5} + 3{,}6 \cdot s$ $t_2 = 1{,}2 \cdot s \cdot (k \cdot p)^{0{,}5}$
p = design load [kN/m²] defined in 3.1		

Table 6.11 Shell structure net scantlings

Item	Scantlings	Minimum web thickness [mm]
Bottom, side and deck longitudinals	Net section modulus [cm^3]: $w = 0{,}45 \cdot \beta_b \cdot \eta \cdot p \cdot s \cdot \ell^2$ Net shear sectional area [cm^2]: $A_{sh} = 0{,}045 \cdot \beta_s \cdot \eta \cdot p \cdot s \cdot \ell$	– for $L < 120$ m: $t = 1{,}63 + 0{,}004 \cdot L \cdot k^{0,5} + 4{,}5 \cdot s$ – for $L \geq 120$ m: $t = 3{,}9 \cdot k^{0,5} + s$
Deck beams	Net section modulus, in [cm^3]: $w = 0{,}58 \cdot \beta_b \cdot \eta \cdot p \cdot s \cdot \ell^2$ Net shear sectional area [cm^2]: $A_{sh} = 0{,}045 \cdot \beta_s \cdot \eta \cdot p \cdot s \cdot \ell$	
Floors and bottom transverses Deck transverses	Net section modulus [cm^3]: $w = 0{,}58 \cdot \beta_b \cdot p \cdot a \cdot \ell^2$ Net shear sectional area [cm^2]: $A_{sh} = 0{,}045 \cdot \beta_s \cdot p \cdot a \cdot \ell$	$t = 3{,}8 + 0{,}016 \cdot L \cdot k^{0,5}$
Deck girders	Net section modulus [cm^3]: $w = \frac{4{,}36 \cdot \gamma_R}{m} \cdot \beta_b \cdot p \cdot S \cdot \ell^2$ Net shear sectional area [cm^2]: $A_{sh} = 0{,}045 \cdot \gamma_R \cdot \beta_s \cdot p \cdot S \cdot \ell$	
Side frames	Net section modulus [cm^3]: $w = 0{,}58 \cdot \beta_b \cdot \eta \cdot s \cdot (1{,}2 \cdot k_0 \cdot p \cdot \ell_0^2 + \lambda_t \cdot p_{\gamma E} \cdot \ell_F^2)$ Net shear sectional area [cm^2]: $A_{sh} = 0{,}045 \cdot \beta_s \cdot \eta \cdot k_0 \cdot p \cdot s \cdot \ell_0$	– for $L < 120$ m: $t = 1{,}63 + 0{,}004 \cdot L \cdot k^{0,5} + 4{,}5 \cdot s$ – for $L \geq 120$ m: $t = 3{,}9 \cdot k^{0,5} + s$
Side web frames Side transverses	Net section modulus [cm^3]: $w = 0{,}70 \cdot \beta_b \cdot k_0 \cdot p \cdot S \cdot \ell_0^2$ Net shear sectional area [cm^2]: $A_{sh} = 0{,}063 \cdot \beta_s \cdot k_0 \cdot p \cdot S \cdot \ell_0$	$t = 3{,}8 + 0{,}016 \cdot L \cdot k^{0,5}$
Side stringers	Net section modulus [cm^3]: $w = 0{,}75 \cdot \beta_b \cdot p \cdot S \cdot \ell^2$ Net shear sectional area [cm^2]: $A_{sh} = 0{,}056 \cdot \beta_s \cdot p \cdot S \cdot \ell$	

a = primary supporting member spacing [m]:
= s for floors
= S for other primary supporting members

p = design load [kN/m^2] to be determined according to 3.1.1, in general
= $4{,}9 \cdot (T - H_F + 0{,}6 \cdot n)$ for side vertical stiffeners

$p_{\gamma E}$ = floor design load [kN/m^2]:
= $9{,}81 \cdot (T + 0{,}6 \cdot n)$

ℓ_0 = $T - H_F + 0{,}6 \cdot n$

k_0 = $1 + (\ell - \ell_0) / \ell_0$

ℓ_F = floor span [m]

H_F = floor height or bottom transverse height [m]

λ_t = coefficient to be taken equal to:

$$= 0{,}1 \cdot \left(0{,}8 - \frac{\ell^2}{\ell_F^2}\right), \lambda_t \geq 0$$

= 0 in combination framing system

m = boundary coefficient defined in 1.

γ_R = resistance partial safety factor defined in Table 6.1.

6.2.2 Side stringers

In the machinery space, where the mean value of the depth exceeds 2 m, a side stringer is generally fitted at half the vessel's depth. Its scantlings are to be the same as those of the web frames.

The plate connecting the stringer to the shell plating is to be an intercostal plate between web frames.

Stringer strength continuity in way of the web frames is to be obtained by a suitable assembly.

Stringers located in fuel bunkers are determined in the same way as bulkhead stringers.

In case a side stringer is fitted in the engine room, it is to be continued behind the aft bulkhead by a bracket at least over two frame spacings.

6.3 Longitudinally framed side

6.3.1 Extension of the hull longitudinal structure within the machinery space

In vessels 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.

6.3.2 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.

The side transverse spacing is to be not greater than 4 frame spacings.

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 not more than 750 mm, in transverse bulkheads

7.2 Openings

7.2.1 General

All machinery space openings, which are to comply with the requirements in G.8., 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.

7.2.2 Access doors

Access doors to casings are to comply with G.9.4

7.3 Scantlings

7.3.1 Design loads

Design loads for machinery casing scantling are to be determined as stated under D.3.

7.3.2 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 D.

8. Engine foundation

8.1 General

The arrangement and scantlings of the engine foundation are to be in compliance with the manufacturer recommendations. The net scantlings of the structural elements in way of the seatings of main engines are to be determined as required in 8.2 to 8.4.

8.2 Longitudinal girders

8.2.1 Extension

The longitudinal girders under the engine are to extend over the full length of the engine room and extend beyond the bulkheads, at least for one frame spacing, by means of thick brackets.

Where such an arrangement is not practicable aft, because of the lines, the girders may end at a deep floor strengthened to that effect and in way of which the frames are to be fitted.

As a rule, longitudinal girders under the engine are to be continuous and the floors are to be intercostal, except for large size engine rooms. Strength continuity is anyhow to be ensured over the full girder length. More specially, cutouts and other discontinuities are to be carefully compensated.

8.2.2 Scantlings

The longitudinal girder net section modulus w [cm^3] and net shear sectional area A_{Sh} [cm^2] are not to be less than:

$$w = 0{,}75 \cdot \beta_b \cdot p \cdot b \cdot \ell_E^2$$

$$A_{sh} = 0{,}056 \cdot \beta_s \cdot p \cdot b \cdot \ell_E$$

b = plating parameter [m] to be obtained from the following formula:

$$b = \frac{B_1 - n_E \cdot S}{2 \cdot (n_E + 1)} + \frac{S}{2}$$

S = longitudinal girders spacing [m] (under main engine)

n_E = number of engines

ℓ_E = length of the engine foundation [m] to be not taken less than 3 m

B_1 = width of the machinery space [m]

The ratio of the longitudinal girder height to the web thickness is to be not greater than 50.

Over the outer quarters of the longitudinal girder length, the section modulus of the girder may decrease towards the ends up to a quarter of this value.

The scantlings given herebefore may be reduced when additional longitudinal bottom girders, either centre or side girders, are provided over the full length of the engine room.

The net cross sectional area [cm²] of top plate is to be not less than:

$$A = 40 + 23 \cdot \frac{P}{n_R}$$

Its minimum net thickness [mm] is to be determined using the formula:

$$t = 18 + 2,3 \cdot \frac{P}{n_R}$$

8.3 Floors

8.3.1 Floor strength continuity is to be obtained as shown in Fig. 6.1 or Fig. 6.2, or according to any other method considered equivalent by GL.

8.3.2 Scantlings

In way of the engine foundation, the floor net section modulus w [cm³] and shear sectional area A_{sh} [cm²] are not to be less than:

$$w = 0,58 \cdot \beta_b \cdot p \cdot s \cdot \ell^2 + 175 \cdot \frac{P}{n_R}$$

$$A_{sh} = 0,045 \cdot \beta_S \cdot p \cdot s \cdot \ell + 17,5 \cdot \frac{P}{n_R}$$

The section modulus of the floors in the section A-A (see Fig. 6.1 and Fig. 6.2) shall be at least 0,6 times that determined according to the formula here above.

8.4 Bottom plating in way of engine foundation

The net thickness of the bottom plating [mm] in way of the engine seatings is to be determined using the formula:

$$t = t_0 + 2,3 \cdot \frac{P}{n_R}$$

t_0 = net thickness of the bottom plating [mm] in the central part.

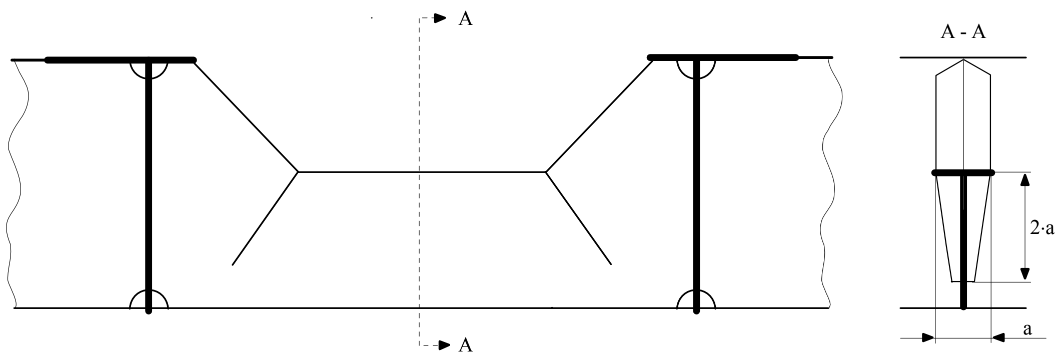


Fig. 6.1 Floor in way of main engine seating: 1st version

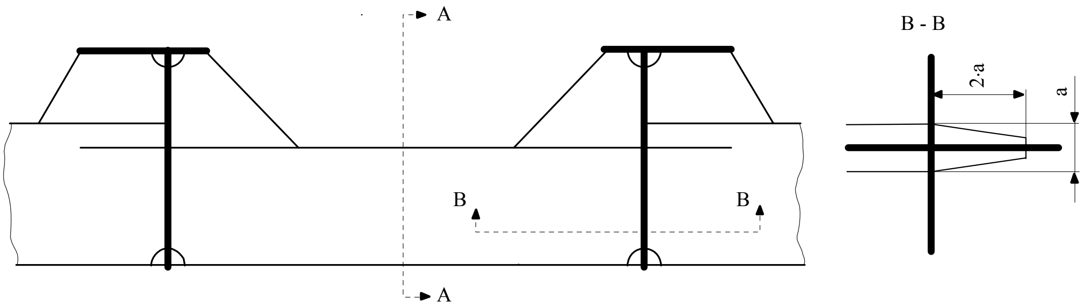


Fig. 6.2 Floor in way of main engine seating: 2nd version

D. Superstructures and Deckhouses

1. Symbols

L = Rule length [m] defined in Section 1, A.1.

s = spacing [m] of ordinary stiffeners

S = spacing [m] of primary supporting members

t = net thickness [mm] of plating

w = net section modulus [cm^3]

A_{sh} = net web sectional area [cm^2]

k = material factor defined in Section 2, A.2.4 and Section 2, A.3.2

n = navigation coefficient defined in Section 3, B.

= 0,85·H

H = significant wave height [m] defined in Section 3, B.

2. General

2.1 Application

The following requirements apply for the scantlings 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.

As to the requirements which are not explicitly dealt with in the following, refer to the previous Sections.

2.2 Definitions

2.2.1 Deckhouses

A closed deckhouse is a construction consisting of strong bulkheads permanently secured to the deck and made watertight. The openings are to be fitted with efficient weathertight means of closing.

The deckhouses considered have:

– for an aft deckhouse: the fore bulkhead less than 0,25·L from the aft perpendicular

– for a midship deckhouse: a length at most equal to L/6

– for a fore deckhouse: the aft bulkhead less than 0,25·L from the fore perpendicular

2.2.2 Superstructures

Superstructures are defined in Section 1, A.1.2.

2.2.3 Superstructures and deckhouses contributing to the longitudinal strength

A superstructure may be considered as contributing to the longitudinal strength if its deck satisfies the basic criteria given in the GL Additional Requirements for Notations (I-2-4), Section 2, D.7.1.

2.2.4 Tiers of superstructures and deckhouses

The lowest tier is normally that which is directly situated above the strength deck defined in Section 1, A.1.2.8

The second tier is that located immediately above the lowest tier, and so on.

2.3 Material factor

When steels with a minimum guaranteed yield stress R_{eH} other than 235 N/mm^2 are used on a vessel, the scantlings are to be determined by taking into account the material factor as follows:

– thickness: see relevant requirements in the following

– section modulus: $w = k \cdot w_0$

– sectional area: $A = k \cdot A_0$

w_0, A_0 = scantlings corresponding to a steel with a minimum guaranteed yield stress R_{eH} = 235 N/mm^2.

3. Arrangements

3.1 Connections of superstructures and deckhouses with the hull structure

3.1.1 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.

3.1.2 Connection to the deck of corners of superstructures and deckhouses is considered by GL on a case-by-case basis. Where necessary, doublers or reinforced welding may be required.

3.1.3 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.

3.1.4 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.

3.2 Arrangement

3.2.1 The accommodation shall be separated from engine rooms, boiler rooms and holds by gastight bulkheads.

3.2.2 The accommodation shall be arranged behind the collision bulkhead.

4. Design loads

4.1 Sides and bulkheads

The lateral pressure to be used for the determination of scantlings of structure of sides and bulkheads of superstructures, deckhouses and machinery casing is to be obtained [kN/m²] from the following formula:

$$p = 2 + p_{WD}$$

p_{WD} = specific wind pressure [kN/m²] defined in Table 6.12.

Table 6.12 Specific wind pressure

Navigation notation	Wind pressure p_{WD} [kN/m²]
IN(1,2) to **IN(2)**	0,4·n
IN(0,6), **IN(0)**	0,25

4.2 Pressure on decks

The pressure on decks is to be defined by the designer and, in general, may not be taken less than the values given in Table 6.13 or Table 6.14.

Table 6.13 Deck pressure in accommodation compartments

Type of accommodation compartment	p [kN/m²]
– Large spaces, such as: restaurants, halls, cinemas, lounges, kitchen, service spaces, games and hobbies rooms, hospitals	4,0
– Cabins	3,0
– Other compartments	2,5

Table 6.14 Pressure on exposed decks

Exposed deck location	p [kN/m²]
– First tier (non-public)	2,0
– Upper tiers (non-public)	1,5
– Public	4,0

Local reinforcements are to be provided in way of areas supporting cars or ladders.

5. Scantlings

5.1 Net scantlings

All scantlings referred to in the following are net scantlings, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Section 2, B.6.

5.2 Scantling requirements

5.2.1 General

GL may request additional arrangements deemed necessary in order to keep the level of stresses liable to occur in the superstructure structural members within acceptable limits.

5.2.2 Superstructures and deckhouses not contributing to the longitudinal strength

The net scantlings of superstructures and deckhouses not contributing to the longitudinal strength are to be derived from formulae given in Table 6.15.

5.2.3 Superstructures and deckhouses contributing to the longitudinal strength

The net scantlings of superstructures contributing to the longitudinal strength are to be determined in accordance with Table 6.16 and Table 6.17.

Table 6.15 Net scantlings for non-contributing superstructures

Item	Parameter	Scantling
Plating of sides Plating of aft end bulkheads Plating of non-exposed deck	thickness [mm]	$t = MAX\ (t_1;\ t_2)$ $t_1 = 3{,}5 + 0{,}01 \cdot L \cdot k^{0,5}$ $t_2 = 0{,}8 \cdot s \cdot (k \cdot p)^{0,5}$
Plating of exposed decks Plating of front bulkheads	thickness [mm]	$t = MAX\ (t_1;\ t_2)$ $t_1 = 4 + 0{,}01 \cdot L \cdot k^{0,5}$ $t_2 = 1{,}6 \cdot s \cdot (k \cdot p)^{0,5}$
Longitudinal ordinary stiffeners	section modulus [cm³]	$w = 0{,}4 \cdot p \cdot s \cdot \ell^2$
Other ordinary stiffeners	section modulus [cm³]	$w = k_1 \cdot p \cdot s \cdot \ell^2$
Primary supporting members	section modulus [cm³]	$w = k_1 \cdot p \cdot S \cdot \ell^2$

p = design load defined in 4.
ℓ = span [m] of ordinary stiffeners or primary supporting members
≥ 2,5 m
k_1 = load coefficient:
= 0,58 for horizontal stiffeners
= $0{,}58 + 0{,}1 \cdot n_t$ for vertical stiffeners
n_t = number of tiers above the tier considered

Table 6.16 Plating net thickness for contributing superstructures

Item	Framing system	Scantling
Side plating	Transverse framing	$t = MAX(t_i)$ $t_1 = 1{,}68 + 0{,}025 \cdot L \cdot k^{0{,}5} + 3{,}6 \cdot s$ $t_2 = 1{,}6 \cdot s \cdot (k \cdot p)^{0{,}5}$
	Longitudinal framing	$t = MAX(t_i)$ $t_1 = 1{,}25 + 0{,}02 \cdot L \cdot k^{0{,}5} + 3{,}6 \cdot s$ $t_2 = 1{,}2 \cdot s \cdot (k \cdot p)^{0{,}5}$
Deck plating	Transverse framing	$t = MAX(t_i)$ for exposed decks $t_1 = 4 + 0{,}01 \cdot L \cdot k^{0{,}5}$ for non-exposed decks $t_1 = 3{,}5 + 0{,}01 \cdot L \cdot k^{0{,}5}$ $t_2 = 1{,}6 \cdot s \cdot (k \cdot p)^{0{,}5}$ $t_3 = 74 \cdot \frac{s}{k_2} \cdot \sqrt{\frac{\psi \cdot M_S}{Z_D}}$ if $t_3 / s > 23{,}9 / (k^{0{,}5} \cdot k_2)$: $t_3 = \frac{7{,}76 \cdot k^{0{,}5} \cdot s}{k_2 \cdot \sqrt{0{,}21 - \frac{\psi \cdot M_S}{Z_D}}}$ see [1]
	Longitudinal framing	$t = MAX(t_i)$ $t_1 = 0{,}57 + 0{,}031 \cdot L \cdot k^{0{,}5} + 3{,}6 \cdot s$ $t_2 = 1{,}2 \cdot s \cdot (k \cdot p)^{0{,}5}$ $t_3 = 39 \cdot s \cdot \sqrt{\frac{\psi \cdot M_S}{Z_D}}$ see [1]
Plating of end bulkheads	all	$t = MAX(t_i)$ $t_1 = 3{,}5 + 0{,}01 \cdot L \cdot k^{0{,}5}$ $t_2 = 1{,}6 \cdot s \cdot (k \cdot p)^{0{,}5}$
Plating of front bulkheads	all	$t = MAX(t_i)$ $t_1 = 4 + 0{,}01 \cdot L \cdot k^{0{,}5}$ $t_2 = 1{,}6 \cdot s \cdot (k \cdot p)^{0{,}5}$

p = design load defined in 4.
k_2 = coefficient
 = $1 + \alpha^2$
α = b_2 / b_1
b_1 = unsupported deck width in y direction [m]
b_2 = unsupported deck width in x direction [m]
Z_D = net hull girder section modulus at deck level [cm^3]
M_S = design bending moment [kNm] in sagging condition
ψ = superstructure efficiency defined in the GL Additional Requirements for Notations (I-2-4), Section 2, D.8.1.1 and 8.1.2

[1] A lower value of thickness t_3 may be accepted if in compliance with the buckling analysis carried out according to Section 2, C.

Table 6.17 Structural member net scantlings for contributing superstructures

Item	w	A_{sh}
Longitudinal ordinary stiffeners	$w = \dfrac{83,3}{214 - \psi \cdot \sigma_1} p \cdot s \cdot \ell^2$	$A_{sh} = 0,045 \cdot p \cdot s \cdot \ell$
Other ordinary stiffeners	$w = k_1 \cdot p \cdot s \cdot \ell^2$	
Longitudinal primary supporting members	$w = \dfrac{125}{(14 - \psi \cdot \sigma_1)} \cdot p \cdot S \cdot \ell^2$	$A_{sh} = 0,045 \cdot p \cdot S \cdot \ell$
Other primary supporting members	$w = 0,58 \cdot p \cdot S \cdot \ell^2$	

σ_1 = hull girder normal stress [N/mm²]
Ψ = superstructure efficiency defined in the GL Additional Requirements for Notations (I-2-4), Section 2, D.8.1.1 and 8.1.2
For other symbols, see definitions in Table 6.15.

6. Additional requirements applicable to movable wheelhouses

6.1 General

6.1.1 The structures of movable wheelhouse are to be checked in low and high position.

6.1.2 Mechanical locking devices are to be fitted in addition to hydraulic systems.

6.1.3 The supports or guide of movable wheelhouses, connections with the deck, under deck reinforcements and locking devices are to be checked considering loads due to list and wind action defined in the GL Additional Requirements for Notations (I-2-4), Section 2, D.6.4 and, eventually, inertial loads defined in the Additional Requirements for Notations (I-2-4), Section 2, D.6.5

6.1.4 The safety of persons on board is to be guaranteed in any position of the wheelhouse. The wheelhouse can be fixed in different positions along the vertical axis.

Movements of the wheelhouse are to be signalled by optical and acoustic means.

6.1.5 In the case of emergency it should be possible to lower the wheelhouse by means independent of the power drive. Emergency lowering of the wheelhouse is to be effected by its own weight and is to be smooth and controllable. It should be possible from both inside and outside the wheelhouse and can be effected by one person under all conditions.

6.2 Arrangement

6.2.1 The hoisting mechanism is to be capable to hoist at least 1,5 times the weight of the wheelhouse fully equipped and manned.

6.2.2 The feed cables for systems inside the wheelhouse are to be arranged in such a way as to exclude the possibility of mechanical damage to them.

7. Elastic bedding of deckhouses

7.1 General

7.1.1 The structural members of elastically bedded deckhouses may, in general, be dimensioned in accordance with 5.

7.1.2 Strength calculations for the load bearing rails, elastic elements and antilift-off devices as well as for supporting structure of the deckhouse bottom and the hull are to be carried out assuming the following loads:

– vertical:

$P = 1,2 \cdot G$

– horizontal:

$P = 0,3 \cdot G$

G = total weight of the complete deckhouse, outfit and equipment included

Additional loads due to vessel's heel need not be considered, in general.

E. Hatch Covers

1. Symbols

L = Rule length [m] defined in Section 1, A.1.

t = net thickness [mm]

s = spacing of ordinary stiffeners [m]

S = spacing of primary supporting members [m]

m = boundary coefficient for ordinary stiffeners and primary supporting members

= 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

= 12 in the case of ordinary stiffeners and primary supported members clamped at both ends w = net section modulus [cm^3], of ordinary stiffeners or primary supporting members

A_{sh} = net web sectional area [cm^2]

k = material factor defined in Section 2, A.2.4 and Section 2, A.3.2

P = hatchway design load [kN/m^2]

n = navigation coefficient defined in Section 3, B.

= 0,85·H

H = significant wave height [m]

2. General

2.1 Application

2.1.1 The following requirements apply to hatchways which are closed with self-bearing hatchcovers. These are to bear on coamings.

2.1.2 Hatch covers supported by hatchway beams and other supporting systems are to be considered by GL on a case-by-case basis. In any case, they are to ensure the same degree of strength and weathertightness.

2.1.3 These Rules do not cover the classification of vessels with range of navigation **IN(0)**, for which however the Rules applicable to the range of navigation **IN(0,6)** may be used.

2.2 Definitions

2.2.1 Weathertightness

Weathertightness is ensured when, for all the navigation conditions envisaged, the closing devices are in compliance with the GL Additional Requirements for Notations (I-2-4), Section 4, F.2.2.7.

Systems to ensure the weathertightness are mentioned in 3.3.

2.2.2 Watertightness

Watertightness is ensured when, for all the navigation conditions envisaged, the closing devices are in compliance with the GL Additional Requirements for Notations (I-2-4), Section 4, F.2.2.8.

2.3 Materials

Hatch covers are to be made of steel or aluminium alloy. The use of other materials is to be considered by GL on a case-by-case basis.

2.4 Net scantlings

All scantlings referred to in the following are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Section 2, B.6.

2.5 Design loads

2.5.1 General

The design loads to be considered for the scantling of hatch covers are, on one hand, the structural weight of the items themselves, and on the other, the expected deck load, if any, defined in 2.5.2.

2.5.2 Hatch covers carrying uniform cargoes

The expected hatch cover load is to be defined by the designer and, in any case, is not to be taken less than:

$$p = MAX\,(1{,}5;\ 6 \cdot n - 1{,}5)$$

3. Arrangements

3.1 Hatch covers on exposed decks

Hatchways on exposed decks are to be fitted with hatchcovers the strength, rigidity and weathertightness of which are to be adequate:

– on vessels assigned the ranges of navigation **IN(1,2)** to **IN(2)**

– on vessels assigned the range of navigation **IN(0,6)** on which the height of the hatch coaming above the deck [m], h_C, is such that:

$$D + h_C > T + n / 1{,}7 + 0{,}15$$

3.2 Hatch covers in closed superstructures

Hatch covers in closed superstructures need not to be weathertight.

However, hatch covers fitted in way of ballast tanks, fuel oil tanks or other tanks are to be watertight.

3.3 Weathertightness of hatch covers

The hatch cover tightness is not subjected to test.

Tightness may be obtained by fitting of flanged metal hatch covers which constitute baffles intended to prevent water penetrating into the hold below.

Hatch covers are to have a mean slope of not less than 0,1, unless they are covered by tarpaulins. Where tarpaulins are fitted, they are to have adequate characteristics of strength and weathertightness. The tarpaulin is to be secured by means of batten, cleats and wedges.

3.4 Securing of hatch covers

The positioning and securing of hatch covers are to be ensured by supports or guides of efficient construction. Where broaches or bolts are used, their diameter is to be such that the mean shearing stress, under the action of the loads mentioned in 2.5, does not exceed 44 N/mm^2.

Efficient arrangements are to be made to prevent unexpected displacement or lifting of the hatchcovers.

3.5 The width of each bearing surface for hatch covers is to be at least 65 mm.

3.6 Hatch covers carrying containers

The design, construction and arrangement of hatch covers carrying containers are to be in compliance with the GL Additional Requirements for Notations (I-2-4), Section 2, B.

3.7 Hatch covers carrying wheeled loads

The design, construction and arrangement of hatch covers carrying wheeled loads are to be in compliance with the GL Additional Requirements for Notations (I-2-4), Section 2, C.

4. Scantlings

4.1 Application

The following scantling rules are applicable to rectangular hatch covers subjected to a uniform pressure.

In the case of hatch covers arranged with primary supporting members as a grillage, the scantlings are to be determined by direct calculations.

4.2 Plating of hatch covers

4.2.1 Minimum net thickness of steel hatch covers

In any case, the thickness of steel hatch covers is not to be less than:

– galvanized steel: 2 mm

– other cases: 3 mm.

4.2.2 Net thickness of metal hatch covers

The net thickness of metal hatch covers subjected to lateral uniform load is not to be less than:

$$t = 1,2 \cdot s \cdot \sqrt{k \cdot p}$$

nor than the thickness derived from the following formulae:

– for **IN(1,2)** to **IN(2)**:

$$t = 4,9 \cdot s \cdot \sqrt[3]{k^{1,5} \cdot (1 + 0,34 \cdot p)}$$

– for **IN(0,6)**:

$$t = 3,4 \cdot s \cdot \sqrt[3]{k^{1,5} \cdot (1 + p)}$$

4.3 Stiffening members of self-bearing hatch covers

4.3.1 Width of attached plating

The width of the attached plating is to be in compliance with Section 2, B.4.3 or Section 2, B.5.2 as applicable.

4.3.2 Minimum web thickness

The minimum thickness of the web of the stiffeners [mm] is to be not less than the thickness of the plating of the hatch covers, given in 4.2.

4.3.3 Section modulus and shear sectional area

The net section modulus w [cm^3] and the net shear sectional area A_{sh} [cm^2] of self-bearing hatchcover ordinary stiffeners and primary supporting members are not to be less than those obtained from the following formulae:

$$w = 4,6 \cdot k \cdot \frac{p}{m} \cdot a \cdot \ell^2$$

$$A_{sh} = 0,045 \cdot k \cdot p \cdot a \cdot \ell$$

a = Stiffener spacing [m]

= s for ordinary stiffeners

= S for primary supporting members

F. Movable Decks and Ramps

1. Movable decks and inner ramps

1.1 Materials

The movable decks and inner ramps are to be made of steel or aluminium alloys complying with the requirements of Chapter 4. Other materials of equivalent strength may be used, subject to a case-by-case examination by GL.

1.2 Net scantlings

As specified in Section 2, B.6. all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are to be obtained as specified in Section 2, B.6.

1.3 Plating

The net thickness of plate panels subjected to wheeled loads is not to be less than the value obtained from the GL Additional Requirements for Notations (I-2-4), Section 2, C.3.2, where ($n_P \cdot F$) is not to be taken less than 50 kN.

n_P = number of wheels on the plate panel, taken equal to:

= 1 in the case of a single wheel

= the number of wheels in the case of double or triple wheels

F = wheeled force [kN]

1.4 Ordinary stiffeners

The net section modulus and the net shear sectional area of ordinary stiffeners subjected to wheeled loads are not to be less than the value obtained from GL Additional Requirements for Notations (I-2-4), Section 2, C.3.3.1

1.5 Primary supporting members

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 in navigation conditions

– movable deck in service, loaded, in lower position, resting on supports or supporting legs and locked in navigation conditions

– 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, in navigation conditions

1.5.2 Loading cases

The scantlings of the structure are to be verified in both navigation and harbour conditions for the following cases:

– loaded movable deck or inner ramp under loads according to the load distribution indicated by the designer

– loaded movable deck or inner ramp under uniformly distributed loads corresponding to a pressure [kN/m^2] taken equal to:

$$p_1 = \frac{n_V \cdot P_V + P_P}{A_P}$$

– empty movable deck under uniformly distributed masses corresponding to a pressure [kN/m^2] taken equal to:

$$p_0 = \frac{P_P}{A_P}$$

n_V = maximum number of vehicles loaded on the movable deck or inner ramp

P_V = weight of a vehicle [kN]

P_P = weight of the movable deck or inner ramp [kN]

A_P = effective area of the movable deck or inner ramp [m^2]

1.5.3 Lateral pressure

The lateral pressure is constituted by still water pressure and inertial pressure. The lateral pressure is to be obtained [kN/m^2] from the following formula:

$$p = p_S + 1{,}10 \cdot p_W$$

p_S, p_W = still water and inertial pressures transmitted to the movable deck or inner ramp structures, obtained [kN/m^2] from Table 6.18.

1.5.4 Checking criteria

It is to be checked that the combined stress σ_{VM} [N/mm^2] is in compliance with the criteria defined in Section 2, E.3.3.3.

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} [N/mm^2] in rigid supports and locking devices is in compliance with the criteria defined in Section 2, E.3.4.

1.7 Tests and trials

1.7.1 Tests and trials are to be carried out in the presence of the Surveyor, in compliance with GL Rules.

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 net thicknesses of plating and the net scantlings of ordinary stiffeners and primary supporting members are to be determined under vehicle loads in harbour condition, at rest, as defined in Table 6.18.

2.1.3 The external ramps are to be examined for their watertightness, if applicable.

2.1.4 The locking of external ramps in stowage position in navigation conditions is examined by GL on a case-by-case basis.

2.1.5 The vessel's structure under the reactions due to the ramp is examined by GL on a case-by-case basis.

Table 6.18 Movable decks and inner ramps - still water and inertial pressures

Vessel condition	Load case	Still water pressure p_S and inertial pressure p_W [kN/m^2]	
Still water condition		$p_S = p_0$ in harbour condition during lifting $p_S = p_1$ in other cases	
Upright navigation condition		$p_{W,X} = 0{,}1 \cdot a_{X1} \cdot p_1$ $p_{W,Z} = 0{,}1 \cdot a_{Z1} \cdot p_1$	in x direction in z direction
Inclined navigation condition		$p_{W,Y} = 0{,}07 \cdot a_{Y2} \cdot p_1$ $p_{W,Z} = 0{,}07 \cdot a_{Z2} \cdot p_1$	in y direction in z direction
Harbour condition [1]	during lifting	$p_{W,X} = 0{,}035 \cdot p_0$ $p_{W,Y} = 0{,}087 \cdot p_0$ $p_{W,Z} = 0{,}200 \cdot p_0$	in x direction in y direction in z direction
	at rest	$p_{W,X} = 0{,}035 \cdot p_1$ $p_{W,Y} = 0{,}087 \cdot p_1$ $p_{W,Z} = 0{,}100 \cdot p_1$	in x direction in y direction in z direction

[1] For harbour conditions, a heel angle of 5° and a trim angle of 2° are taken into account.

p_0, p_1 = pressures [kN/m^2] to be calculated according to 1.5.2 for the condition considered

a_{X1}, a_{Z1}, a_{Y2}, a_{Z2} = reference values of the accelerations defined in Section 3, C., Table 3.5.

G. Arrangements for Hull and Superstructure Openings

1. Symbols

L = Rule length [m] defined in Section 1, A.1

B = breadth [m] defined in Section 1, A.1.

D = depth [m] defined in Section 1, A.1.

T = draught [m] defined in Section 1, A.1.

n = navigation coefficient defined in Section 3, B.

= 0,85 · H

H = significant wave height [m] defined in Section 3, B.

2. Side shell openings

2.1 General

Openings in the vessel's sides, e.g. for cargo ports, are to be well rounded at the corners and located well clear of superstructure ends or any openings in the deck areas at sides of hatchways.

2.2 Arrangement

2.2.1 Shell plating openings

Openings are to be compensated if their edge is less than 0,25·D from the bottom or from the deck and if all these openings are located over 0,25·L from either end perpendicular.

Compensation is not required for circular openings having a diameter at most equal to 300 mm.

2.2.2 Openings for water intakes

Openings for water intakes are to be well rounded at the corners and, within 0,6·L amidships, located outside the bilge strakes. Where arrangements are such that water intakes are unavoidably located in the curved zone of the bilge strakes, such openings are to be elliptical with the major axis in the longitudinal direction.

2.2.3 Other openings

Other openings are considered by GL on a case-by-case basis.

2.2.4 Sheerstrake openings

Circular openings on the sheerstrake need not be compensated where their diameter does not exceed 20 % of the sheerstrake minimum width, and where they are located away from openings on deck at the side of hatchways or superstructure ends.

2.3 Strengthening

Openings in 2.2 and, when deemed necessary by GL, other openings of considerable size, are to be compensated by means of insert plates or doublers sufficiently extended in length. Such compensation is to be partial or total depending on the stresses occurring in the area of the openings.

3. Deck openings

3.1 Openings in the strength deck

Openings in the strength deck are to be kept to a minimum and spaced as far apart from one another and from breaks of effective superstructures as practicable. Openings are to be cut as far as practicable from hatchway corners.

Stringer plate cut-outs situated in the cargo hold space of open deck vessels are to be strengthened by means of plates having an increased thickness or by means of doubling plates. This is not applicable to scupper openings.

3.1.1 In case of flush deck vessels, no compensation is required where the openings are:

– circular of less than 350 mm in diameter and at a distance, sufficiently far, from any other opening

– elliptical with the major axis in the longitudinal direction and the ratio of the major to minor axis not less than 2.

4. Cargo hatchways on open deck vessels

4.1 Corners of hatchways

The corners of hatchways are recommended to be rounded.

In any case, continuity is to be ensured by means of brackets and extended girders.

4.2 Deck strengthening in way of hatch corners

4.2.1 Plating thickness in way of the corners

The deck plating where the hatchways form corners is to have:

– twice the thickness of the stringer plate over 0,5·L amidships

– the same thickness as the stringer plate over 0,15·L at the ends of the vessel

As an alternative for small hatch openings, the deck plating may be strengthened by a doubling plate having the same thickness as the stringer plate.

4.2.2 The area of strengthened plating is to extend over twice the actual stringer plate width on either side of the hatch end and, if necessary, beyond the transverse bulkheads of passenger and crew accommodation if the floor of these cabins is not level with the upper deck.

4.2.3 The strengthenings referred to herebefore may be partly or wholly dispensed with if the hatch coamings blend with the longitudinal bulkheads of the accommodation located beyond the hatchway, thus ensuring longitudinal strength continuity in that region.

4.3 Coamings on open deck vessels

4.3.1 Scantling and stiffening

See Section 5, D., deck scantlings.

4.3.2 Cut-outs

Where there are cut-outs in the coaming upper part to make way for the hatchway beams, the edges of the cut-outs are to be carefully rounded and a doubling plate or a plate with an increased thickness is to be provided to ensure adequate bearing capability of the hatchway beams.

4.3.3 Extension and strength continuity

Longitudinal coamings are to be extended under the deck. In the case of single hull vessels, the longitudinal coaming extension is to be bent under the brackets to which it is connected.

It is recommended to extend the part of the hatch coaming which is located above deck and to connect it to the side bulkheads of the accommodation spaces.

At the end of large-size hatchways, strength continuity of the top structure is to be ensured. This is to be arranged by extending the deck girders beyond the hatchways over two frame spacings or over a distance equal to the height of the hatch coaming.

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 up to the next deck girder.

5. Cargo hatchways on flush deck vessels

5.1 Corners of hatchways

5.1.1 Hatchways are to be rounded at their corners. The radius of circular corners is to be not less than:

– 5 % of the hatch width, where a continuous longitudinal deck girder is fitted below the hatch coaming

– 8 % of the hatch width, where no continuous longitudinal deck girder is fitted below the hatch coaming

Corner radiusing, in the case of the arrangement of two or more hatchways athwartships, is considered by GL on a case-by-case basis.

5.1.2 Elliptical and parabolic corners

Strengthening by insert plates in the cargo area are, in general, not required in way of corners where the plating cutout has an elliptical or parabolic profile and the half axis of elliptical openings, or the half lengths of the parabolic arch, are not less than:

– 1/20 of the hatchway width or 600 mm, whichever is the lesser, in the transverse direction

– twice the transverse dimension, in the fore and aft direction

5.2 Deck strengthening in way of hatch corners

The deck plating where the hatchways form corners, is to be increased by 60 % with respect to the adjacent plates. As an alternative, the deck plating may be strengthened by a doubling plate having the same thickness.

A lower thickness may be accepted by GL on the basis of calculations showing that stresses at hatch corners are lower than permissible values.

5.3 Coamings on flush deck vessels

5.3.1 Scantling and stiffening

See Section 5, D., deck scantlings.

The edges of cut-outs are to be carefully rounded.

5.3.2 Extension and strength continuity

The lower part of longitudinal coamings are to extend to the lower edge of the nearest beams to which they are to be efficiently secured.

In case of girders fitted under deck or under beams in the plane of the coaming longitudinal sides, strength continuity is to be ensured by means of suitable shifting. The same applies in case of strengthened beams in the plane of the coaming transverse boundaries.

5.3.3 Vertical brackets or stays

Where necessary, the coaming boundaries are to be stiffened with stays, as mentioned in Section 5, D.4.3.5.

5.4 Small hatches

5.4.1 The following requirements apply to small hatchways with a length and width of not more than 1,2 m.

5.4.2 In case of small hatches, no brackets are required.

Small hatch covers are to have strength equivalent to that required for main hatchways. In any case, weathertightness is to be maintained.

5.4.3 The sill's upper edge is neither to be less than 0,15 m above the deck nor than (n/1,7 + 0,15) m above the load waterline.

5.4.4 Access openings to cofferdams and ballast tanks shall be of the manhole type, fitted with watertight covers fixed with bolts which are closely spaced, and are to be in accordance with a recognized standard, e.g. ISO 5894.

5.4.5 Manholes and flush scuttles exposed to the weather 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.

5.4.6 Hatchways of special design are considered by GL on a case-by-case basis.

6. Side scuttles, windows and skylights

6.1 Definition

6.1.1 Side scuttles are round or oval openings with an area not exceeding 0,16m^2. Round or oval openings having areas exceeding 0,16m^2 are to be treated as windows.

6.1.2 The safety range is equivalent to the significant wave height H to be deducted from the uppermost load line, but at least up to the bulkhead deck.

6.2 Requirements

6.2.1 Side scuttles shall be built and tested in accordance with ISO 1751.

6.2.2 Windows shall be built and tested in accordance with ISO 3903.

6.2.3 Skylights of fixed or opening type are to have a glass thickness appropriate to their size and position, as required for windows and side scuttles.

Skylight glasses are to be protected from mechanical damage if they can be damaged by e.g. loading operations.

6.2.4 Alternative constructions to the standards mentioned above shall be of equivalent and approved design.

6.2.5 Toughened safety glass pane (ESG) or laminated safety glass (VSG) is to be used, in accordance with ISO 21005.

6.2.6 In case of glued glass panes the GL Guidelines for Elastomeric Adhesives and Adhesive Joints (II-2-3) shall be observed.

6.3 Arrangement

6.3.1 Windows and side scuttles fitted in the side shell below the bulkhead deck shall be watertight and of the non-opening type and in accordance with ISO 3903 (type E) or ISO 1751 (type B), each to be provided with a permanently attached inside deadlight.

Windows and side scuttles in the shell are to be adequately protected against direct contact by efficient fenders or are to be recessed into the shell.

Deadlights are not required on ships with the service range **IN(0)** and **IN(0,6)**.

6.3.2 Windows, side scuttles and skylights situated above the bulkhead deck with their lower glass edges within the safety range defined in 6.1.2 shall be watertight and of the non-opening type.

If they do not protect a direct access leading below bulkhead deck, or are provided with a sill of at least

0.15 m, they shall be weathertight and may be of the opening type.

6.3.3 The examination of windows, side scuttles and skylights located above the range defined in 6.1.2 is no matter of class – except for windows according to 6.3.4.

6.3.4 Windows used for protection against falling down, e.g. windscreens or full-height windows, shall be shown to have equivalent strength against the loads as provided by EN 711. For these windows, laminated safety glass (VSG) or heat-soak-tested toughened safety glass (ESG-H) shall be used.

6.4 Glass thickness

6.4.1 The thickness of toughened safety glass in side scuttles is to be neither less than 6 mm nor less than the value [mm] obtained from the following formula:

$$t = \frac{d}{358} \cdot \sqrt{p}$$

d = side scuttle diameter [mm]

p = lateral pressure [kN/m^2] defined in Section 3, C.4. for vessel hull or in D.3. for superstructures and deckhouses.

6.4.2 Thickness of toughened glasses in rectangular windows

The thickness of toughened glasses in rectangular windows is neither to be less than 6 mm nor less than the value [mm] obtained from the following formula:

$$t = \frac{b}{200} \cdot \sqrt{\beta \cdot p}$$

p = lateral pressure [kN/m^2] defined in 6.4

β = coefficient defined in Table 6.19. β may be obtained by linear interpolation for intermediate values of a / b

a = length [mm] of the longer side of the window

b = length [mm] of the shorter side of the window

Table 6.19 Coefficient β

a/b	β
1,0	0,284
1,5	0,475
2,0	0,608
2,5	0,684
3,0	0,716
3,5	0,734
≥ 4,0	0,750

6.5 Miscellaneous

6.5.1 National statutory rules and regulations are to be observed, as far as applicable.

6.5.2 Required tests have to be carried out in the presence and to the satisfaction to our surveyor.

6.5.3 GL 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.

7. Scuppers and discharges

7.1 Material

The scuppers and discharge pipes are to be constructed of steel. Other equivalent materials are considered by GL on a case-by-case basis.

7.2 Wall thickness

The wall thickness of scuppers and discharge pipes is to be not less than the shell plating thickness in way of the scuppers, respectively discharge pipes, but needs not exceed 8 mm.

8. Freeing ports

8.1 General provisions

Where bulwarks on weather decks form wells, provisions are to be made for rapidly freeing the decks of water and draining them.

A well is any area on the deck exposed to the weather, where water may be entrapped.

9. Machinery space openings

9.1 Closing devices

Openings in machinery space casings are to be surrounded by a steel casing of efficient construction. The openings of the casings exposed to the weather are to be fitted with strong and weathertight doors.

9.2 Position of openings

The height [m] of the lower edge of the opening above the load waterline is not to be less than n/1,7.

9.3 Entrances

The height [m] of entrances to machinery space, h_C, above the deck is not to be less than the values given in Table 6.20.

Furthermore, this height, h_C, above the deck is to be such that:

$$D + h_C > T + n / 1,7 + 0,15$$

Table 6.20 Height of machinery space entrance

Vessel type	Significant wave height, H [m]	h_C [m]
Carriage of dangerous goods	$0 \le H \le 2$	0,5
Other vessels	$H \le 1,2$	0,3
	$H > 1,2$	0,5

10. Companionway

10.1 Companionway

Companions leading under the freeboard deck are to be protected by a superstructure or closed deckhouse, or by a companionway having equivalent strength and tightness.

10.2 Companionway sill height

In vessels assigned the range of navigation **IN(0)**, the companion sill height, above the deck, h_C, is not to be less than 0,05 m.

In other vessels, the sill upper edge is neither to be less than 0,15 m above the deck nor less than (n/1,7 + 0,15) m above the load waterline.

11. Ventilators

11.1 General

11.1.1 Ventilator openings below main deck are to have coamings of steel or other equivalent material, substantially constructed and efficiently connected to the deck.

11.1.2 Coamings

In vessels assigned the range of navigation other than **IN(0)**, the coaming height, above the deck, h_C, is not to be less than 0,3 m.

Furthermore, this height, h_C, above the deck is to be such that:

$$D + h_C > T + n / 1,7 + 0,15$$

Section 7

Hull Outfitting

A. Rudders

1. Symbols

L = Rule length [m] defined in Section 1, A.1.

B = breadth [m] defined in Section 1, A.1.

D = depth [m] defined in Section 1, A.1.

T = draught [m] defined in Section 1, A.1.

n = navigation coefficient defined in Section 3, B.

= $0{,}85 \cdot H$

H = significant wave height [m]

V_{AV} = maximum ahead service speed [km/h] at maximum draught T; this value is not to be taken less than 8

V_{AD} = maximum astern speed [km/h] to be taken not less than $0{,}5 \cdot V_{AV}$

A = total area of the rudder blade [m^2] bounded by the blade external contour, including the main piece and the part forward of the centreline of the rudder pintles, if any

k_1 = material factor, defined in 2.4.3

k = material factor, defined in Section 2, A.2.4 (see also 2.4.5)

C_R = rudder force [N] acting on the rudder blade, defined in 3.1.2

M_{TR} = rudder torque [N·m] acting on the rudder blade, defined in 3.1.3

M_B = bending moment [N·m] in the rudder stock, defined in 5.1

2. General

2.1 Application

2.1.1 Ordinary profile rudders

The following requirements apply to ordinary profile rudders, without any special arrangement for increasing the rudder force, whose maximum orientation at maximum vessel speed is limited to 35° on each side.

In general, an orientation greater than 35° is accepted for manoeuvres or navigation at very low speed.

2.1.2 High lift profiles

The following requirements also apply to rudders fitted with flaps to increase rudder efficiency. For these rudder types, an orientation at maximum speed greater than 35° may be accepted. In these cases, the rudder forces are to be calculated by the designer for the most severe combinations between orientation angle and vessel speed. These calculations are to be considered by GL on a case-by-case basis.

The rudder scantlings are to be designed so as to be able to sustain possible failures of the orientation control system, or, alternatively, redundancy of the system itself may be required.

2.1.3 Steering nozzles

The requirements for steering nozzles are given in 9.

2.1.4 Special rudder types

Rudders others than those in 2.1.1, 2.1.2 and 2.1.3 will be considered by GL on a case-by-case basis.

2.2 Gross scantlings

With reference to Section 2, B.6., all scantlings and dimensions referred to in the following are gross, i.e. they include the margins for corrosion.

2.3 Arrangements

2.3.1 Effective means are to be provided for supporting the weight of the rudder without excessive bearing pressure, e.g. by means of a rudder carrier attached to the upper part of the rudder stock. The hull structure in way of the rudder carrier is to be suitably strengthened.

2.3.2 Suitable arrangements are to be provided to prevent the rudder from lifting.

2.3.3 The rudder stock is to be carried through the hull either enclosed in a watertight trunk or with glands to be fitted above the deepest load waterline, so as to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier. If the top of the rudder trunk is below the deepest waterline, two separate stuffing boxes are to be provided.

2.3.4 The steering system as a whole has to be designed for a permanent heeling of up to 15° and ambient temperatures from –20 °C to +50 °C.

2.4 Materials

2.4.1 Rudder stocks, pintles, coupling bolts, keys and cast parts of rudders are to be made of rolled steel, steel forgings or steel castings according to the applicable GL Rules for Materials.

2.4.2 The material used for rudder stocks, pintles, keys and bolts is to have a minimum yield stress not less than 200 N/mm^2.

2.4.3 The requirements relevant to the determination of scantlings contained in the following apply to steels having a minimum yield stress equal to 235 N/mm^2.

Where the material used for rudder stocks, pintles, coupling bolts, keys and cast parts of rudders has a yield stress different from 235 N/mm^2, the scantlings calculated with the formulae contained in the requirements are to be modified, as indicated, depending on the material factor k_1, to be obtained from the following formula:

$$k_1 = \left(\frac{235}{R_{eH}}\right)^{n_1}$$

R_{eH} = yield stress [N/mm^2], of the steel used, and not exceeding the lower of 0,7 R_m and 450 N/mm^2

R_m = minimum ultimate tensile strength [N/mm^2], of the steel used

n_1 = coefficient to be taken equal to:

= 0,75 for $R_{eH} > 235$ N/mm^2

= 1,00 for $R_{eH} \le 235$ N/mm^2

2.4.4 Significant reductions in rudder stock diameter due to the application of steels with yield stresses greater than 235 N/mm^2 may be accepted by GL subject to the results of a check calculation of the rudder stock deformations.

Large rudder stock deformations are to be avoided in order to avoid excessive edge pressures in way of bearings.

2.4.5 Welded parts of rudders are to be made of approved rolled hull materials. For these members, the material factor k defined in Section 2, A.2.4 is to be used.

3. Force and torque acting on the rudder

3.1 Rudder blade

3.1.1 Rudder blade description

A rudder blade may have trapezoidal or rectangular contour.

3.1.2 Rudder force

The rudder force C_R is to be obtained [N] from the following formula:

$$C_R = 28{,}86 \cdot (1 + n)^{0{,}15} A \cdot V^2 \cdot r_1 \cdot r_2 \cdot r_3$$

V = V_{AV}, or V_{AD}, depending on the condition under consideration (for high lift profiles see 2.1.2)

r_1 = shape factor, to be taken equal to:

$$r_1 = \frac{\lambda + 2}{3}$$

λ = coefficient, to be taken equal to:

$$\lambda = \frac{h^2}{A_T}$$

and not greater than 2

h = mean height [m], of the rudder area to be taken equal to (see Fig. 7.1)

$$= \frac{z_3 + z_4 - z_2}{2}$$

A_T = area [m^2] to be calculated by adding the rudder blade area A to the area of the rudder post or rudder horn, if any, up to the height h

r_2 = coefficient to be obtained from Table 7.1

r_3 = coefficient

= 0,8 for rudders outside the propeller jet (centre rudders on twin screw vessels, or similar cases)

= 1,15 for rudders behind a fixed propeller nozzle

= 1,0 in other cases

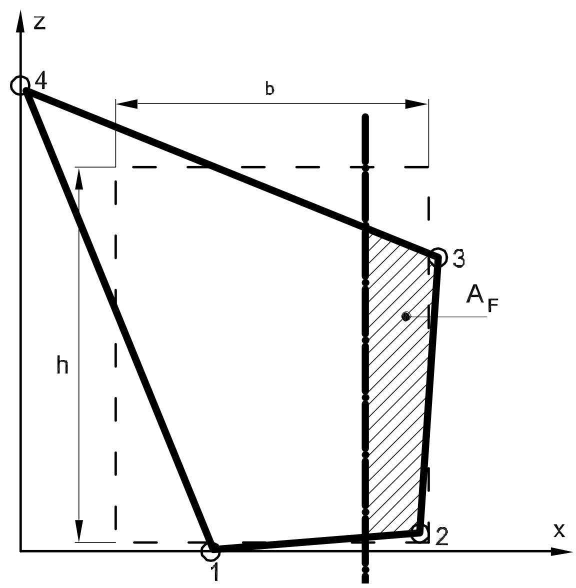
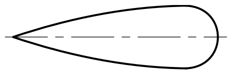
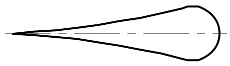
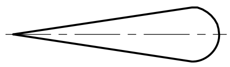
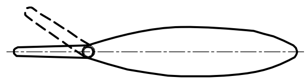
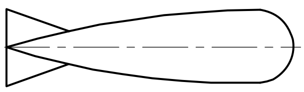
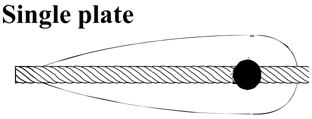


Fig. 7.1 Geometry of rudder blade without cut-outs

Table 7.1 Values of coefficient r_2

Rudder profile type	r_2 for ahead condition	r_2 for astern condition
NACA 00 – Goettingen 	1,10	0,80
Hollow 	1,35	0,90
Flat side 	1,10	0,90
High lift 	1,70	1,30
Fish tail 	1,40	0,80
Single plate 	1,00	1,00

3.1.3 Rudder torque

The rudder torque M_{TR}, for both ahead and astern conditions, is to be obtained [N·m] from the following formula:

$$M_{TR} = C_R \cdot r$$

r = lever of the force C_R [m], equal to:

$$r = b \cdot \left(\alpha - \frac{A_F}{A} \right)$$

and to be taken not less than 0,1·b for the ahead condition

b = mean breadth [m], of rudder area (see Fig. 7.1)

$$= \frac{x_2 + x_3 - x_1}{2}$$

α = coefficient

= 0,33 for ahead condition

= 0,66 for astern condition

A_F = area [m²], of the rudder blade portion in front of the centreline of rudder stock (see Fig. 7.1)

4. Rudder stock scantlings

4.1 Rudder stock diameter

4.1.1 Rudder stock subjected to torque only

For rudder stocks subjected to torque only, the diameter is to be not less than the value obtained [mm], from the following formula:

$$d_T = 4{,}2 \cdot (M_{TR} \cdot k_1)^{1/3}$$

4.1.2 Rule stock diameter

The rudder stock diameter, at the lower part, is to be not less than the value obtained [mm], from the following formula:

$$d_{TF} = 4{,}2 \cdot \left(M_{TR} \cdot k_1\right)^{1/3} \cdot \left[1 + \frac{4}{3} \cdot \left(\frac{M_B}{M_{TR}}\right)^2\right]^{1/6}$$

M_B = maximum absolute value of bending moment M_{Bi} over the rudder stock length, to be obtained according to 6.1.

4.1.3 Rule rudder stock diameter in way of the tiller

In general, the diameter of a rudder stock subjected to torque and bending may be gradually tapered above the lower stock bearing so as to reach, from d_{TF} value, the value of d_T in way of the quadrant or the tiller.

5. Rudder stock couplings

5.1 Horizontal flange couplings

5.1.1 General

In general, the coupling flange and the rudder stock are to be forged from a solid piece. A shoulder radius as large as practicable is to be provided for between the rudder stock and the coupling flange. This radius is to be not less than 0,13·d_1, where d_1 is the greater of the rudder stock diameters d_T and d_{TF} [mm] to be calculated in compliance with the requirements in 4.1.

The coupling flange may be welded onto the stock provided that its thickness is increased by 10 %, and that the weld extends through the full thickness of the coupling flange and that the assembly obtained is subjected to heat treatment. This heat treatment is not required if the diameter of the rudder stock is less than 75 mm.

Where the coupling flange is welded, the grade of the steel used is to be of weldable quality, particularly with a carbon content not greater than 0,25 % and the welding conditions are to be defined to the satisfaction of GL. The throat weld at the top of the flange is to be concave shaped to give a fillet shoulder radius as large as practicable.

5.1.2 Bolts

Horizontal flange couplings are to be connected by fitted bolts having a diameter not less than the value obtained [mm] from the following formula:

$$d_B = 0,62 \cdot \sqrt{\frac{d_1^3 \cdot k_{1B}}{n_B \cdot e_M \cdot k_{1S}}}$$

d_1 = rudder stock diameter [mm] defined in 4.1.2

k_{1S} = material factor k_1 for the steel used for the rudder stock

k_{1B} = material factor k_1 for the steel used for the bolts

e_M = mean distance [mm] from the bolt axes to the longitudinal axis through the coupling centre (i.e. the centre of the bolt system)

n_B = total number of bolts, which is to be not less than 6

Non-fitted bolts may be used provided that, in way of the mating plane of the coupling flanges, a key is fitted having a section of $(0,25 \cdot d_T \times 0,10 \cdot d_T)$ [mm^2] and keyways in both the coupling flanges, and provided that at least two of the coupling bolts are fitted bolts.

The distance from the bolt axes to the external edge of the coupling flange is to be not less than $1,2 \cdot d_B$.

5.1.3 Coupling flange

The thickness of the coupling flange is to be not less than the value obtained [mm] from the following formula:

$$t_P = d_B \cdot \sqrt{\frac{k_{1F}}{k_{1B}}}$$

d_B = bolt diameter [mm] calculated in accordance with 5.1.2, where the number of bolts n_B is to be taken not greater than 8

k_{1F} = material factor k_1 for the steel used for the flange

k_{1B} = material factor k_1 for the steel used for the bolts

In any case, the thickness t_P is to be not less than $0,9 \cdot d_B$.

5.1.4 Locking device

A suitable locking device is to be provided to prevent the accidental loosening of nuts.

5.2 Couplings between rudder stocks and tillers

5.2.1 Application

The requirements of this sub-Article apply in addition to those specified in Chapter 3, Section 1, E.4.2.

The requirements specified in 5.2.3 and 5.2.4 apply to solid rudder stocks in steel and to tiller bosses, either in steel or in SG iron, with constant external diameter. Solid rudder stocks others than those above will be considered by GL on a case-by-case basis.

5.2.2 General

The entrance edge of the tiller bore and that of the rudder stock cone are to be rounded or bevelled.

The right fit of the tapered bearing is to be checked before final fit up, to ascertain that the actual bearing is evenly distributed and at least equal to 80 % of the theoretical bearing area; push-up length is measured from the relative positioning of the two parts corresponding to this case.

The required push-up length is to be checked after releasing of hydraulic pressures applied in the hydraulic nut and in the assembly.

5.2.3 Push-up length of cone couplings with hydraulic arrangements for assembling and disassembling the coupling

It is to be checked that the push-up length Δ_E of the rudder stock tapered part into the tiller boss is in compliance with the following formula:

$$\Delta_0 \le \Delta_E \le \Delta_1$$

$$\Delta_0 = 6,2 \cdot \frac{M_{TR} \cdot \eta \cdot \gamma}{c \cdot d_M \cdot t_S \cdot \mu_A \cdot \beta} \cdot 10^{-3}$$

$$\Delta_1 = \frac{2 \cdot \eta + 5}{1,8} \cdot \frac{\gamma \cdot d_0 \cdot R_{eH}}{c} \cdot 10^{-6}$$

η = coefficient

= 1 for keyed connections

= 2 for keyless connections

c = taper of conical coupling measured on diameter, to be obtained from the following formula:

= $(d_U - d_0) / t_S$

t_S, d_U, d_0 = geometrical parameters of the coupling, defined in Fig. 7.2

β = coefficient

$$= 1 - \left(\frac{d_M}{d_E}\right)^2$$

d_M = mean diameter [mm] of the conical bore, to be obtained from the following formula:

$$= d_U - 0{,}5 \cdot c \cdot t_S$$

d_E = external boss diameter [mm]

μ_A = coefficient

$$= \sqrt{\mu^2 - 0{,}25 \cdot c^2}$$

μ, γ = coefficients to be taken equal to:

– for rudder stocks and bosses made of steel:

$\mu = 0{,}15$

$\gamma = 1{,}0$

– for rudder stocks made of steel and bosses made of SG iron:

$\mu = 0{,}13$

$\gamma = 1{,}24 - 0{,}1 \cdot \beta$

R_{eH} = defined in 2.4.3

5.2.4 Boss of cone couplings with hydraulic arrangements for assembling and disassembling the coupling

The scantlings of the boss are to comply with the following formula:

$$\frac{1{,}8}{2 \cdot \eta + 5} \cdot \frac{\Delta_E \cdot c}{\gamma \cdot d_0} \cdot 10^6 \le R_{eH}$$

Δ_E = push-up length adopted [mm]

c, η, γ = defined in 5.2.3

d_0 = defined in Fig. 7.2

R_{eH} = defined in 2.4.3

5.2.5 Cylindrical couplings by shrink fit

It is to be checked that the diametral shrinkage allowance δ_E is in compliance with the following formula:

$$\delta_0 \le \delta_E \le \delta_1$$

$$\delta_0 = 6{,}2 \cdot \frac{M_{TR} \cdot \eta \cdot \gamma}{d_U \cdot t_S \cdot \mu \cdot \beta_1} \cdot 10^{-3}$$

$$\delta_1 = \frac{2 \cdot \eta + 5}{1{,}8} \cdot \gamma \cdot d_U \cdot R_{eH} \cdot 10^{-6}$$

η, μ, γ = defined in 5.2.3

d_U = defined in Fig. 7.2

β_1 = coefficient

$$= 1 - \left(\frac{d_U}{d_E}\right)^2$$

R_{eH} = defined in 2.4.3

5.2.6 Keyless couplings through special devices

The use of special devices for frictional connections, such as expansible rings, may be accepted by GL on a case-by-case basis provided that the following conditions are complied with:

– evidence that the device is efficient (theoretical calculations and results of experimental tests, references of behaviour during service, etc.) is to be submitted to GL

– the torque transmissible by friction is to be not less than $2 \cdot M_{TR}$

– design conditions and strength criteria are to comply with 5.2.1

– instructions provided by the manufacturer are to be complied with, notably concerning the pre-stressing of the tightening screws

5.3 Cone couplings between rudder stocks and rudder blades

5.3.1 Taper on diameter

The taper on diameter of the cone couplings is to be in compliance with the following formulae:

– for cone couplings without hydraulic arrangements for assembling and disassembling the coupling:

$$\frac{1}{12} \le \frac{d_U - d_0}{t_S} \le \frac{1}{12}$$

– for cone couplings with hydraulic arrangements for assembling and disassembling the coupling (assembling with oil injection and hydraulic nut):

$$\frac{1}{20} \le \frac{d_U - d_0}{t_S} \le \frac{1}{12}$$

d_U, t_S, d_0 = geometrical parameters of the coupling, defined in Fig. 7.2.

5.3.2 Push-up length of cone coupling with hydraulic arrangements for assembling and disassembling the coupling

It is to be checked that the push-up length ΔE of the rudder stock tapered part into the boss is in compliance with the following formula:

$$\Delta_0 \le \Delta_E \le \Delta_1$$

where Δ_0 and Δ_1 are to be obtained from the formulae in Table 7.2.

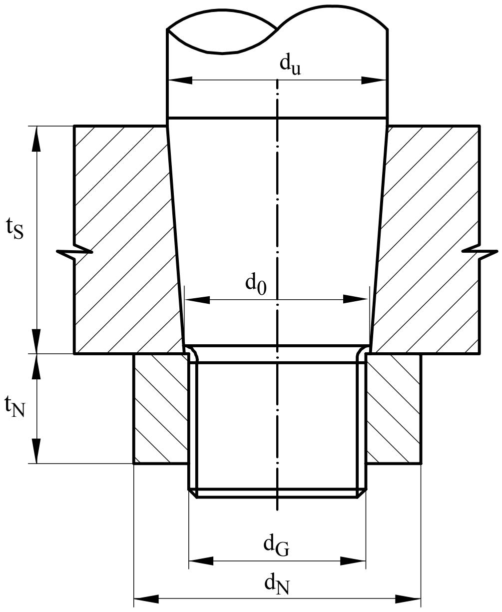


Fig. 7.2 Geometry of cone coupling

5.3.3 Lower rudder stock end

The lower rudder stock end is to be fitted with a threaded part having a core diameter, d_G [mm] not less than:

$$d_G = 0{,}65 \cdot d_1$$

d_1 = rudder stock diameter defined in 4.1.2.

This threaded part is to be fitted with an adequate slogging nut efficiently locked in rotation.

The dimensions of the massive part and slogging nut are to be in accordance with the following formulae:

$$t_S \geq 1{,}5 \cdot d_1$$

$$d_E \geq d_M + 0{,}6 \cdot d_1$$

$$t_N \geq 0{,}60 \cdot d_G$$

$$d_N \geq 1{,}2 \cdot d_0 \quad \text{and, in any case,} \quad d_N \geq 1{,}5 \cdot d_G$$

d_1 = rudder stock diameter defined in 4.1.1

d_E = external diameter [mm] of the massive part of Fig. 7.2, having the thickness t_S

d_M = mean diameter [mm] of the conical bore, as defined in 5.2.3

t_S, d_G, t_N d_N, d_0 = geometrical parameters of the coupling, defined in Fig. 7.2

The above minimum dimensions of the locking nut are only given for guidance, the determination of adequate scantlings being left to the designer.

5.3.4 Washer

For cone couplings with hydraulic arrangements for assembling and disassembling the coupling, a washer is to be fitted between the nut and the rudder gudgeon, having a thickness not less than $0{,}13 \cdot d_G$ and an outer diameter not less than $0{,}13 \cdot d_0$ or $1{,}6 \cdot d_G$, whichever is the greater.

5.3.5 Key

For cone couplings without hydraulic arrangements for assembling and disassembling the coupling, a key is to be fitted having a section of $(0{,}25 \cdot d_T \cdot x \cdot 0{,}10 \cdot d_T)$ [mm^2] and keyways in both the tapered part and the rudder gudgeon.

The key is to be machined and located on the fore or aft part of the rudder. The key is to be inserted at half-thickness into stock and into the solid part of the rudder.

For cone couplings with hydraulic arrangements for assembling and disassembling the coupling, the key may be omitted. In this case the designer is to submit to GL shrinkage calculations supplying all data necessary for the relevant check.

5.3.6 Instructions

All necessary instructions for hydraulic assembly and disassembly of the nut, including indication of the values of all relevant parameters, are to be available on board.

5.4 Vertical flange couplings

5.4.1 Vertical flange couplings are to be connected by fitted bolts having a diameter not less than the value obtained [mm], from the following formula:

$$d_B = \frac{0{,}81 \cdot d_1}{\sqrt{n_B}} \cdot \sqrt{\frac{k_{1B}}{k_{1S}}}$$

d_1 = rudder stock diameter [mm], defined in 4.1.2

k_{1S}, k_{1B} = material factors, defined in 5.1.2

n_B = total number of bolts, which is to be not less than 8

5.4.2 The first moment of area of the sectional area of bolts about the vertical axis through the centre of the coupling is to be not less than the value obtained [cm^3] from the following formula:

$$M_S = 0{,}43 \cdot d_1^3 \cdot 10^{-6}$$

d_1 = rudder stock diameter [mm], defined in 4.1.2

5.4.3 The thickness of the coupling flange [mm] is to be not less than d_B, defined in 5.4.1.

Table 7.2 Push-up length values

Rudder type	Δ_0	Δ_1
Rudder without intermediate pintles Spade rudders	The greater of: – $6{,}2 \cdot \dfrac{M_{TR} \cdot \eta \cdot \gamma}{c \cdot d_M \cdot t_S \cdot \mu_A \cdot \beta} \cdot 10^{-3}$ – $16 \cdot \dfrac{M_{TR} \cdot \eta \cdot \gamma}{c \cdot t_S^2 \cdot \beta} \cdot \sqrt{\dfrac{d_{1L}^6 - d_{1S}^6}{d_{1S}^6}} \cdot 10^{-3}$	$\dfrac{2 \cdot \eta + 5}{1{,}8} \cdot \dfrac{\gamma \cdot d_0 \cdot R_{eH}}{10^6 \cdot c \cdot (1 + p_1)}$
High lift profile and special rudder types	The greater of: – $6{,}2 \cdot \dfrac{M_{TR} \cdot \eta \cdot \gamma}{c \cdot d_M \cdot t_S \cdot \mu_A \cdot \beta} \cdot 10^{-3}$ – $16 \cdot \dfrac{M_{TR} \cdot \eta \cdot \gamma}{c \cdot t_S^2 \cdot \beta} \cdot \sqrt{\dfrac{d_{1L}^6 - d_{1S}^6}{d_{1S}^6}} \cdot 10^{-3}$ – $6{,}2 \cdot \dfrac{M_T \cdot \eta \cdot \gamma}{c \cdot d_M \cdot t_S \cdot \mu_A \cdot \beta} \cdot 10^{-3}$ – $18{,}4 \cdot \dfrac{M_F \cdot \eta \cdot \gamma}{c \cdot t_S^2 \cdot \beta} \cdot 10^{-3}$	The smaller of: – $\dfrac{2 \cdot \eta + 5}{1{,}8} \cdot \dfrac{\gamma \cdot d_0 \cdot R_{eH}}{10^6 \cdot c \cdot (1 + p_1)}$ – $\dfrac{2 \cdot \eta + 5}{1{,}8} \cdot \dfrac{\gamma \cdot d_0 \cdot R_{eH}}{10^6 \cdot c \cdot (1 + p_2)}$

$$p_1 = \frac{80 \cdot \sqrt{d_{1L}^6 - d_{1S}^6}}{R_{eH} \cdot d_M \cdot t_S^2 \cdot \left[1 - \left(\dfrac{d_0}{d_E}\right)^2\right]}$$

$$p_2 = \frac{7{,}4 \cdot M_F \cdot 10^3}{R_{eH} \cdot d_M \cdot t_S^2 \cdot \left[1 - \left(\dfrac{d_0}{d_E}\right)^2\right]}$$

R_{eH} = defined in 2.4.3
M_F, M_T = bending moment and torsional moment, respectively [N·m] provided by the manufacturer
d_{1L} = rudder stock diameter d_{TF} [mm] calculated in way of the lower part of the rudder stock (between the top of the rudder plate and the lower bearing of the rudder stock) in compliance with 4.1.2, considering $k_1 = 1$
d_{1S} = rudder stock diameter d_T [mm] calculated in way of the upper part of the rudder stock (at tiller level) in compliance with 4.1.1, considering $k_1 = 1$
η, c, β, d_M, d_E, μ_A, μ, γ = defined in 5.2.3
t_S, d_U, d_0 = defined in Fig. 7.2

5.4.4 The distance [mm] from the bolt axes to the external edge of the coupling flange is to be not less than $1{,}2 \cdot d_B$, where d_B is defined in 5.4.1.

5.4.5 A suitable locking device is to be provided to prevent the accidental loosening of nuts.

5.5 Couplings by continuous rudder stock welded to the rudder blade

5.5.1 When the rudder stock extends through the upper plate of the rudder blade and is welded to it, the thickness of this plate in the vicinity of the rudder stock is to be not less than $0{,}20 \cdot d_1$, where d_1 is defined in 4.1.2.

5.5.2 The welding of the upper plate of the rudder blade with the rudder stock is to be made with a full penetration weld and is to be subjected to non-destructive inspection through dye penetrant or magnetic particle test and ultrasonic testing.

The throat weld at the top of the rudder upper plate is to be concave shaped to give a fillet shoulder radius as large as practicable. This radius is to be not less than $0{,}15 \cdot d_1$, where d_1 is defined in 4.1.2.

5.6 Skeg connected with rudder trunk

In case of a rudder trunk connected with the bottom of a skeg, the throat weld is to be concave shaped to give a fillet shoulder radius as large as practicable. This radius is considered by GL on a case-by-case basis.

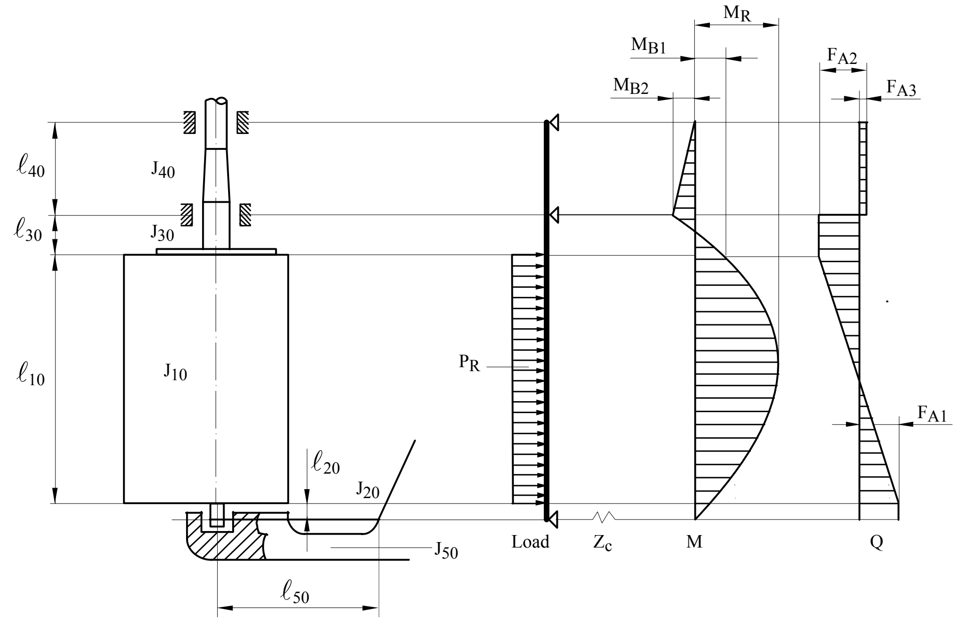


Fig. 7.3 Rudder supported by sole piece

6. Rudder stock and pintle bearings

6.1 Forces on rudder stock and pintle bearings

6.1.1 Support forces F_{Ai}, for i = 1, 2, 3 are to be obtained according to 6.1.2 and 6.1.3.

The spring constant Z_C for the support in the sole piece (see Fig. 7.3) is to be obtained [N/m] from the following formula:

$$Z_C = \frac{6{,}18 \cdot J_{50}}{\ell_{50}^3} \cdot 10^3$$

ℓ_{50} = length [m] of the sole piece

J_{50} = moment of inertia about the z axis [cm^4] of the sole piece

6.1.2 Rudder supported by sole piece

The rudder structure is to be calculated according to load, shear force and bending moment diagrams shown in Fig. 7.3.

The force per unit length p_R acting on the rudder body is to be obtained [N/m] from the following formula:

$$p_R = \frac{C_R}{\ell_{10}}$$

ℓ_{10} = height of the rudder blade [m]

The spring constant Z_c is to be calculated according to 6.1.1.

6.1.3 Spade rudders

The rudder structure is to be calculated according to load, shear force and bending moment diagrams shown in Fig. 7.4.

The force per unit length p_R acting on the rudder body is to be obtained [N/m] from the following formula:

$$p_{Rz} = p_{R1} + \left(\frac{p_{R2} - p_{R1}}{\ell_{10}}\right) \cdot z$$

z = position of rudder blade section [m] taken over ℓ_{10} length

p_{Rz} = force per unit length [N/m] obtained at the z position

p_{R1} = force per unit length [N/m] obtained for z equal to zero

p_{R2} = force per unit length [N/m] obtained for z equal to ℓ_{10}

For this type of rudder, the results of calculations performed according to diagrams shown in Fig. 7.4 may also be obtained from the following formulae:

– maximum bending moment in the rudder stock [N·m]:

$$M_B = C_R \cdot \left[\ell_{20} + \frac{\ell_{10} \cdot (2 \cdot C_1 + C_2)}{3 \cdot (C_1 + C_2)}\right]$$

where C_1 and C_2 are the lengths [m] defined in Fig. 7.4

– support forces [N]:

$$F_{A3} = \frac{M_B}{\ell_{30}}$$

$$F_{A2} = C_R + F_{A3}$$

– maximum shear force in the rudder body [N]:

$$Q_R = C_R$$

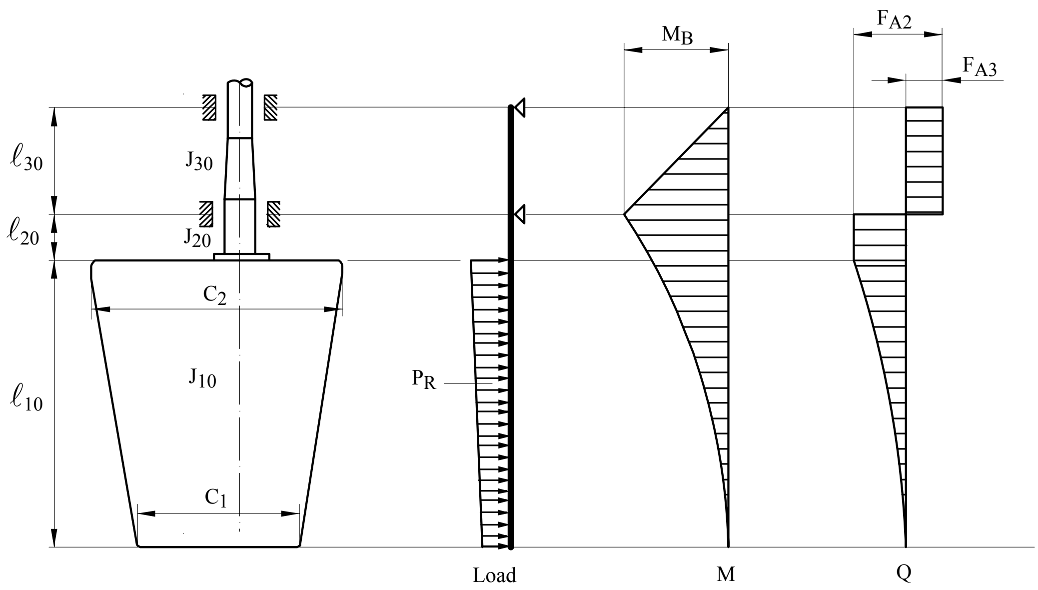


Fig. 7.4 Spade rudders

6.2 Rudder stock bearing

6.2.1 The mean bearing pressure acting on the rudder stock bearing is to be in compliance with the following formula:

$$p_F \leq p_{F,ALL}$$

p_F = mean bearing pressure acting on the rudder stock bearings [N/mm^2]

$$= \frac{F_{Ai}}{d_m \cdot h_m}$$

F_{Ai} = force acting on the rudder stock bearing [N]

d_m = actual inner diameter [mm] of the rudder stock bearings (contact diameter)

h_m = bearing length [mm] (see 6.2.3)

$p_{F,ALL}$ = allowable bearing pressure [N/mm^2] defined in Table 7.3.

Values greater than those given in Table 7.3 may be accepted by GL on the basis of specific tests

6.2.2 An adequate lubrication of the bearing surface is to be ensured.

6.2.3 The length/diameter ratio of the bearing surface is to be not greater than 1,2.

6.2.4 The manufacturing tolerance t_0 on the diameter of metallic supports is to be not less than the value obtained [mm] from the following formula:

$$t_0 = \frac{d_m}{1000} + 1$$

In the case of non-metallic supports, the tolerances are to be carefully evaluated on the basis of the thermal and distortion properties of the materials employed.

In any case, the tolerance on support diameter is to be not less than 1,5 mm.

Table 7.3 Allowable bearing pressure

Bearing material	$p_{F,ALL}$ [N/mm^2]
Lignum vitae	2,5
White metal, oil lubricated	4,5
Synthetic material with hardness between 60 and 70 Shore D [1]	5,5
Steel, bronze and hot-pressed bronze-graphite materials [2]	7,0

1 Indentation hardness test at 23 °C and with 50 % moisture to be performed according to a recognised standard. Type of synthetic bearing materials is to be approved by GL.

2 Stainless and wear-resistant steel in combination with stock liner approved by GL.

6.3 Pintle bearings

6.3.1 The mean bearing pressure acting on the gudgeons is to be in compliance with the following formula:

$$p_F \leq p_{F,ALL}$$

p_F = mean bearing pressure acting on the gudgeons [N/mm^2]

$$= \frac{F_{Ai}}{d_A \cdot h_L}$$

F_{Ai} = force acting on the pintle [N] calculated as specified in 6.1

d_A = actual diameter [mm] of the rudder pintles

h_L = bearing length [mm] (see 6.3.3)

$p_{F,ALL}$ = allowable bearing pressure [N/mm²] defined in Table 7.3

Values greater than those given in Table 7.3 may be accepted by GL on the basis of specific tests.

6.3.2 An adequate lubrication of the bearing surface is to be ensured.

6.3.3 The length/diameter ratio of the bearing surface is not to be less than 1 and not to be greater than 1,2.

6.3.4 The manufacturing tolerance t_0 on the diameter of metallic supports is to be not less than the value obtained [mm] from the following formula:

$$t_0 = \frac{d_A}{1000} + 1$$

In the case of non-metallic supports, the tolerances are to be carefully evaluated on the basis of the thermal and distortion properties of the materials employed.

In any case, the tolerance on support diameter is to be not less than 1,5 mm.

6.4 Pintles

6.4.1 Rudder pintles are to have a diameter not less than the value obtained [mm] from the following formula:

$$d_A = \left(\frac{0,21 \cdot V_{AV}}{0,54 \cdot V_{AV} + 3} \cdot \sqrt{F_{Ai}} + 30 \right) \cdot \sqrt{k_1}$$

F_{Ai} = force [N] acting on the pintle, calculated as specified in 6.1.1.

6.4.2 Provision is to be made for a suitable locking device to prevent the accidental loosening of pintles.

6.4.3 The pintles are to have a conical coupling with a taper on diameter in accordance with 5.3.1.

The conical coupling is to be secured by a nut the dimensions of which are to be in accordance with 5.3.3.

6.4.4 The length of the pintle housing in the gudgeon is to be not less than the value obtained [mm] from the following formula:

$$h_L = 0,35 \cdot \sqrt{F_{Ai} \cdot k_1}$$

F_{Ai} = force [N] acting on the pintle, calculated as specified in 6.1.1.

The thickness of pintle housing in the gudgeon [mm] is to be not less than $0,25 \cdot d_A$, where d_A is defined in 6.4.1.

7. Rudder blade scantlings

7.1 General

7.1.1 Application

The requirements in 7.1 to 7.5 apply to streamlined rudders and, when applicable, to rudder blades of single plate rudders.

7.1.2 Rudder blade structure

The structure of the rudder blade is to be such that stresses are correctly transmitted to the rudder stock and pintles. To this end, horizontal and vertical web plates are to be provided.

Horizontal and vertical webs acting as main bending girders of the rudder blade are to be suitably reinforced.

7.1.3 Access openings

Streamlined rudders, including those filled with pitch, cork or foam, are to be fitted with plug-holes and the necessary devices to allow their mounting and dismounting.

Access openings to the pintles are to be provided. If necessary, the rudder blade plating is to be strengthened in way of these openings.

The corners of openings intended for the dismantling of pintle or stock nuts are to be rounded off with a radius as large as practicable.

Where the access to the rudder stock nut is closed with a welded plate, a full penetration weld is to be provided.

7.2 Rudder blade plating

7.2.1 Plate thickness

The thickness of each rudder blade plate panel is to be not less than the value obtained [mm] from the following formula:

$$t_F = \left(5,5 \cdot s \cdot \beta \cdot \sqrt{T + 0,6 \cdot n + \frac{C_R \cdot 10^{-4}}{A}} + 1,5 \right) \cdot \sqrt{k}$$

β = coefficient

$$= \sqrt{1,1 - 0,5 \cdot \left(\frac{s}{b_L} \right)^2}$$

to be taken not greater than 1,0 if $b_L/s > 2,5$

s = length [m] of the shorter side of the plate panel

b_L = length [m] of the longer side of the plate panel

7.2.2 Thickness of the top and bottom plates of the rudder blade

The thickness of the top and bottom plates of the rudder blade is to be not less than the thickness t_F defined in 7.2.1, without being less than 1,2 times the thickness obtained from 7.2.1 for the attached side plating.

Where the rudder is connected to the rudder stock with a coupling flange, the thickness of the top plate which is welded in extension of the rudder flange is to be not less than 1,1 times the thickness calculated above.

7.2.3 Web spacing

The spacing between horizontal web plates is to be not greater than 1,20 m.

Vertical webs are to have spacing not greater than twice that of horizontal webs.

7.2.4 Web thickness

Web thickness is to be at least 70 % of that required for rudder plating and in no case is it to be less than 8 mm, except for the upper and lower horizontal webs. The thickness of each of these webs is to be uniform and not less than that of the web panel having the greatest thickness t_F, as calculated in 7.2.1. In any case it is not required that the thickness is increased by more than 20 % in respect of normal webs.

When the design of the rudder does not incorporate a mainpiece, this is to be replaced by two vertical webs closely spaced, having thickness not less than that obtained from Table 7.4.

7.2.5 Welding

The welded connections of blade plating to vertical and horizontal webs are to be in compliance with the applicable requirements of GL's Rules for Materials.

Where the welds of the rudder blade are accessible only from outside of the rudder, slots on a flat bar welded to the webs are to be provided to support the weld root, to be cut on one side of the rudder only.

7.2.6 Rudder nose plate thickness

Rudder nose plates are to have a thickness not less than 1,25 t_F, where t_F is defined in 7.2.1.

In general this thickness need not exceed 22 mm, unless otherwise required in special cases to be considered individually by GL.

7.3 Connections of rudder blade structure with solid parts in forged or cast steel

7.3.1 General

Solid parts in forged or cast steel which ensure the housing of the rudder stock or of the pintle are in general to be connected to the rudder structure by means of two horizontal web plates and two vertical web plates.

7.3.2 Minimum section modulus of the connection with the rudder stock housing

The section modulus of the cross-section of the structure of the rudder blade which is connected with the solid part where the rudder stock is housed, which is made by vertical web plates and rudder plating, is to be not less than that obtained [cm³] from the following formula:

$$w_S = c_S \cdot d_1^3 \cdot \left(\frac{H_E - H_X}{H_E}\right) \cdot \frac{k}{k_1} \cdot 10^{-4}$$

c_S = coefficient

= 1,0 if there is no opening in the rudder plating

= 1,5 if there is an opening in the considered cross-section of the rudder

d_1 = rudder stock diameter [mm] defined in 4.1.2

H_E = vertical distance [m] between the lower edge of the rudder blade and the upper edge of the solid part

H_X = vertical distance [m] between the considered cross-section and the upper edge of the solid part

k, k_1 = material factors, defined in 2.4, for the rudder blade plating and the rudder stock, respectively

7.3.3 Calculation of the actual section modulus of the connection with the rudder stock housing

The actual section modulus of the cross-section of the structure of the rudder blade which is connected with the solid part where the rudder stock is housed is to be calculated with respect to the symmetrical axis of the rudder.

The breadth of the rudder plating to be considered for the calculation of this actual section modulus is to be not greater than that obtained [m] from the following formula:

$$b = s_v + 2 \cdot \frac{H_x}{m}$$

s_V = spacing [m] between the two vertical webs (see Fig. 7.5)

H_X = distance defined in 7.3.2

m = coefficient to be taken, in general, equal to 3

Where openings for access to the rudder stock nut are not closed by a full penetration welded plate according to 7.1.3, they are to be deducted (see Fig. 7.5).

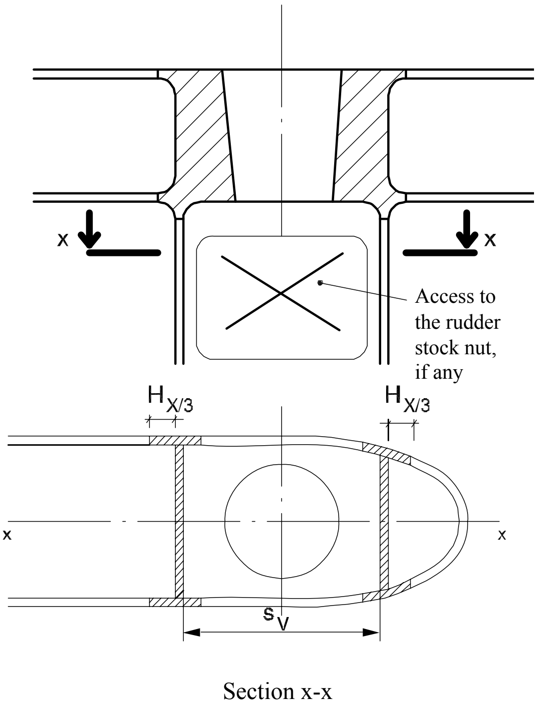


Fig. 7.5 Cross-section of the connection between rudder blade structure and rudder stock housing

7.3.4 Thickness of horizontal web plates

In the vicinity of the solid parts, the thickness of the horizontal web plates, as well as that of the rudder blade plating between these webs, is to be not less than the greater of the values obtained [mm] from the following formulae:

$$t_H = 1{,}2 \cdot t_F$$

$$= 0{,}045 \cdot \frac{d_S^2}{s_H}$$

t_F = thickness defined in 7.2.1

d_S = diameter [mm] to be taken equal to:

- d_1 for the solid part connected to the rudder stock
- d_A for the solid part connected to the pintle

d_1 = rudder stock diameter [mm] defined in 4.1.2

d_A = pintle diameter [mm] defined in 6.4.1

s_H = spacing [mm] between the two horizontal web plates

Different thickness may be accepted when justified on the basis of direct calculations submitted to GL for review.

7.3.5 Thickness of side plating and vertical web plates welded to the solid part

The thickness of the vertical web plates welded to the solid part where the rudder stock is housed as well as the thickness of the rudder side plating under this solid part is to be not less than the values obtained [mm] from Table 7.4.

7.3.6 Solid part protrusions

The solid parts are to be provided with protrusions. Vertical and horizontal web plates of the rudder are to be butt welded to these protrusions.
These protrusions are not required when the web plate thickness is less than:

- 10 mm for vertical web plates welded to the solid part of the rudder stock coupling of spade rudders
- 20 mm for the other web plates

7.4 Connection of the rudder blade with the rudder stock by means of horizontal flanges

7.4.1 Minimum section modulus of the connection

The section modulus of the cross-section of the structure of the rudder blade which is directly connected with the flange, which is made by vertical web plates and rudder blade plating, is to be not less than the value obtained [cm^3] from the following formula:

$$w_S = 1{,}3 \cdot d_1^3 \cdot 10^{-4}$$

where d_1 is the rudder stock diameters d_{TF} [mm] to be calculated in compliance with the requirements in 4.1.2, taking k_1 equal to 1.

Table 7.4 Thickness of the vertical webs and rudder side plating welded to solid part or to rudder flange

Type of rudder	Thickness of vertical web plates [mm]		Thickness of rudder plating [mm]	
	Rudder blade without opening	At opening boundary	Rudder blade without opening	Area with opening
Rudder supported by sole piece	$1{,}2 \cdot t_F$	$1{,}6 \cdot t_F$	$1{,}2 \cdot t_F$	$1{,}4 \cdot t_F$
Spade rudders	$1{,}4 \cdot t_F$	$2{,}0 \cdot t_F$	$1{,}3 \cdot t_F$	$1{,}6 \cdot t_F$
t_F = defined in 7.2.1.				

7.4.2 Actual section modulus of the connection

The section modulus of the cross-section of the structure of the rudder blade which is directly connected with the flange is to be calculated with respect to the symmetrical axis of the rudder.

For the calculation of this actual section modulus, the length of the rudder cross-section equal to the length of the rudder flange is to be considered.

Where the rudder plating is provided with an opening under the rudder flange, the actual section modulus of the rudder blade is to be calculated in compliance with 7.3.3.

7.4.3 Welding of the rudder blade structure to the rudder blade flange

The welds between the rudder blade structure and the rudder blade flange are to be full penetrated (or of equivalent strength) and are to be 100 % inspected by means of non-destructive tests.

Where the full penetration welds of the rudder blade are accessible only from outside of the rudder, a backing flat bar is to be provided to support the weld root.

The external fillet welds between the rudder blade plating and the rudder flange are to be of concave shape and their throat thickness is to be at least equal to 0,5 times the rudder blade thickness.

Moreover, the rudder flange is to be checked before welding by non-destructive inspection for lamination and inclusion detection in order to reduce the risk of lamellar tearing.

7.4.4 Thickness of side plating and vertical web plates welded to the rudder flange

The thickness of the vertical web plates directly welded to the rudder flange as well as the plating thickness of the rudder blade upper strake in the area of the connection with the rudder flange is to be not less than the values obtained [mm] from Table 7.4.

7.5 Single plate rudders

7.5.1 Mainpiece diameter

The mainpiece diameter is to be obtained from the formulae in 4.1.1 and 4.1.2.

In any case, the mainpiece diameter is to be not less than the stock diameter.

For spade rudders the lower third may taper down to 0,75 times the stock diameter.

7.5.2 Blade thickness

The blade thickness is to be not less than the value obtained [mm] from the following formula:

$$t_B = \left(0{,}81 \cdot s \cdot V_{AV} + 2{,}5\right) \cdot \sqrt{k}$$

s = spacing of stiffening arms [m] to be taken not greater than 1 m (see Fig. 7.6)

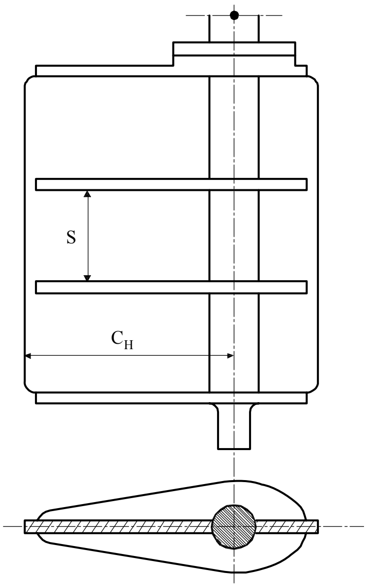


Fig. 7.6 Single plate rudder

7.5.3 Arms

The thickness of the arms is to be not less than the blade thickness.

The section modulus of the generic section is to be not less than the value obtained [cm^3] from the following formula:

$$Z_A = 0{,}15 \cdot s \cdot C_H^2 \cdot V_{AV}^2 \cdot k$$

C_H = horizontal distance [m] from the aft edge of the rudder to the centreline of the rudder stock (see Fig. 7.6)

s = defined in 7.5.2

8. Sole piece scantlings

8.1 General

8.1.1 The weight of the rudder is normally supported by a carrier bearing inside the rudder trunk.

Robust and effective structural rudder stops are to be fitted, except where adequate positive stopping arrangements are provided in the steering gear, in compliance with the requirements of GL Rules for Machinery, Systems and Electricity (I-2-3), Section 1, E.4.5 and/or Section 1, E.4.6.

8.1.2 The bottom plate connected to the stern frame sole piece shall have the following gross thickness t [mm] over a length of at least 5 m:

$$t = 1{,}3 \cdot \sqrt{L + 0{,}1 \cdot P_1}$$

P_1 = maximum power [kW] of main engine driving the central propeller

Where equivalent measures are taken to constrain the sole piece in the body, these strengthening may be dispensed with.

8.2 Scantlings

8.2.1 Bending moment

The bending moment acting on the generic section of the sole piece is to be obtained [N·m] from the following formula:

$$M_S = F_{A1} \cdot x$$

F_{A1} = supporting force [N] in the pintle bearing, to be determined through a direct calculation; where such a direct calculation is not carried out, this force may be taken equal to:

$$= \frac{C_R}{2}$$

x = distance [m], defined in Fig. 7.7

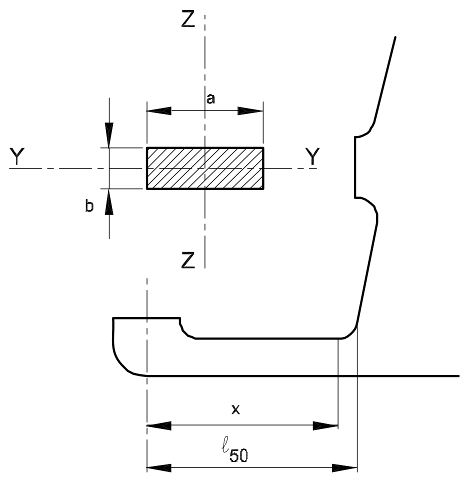


Fig. 7.7 Sole piece geometry

8.2.2 Strength checks

For the generic section of the sole piece within the length ℓ_{50}, defined in Fig. 7.7, it is to be checked that

$$\sigma_E \le \sigma_{E,ALL}$$

$$\sigma_B \le \sigma_{B,ALL}$$

$$\tau \le \tau_{ALL}$$

σ_E = equivalent stress to be obtained [N/mm²] from the following formula:

$$= \sqrt{\sigma_B^2 + 3\tau^2}$$

σ_B = bending stress to be obtained [N/mm²] from the following formula:

$$= \frac{M_S}{W_Z}$$

τ = shear stress to be obtained [N/mm²] from the following formula:

$$= \frac{F_{A1}}{A_S}$$

M_S = bending moment at the section considered [N·m] defined in 8.2.1

F_{A1} = force [N] defined in 8.2.1

W_Z = section modulus [cm³] around the vertical axis Z (see Fig. 7.7)

A_S = shear sectional area in Y direction [mm²]

$\sigma_{E,ALL}$ = allowable equivalent stress [N/mm²]

$= 115 / k_1$

$\sigma_{B,ALL}$ = allowable bending stress [N/mm²]

$= 80 / k_1$

τ_{ALL} = allowable shear stress, in [N/mm²]

$= 48 / k_1$

8.2.3 Minimum section modulus around the horizontal axis

The section modulus around the horizontal axis Y (see Fig. 7.7) is to be not less than the value obtained [cm³] from the following formula:

$$W_Y = 0{,}5 \cdot W_Z$$

W_z = section modulus [cm³] around the vertical axis Z

9. Steering nozzles

9.1 General

9.1.1 The following requirements apply to scantling steering nozzles for which the power transmitted to the propeller is less than the value obtained [kW] from the following formula:

$$P = \frac{16900}{d_M}$$

d_M = inner diameter of the nozzle [m]

Nozzles for which the power transmitted is greater than the value obtained from the above formula are considered on a case-by-case basis.

The following requirements may apply also to fixed nozzle scantlings.

9.1.2 Nozzles normally consist of a double skin cylindrical structure stiffened by ring webs and other longitudinal webs placed perpendicular to the nozzle.

At least two ring webs are to be fitted, one of which, of greater thickness, is to be placed in way of the axis of rotation of the nozzle.

For nozzles with an inner diameter d_M exceeding 3 m, the number of ring webs is to be suitably increased.

9.1.3 Care is to be taken in the manufacture of the nozzle to ensure the welded connection between plating and webs.

9.1.4 The internal part of the nozzle is to be adequately protected against corrosion.

9.2 Nozzle plating and internal diaphragms

9.2.1 The thickness of the inner plating of the nozzle is to be not less than the value obtained [mm] from the following formula:

$$t_F = \left(0,085 \cdot \sqrt{P \cdot d_M} + 9,65\right) \cdot \sqrt{k}$$

$P, d_M =$ defined in 9.1.1.

The thickness t_F is to be extended to a length, across the transverse section containing the propeller blade tips, equal to one third of the total nozzle length.

Outside this length, the thickness of the inner plating is to be not less than $(t_F - 7)$ [mm] and, in any case, not less than 7 mm.

9.2.2 The thickness of the outer plating of the nozzle is to be not less than $(t_F - 9)$ [mm] where t_F is defined in 9.2.1 and, in any case, not less than 7 mm.

9.2.3 The thicknesses of ring webs and longitudinal webs are to be not less than $(t_F - 7)$ [mm] where t_F is defined in 9.2.1, and, in any case, not less than 7 mm.

However, the thickness of the ring web, in way of the headbox and pintle support structure, is to be not less than t_F.

GL may consider reduced thicknesses where an approved stainless steel is used, in relation to its type.

9.3 Nozzle stock

9.3.1 The diameter of the nozzle stock is to be not less than the value obtained [mm] from the following formula:

$$d_{NTF} = 6,42 \cdot (M_T \cdot k_1)^{1/3}$$

M_T = torque, to be taken as the greater of those obtained [N·m] from the following formulae:

– $M_{TAV} = 0,3 \cdot S_{AV} \cdot a$

– $M_{TAD} = S_{AD} \cdot b$

S_{AV} = force [N]

$= 43,7 \cdot V_{AV}^2 \cdot A_N$

S_{AD} = force [N]

$= 58,3 \cdot V_{AD}^2 \cdot A_N$

A_N = area [m²]

$= 1,35 \cdot A_{1N} + A_{2N}$

A_{1N} = area [m²]

$= L_M \cdot d_M$

A_{2N} = area [m²]

$= L_1 \cdot H_1$

a, b, L_M, d_M, L_1, H_1 = geometrical parameters of the nozzle [m] defined in Fig. 7.8

The diameter of the nozzle stock may be gradually tapered above the upper stock bearing so as to reach, in way of the tiller or quadrant, the value obtained [mm] from the following formula:

$$d_{NT} = 0,75 \cdot d_{NTF}$$

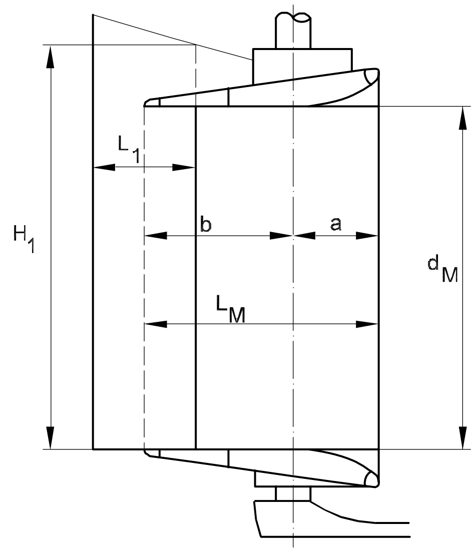


Fig. 7.8 Geometrical parameters of the nozzle

9.4 Pintles

9.4.1 The diameter of the pintles is to be not less than the value obtained [mm] from the following formula:

$$d_A = \left(\frac{0,19 \cdot V_{AV}}{0,54 \cdot V_{AV} + 3} \cdot \sqrt{S_{AV}} + 30\right) \cdot \sqrt{k_1}$$

S_{AV} = defined in 9.3.1

9.4.2 The length/diameter ratio of the pintle is not to be less than 1 and not to be greater than 1,2.

Smaller values of h_A may be accepted provided that the pressure on the gudgeon bearing p_F is in compliance with the following formula:

$$p_F \le p_{F,ALL}$$

p_F = mean bearing pressure acting on the gudgeon [N/mm²] from the following formula:

$$= \frac{0,6 \cdot S'}{d'_A \cdot h'_A}$$

S' = the greater of the values S_{AV} and S_{AD} [N] defined in 9.3.1

d'_A = actual pintle diameter [mm]

h'_A = actual bearing length of pintle [mm]

$p_{F,ALL}$ = allowable bearing pressure [N/mm²] defined in Table 7.3

9.5 Nozzle coupling

9.5.1 Diameter of coupling bolts

The diameter of the coupling bolts is to be not less than the value obtained [mm] from the following formula:

$$d_B = 0,62 \cdot \sqrt{\frac{d_{NTF}^3 \cdot k_{1B}}{n_B \cdot e_M \cdot k_{1S}}}$$

d_{NTF} = diameter of the nozzle stock [mm] defined in 9.3.1

k_{1S} = material factor k_1 for the steel used for the stock

k_{1B} = material factor k_1 for the steel used for the bolts

e_M = mean distance [mm] from the bolt axles to the longitudinal axis through the coupling centre (i.e. the centre of the bolt system)

n_B = total number of bolts, which is to be not less than:

- 4 if $d_{NTF} \geq 75$ mm
- 6 if $d_{NTF} > 75$ mm

Non-fitted bolts may be used provided that, in way of the mating plane of the coupling flanges, a key is fitted having a section of $(0,25 \cdot d_{NT} \cdot x \cdot 0,10 \cdot d_{NT})$ [mm²], where d_{NT} is defined in 9.3.1, and keyways in both the coupling flanges, and provided that at least two of the coupling bolts are fitted bolts.

The distance from the bolt axes to the external edge of the coupling flange is to be not less than $1,2 \cdot d_B$.

9.5.2 Thickness of coupling flange

The thickness of the coupling flange is to be not less than the value obtained [mm] from the following formula:

$$t_P = d_B \cdot \sqrt{\frac{k_{1F}}{k_{1B}}}$$

d_B = bolt diameter [mm] defined in 9.5.1

$k_{1B'}$ = material factor k_1 for the steel used for the bolts

k_{1F} = material factor k_1 for the steel used for the coupling flange

9.5.3 Push-up length of cone couplings with hydraulic arrangements for assembling and disassembling the coupling

It is to be checked that the push-up length Δ_E of the nozzle stock tapered part into the boss is in compliance with the following formula:

$$\Delta_0 \leq \Delta_E \leq \Delta_1$$

Δ_0 = the greater of:

- $$6,2 \cdot \frac{M_{TR} \cdot \eta \cdot \gamma}{c \cdot d_M \cdot t_S \cdot \mu_A \cdot \beta}$$
- $$16 \cdot \frac{M_{TR} \cdot \eta \cdot \gamma}{c \cdot t_S^2 \cdot \beta} \cdot \sqrt{\frac{d_{NTF}^6 - d_{NT}^6}{d_{NT}^6}}$$

d_{NTF}, d_{NT} = nozzle stock diameter [mm] to be obtained from the formula in 9.3.1, considering $k_1 = 1$

η, c, β, d_M, d_E, μ_A, μ, γ = defined in 5.2.3

t_S, d_U, d_0 = defined in Fig. 7.2

R_{eH} = defined in 2.4.3

9.5.4 Locking device

A suitable locking device is to be provided to prevent the accidental loosening of nuts.

10. Azimuth propulsion system

10.1 General

10.1.1 Arrangement

The azimuth propulsion system is constituted by the following sub-systems (see Fig. 7.9):

- steering unit
- bearing
- hull supports
- rudder part of the system
- pod, which contains the electric motor in the case of a podded propulsion system

10.1.2 Application

The following requirements apply to the scantlings of the hull supports, the rudder part and the pod.

The steering unit and the bearing are to comply with the requirements in the GL Rules for Machinery, Systems and Electricity (I-2-3), Section 1, E.

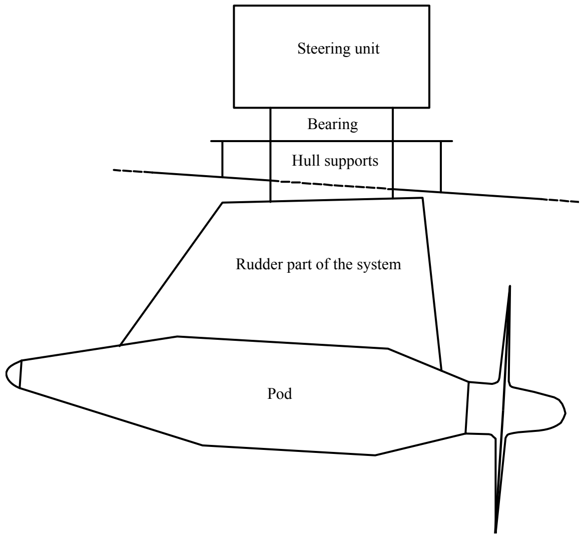


Fig. 7.9 Azimuth propulsion system

10.1.3 Operating conditions

The maximum angle at which the azimuth propulsion system can be oriented on each side when the vessel navigates at its maximum speed is to be specified by the designer. Such maximum angle is generally to be less than 35° on each side.

In general, orientations greater than this maximum angle may be considered by GL for azimuth propulsion systems during manoeuvres, provided that the orientation values together with the relevant speed values are submitted to GL for review.

10.2 Arrangement

10.2.1 Plans to be submitted

In addition to the plans showing the structural arrangement of the pod and the rudder part of the system, the plans showing the arrangement of the azimuth propulsion system supports are to be submitted to GL for review. The scantlings of the supports and the maximum loads which act on the supports are to be specified in these drawings.

10.2.2 Locking device

The azimuth propulsion system is to be mechanically lockable in a fixed position, in order to avoid rotations of the system and propulsion in undesirable directions in the event of damage.

10.3 Primary supporting members

10.3.1 Analysis criteria

The scantlings of primary supporting members of the azimuth propulsion system are to be obtained through direct calculations, to be carried out according to the following requirements:

– the structural model is to include the pod, the rudder part of the azimuth propulsion system, the bearing and the hull supports
– the boundary conditions are to represent the connections of the azimuth propulsion system to the hull structures
– the loads to be applied are those defined in 10.3.2

The direct calculation analyses (structural model, load and stress calculation, strength checks) carried out by the designer are to be submitted to GL for information.

10.3.2 Loads

The following loads are to be considered in the direct calculation of the primary supporting members of the azimuth propulsion system:

– gravity loads
– buoyancy
– maximum loads calculated for an orientation of the system equal to the maximum angle at which the azimuth propulsion system can be oriented on each side when the vessel navigates at its maximum speed
– maximum loads calculated for the possible orientations of the system greater than the maximum angle at the relevant speed (see 10.1.3)
– maximum loads calculated for the crash stop of the vessel obtained through inversion of the propeller rotation
– maximum loads calculated for the crash stop of the vessel obtained through a 180° rotation of the pod

10.3.3 Strength check

It is to be checked that the Von Mises equivalent stress σ_E in primary supporting members, calculated [N/mm²] for the load cases defined in 10.3.2, is in compliance with the following formula:

$$\sigma_E \le \sigma_{ALL}$$

σ_{ALL} = allowable stress [N/mm²] to be taken equal to the lesser of the following values:

– $0{,}275 \cdot R_m$
– $0{,}55 \cdot R_{eH}$

R_m = tensile strength [N/mm²] of the material, defined in Section 2, A.2.1

R_{eH} = minimum yield stress [N/mm²] of the material, defined in Section 2, A.2.1

10.4 Hull supports of the azimuth propulsion system

10.4.1 Analysis criteria

The scantlings of hull supports of the azimuth propulsion system are to be obtained through direct calculations, to be carried out in accordance with the requirements in 10.3.1.

10.4.2 Loads

The loads to be considered in the direct calculation of the hull supports of the azimuth propulsion system are those specified in 10.3.2.

10.4.3 Strength check

It is to be checked that the Von Mises equivalent stress σ_E in hull supports [N/mm^2] calculated for the load cases defined in 10.3.2, is in compliance with the following formula:

$$\sigma_E \le \sigma_{ALL}$$

σ_{ALL} = allowable stress [N/mm^2] equal to:

$$\sigma_{ALL} = 65 / k$$

k = material factor, defined in Section 2, A.2.4

Values of σ_E greater than σ_{ALL} may be accepted by GL on a case-by-case basis, depending on the localisation of σ_E and on the type of direct calculation analysis.

B. Bulwarks and Guard Rails

1. General

1.1 The following requirements apply to the arrangement and scantling of bulwarks and guard rails provided at the boundaries of the main deck and superstructure deck.

2. Bulwark

On all cargo vessels, except pushed barges, bulwarks are to be fitted in way of the fore and aft ship, extending from the stem to the forward end of the foremost hatchway (forward cargo tank on tankers) and from the stern to the forward end of the aft deckhouse.

Between these two areas, a foot guard is to be fitted which is to rise at least 50 mm above the weather deck.

2.1 Height

2.1.1 Cargo carriers

The bulwark is to be at least 700 mm high. This may be required to be increased in way of the stem.

2.1.2 Passenger vessels

On passenger vessels, the bulwarks or guard rails are to be at least 1000 mm high on the decks open to passengers. In way of the after deckhouse, a similar height is to be arranged.

Openings and equipment for embarking or disembarking, and also openings for loading or unloading, shall be such that they can be secured.

2.2 Thickness

The bulwark gross thickness [mm] is not to be less than:

- $L \le 30$ m: $t = 4$
- $30 \text{ m} < L \le 90$ m: $t = 5$
- $L > 90$ m: $t = 6$

2.2.1 Bulwarks are to be aligned with the beam located below or connected to them by means of local transverse stiffeners.

Plate bulwarks are to be supported either by stays or plate brackets spaced not more than 2 m apart.

2.2.2 At its upper part, bulwarks are to be fitted with an efficient section acting as a handrail and supported by means of stays located, as far as practicable, in way of the beams.

3. Guard rails

In general, the guard rails have to be built in compliance with EN 711, as amended.

In case the bulwark height is less than the required guard rail height, a guard rail is to be placed on top of the bulwark.

Alternative guard rail designs and railing fillings made of glass may be used on the basis of individual examination.

C. Propeller Shaft Brackets

1. Symbols

F_C = force [kN]

$$= \left(\frac{2 \cdot \pi \cdot N}{60}\right)^2 \cdot R_P \cdot m$$

m = mass of a propeller blade [t]

N = number of revolutions per minute of the propeller

R_P = distance [m] of the centre of gravity of a blade in relation to the rotation axis of the propeller

σ_{ALL} = allowable stress [N/mm^2]:

= 70

w_A = section modulus [cm^3] of the arm at the level of the connection to the hull with respect to a transversal axis

A = sectional area [cm^2] of the arm

A_S = shear sectional area [cm^2] of the arm

d_P = propeller shaft diameter [mm] measured inside the liner, if any

2. General

2.1 Propeller shafting is either enclosed in bossing or independent of the main hull and supported by shaft brackets.

2.2 Strength check

2.2.1 General

The strength check is to be carried out according to 3., 4. or 5.

2.2.2 Vibration analysis

A vibration analysis according to the GL Rules for Machinery, Systems and Electricity (I-2-3), Section 1, B.5. is recommended to be performed for single-arm propeller shaft brackets.

3. Double arm propeller shaft brackets

3.1 General

3.1.1 Both arms of detached propeller brackets are to form an angle α to each other that differs from the angle included between propeller blades. Where 3- or 5-bladed propellers are fitted, it is recommended that the angle α should be approximately 90°. Where 4-bladed propellers are fitted, the angle α should be approximately 70° or 110°.

Where possible, the axes of the arms should intersect in the axis of the propeller shaft.

Exceptions to this will be considered by GL on a case-by-case basis.

3.1.2 Scantlings of arms

The moment in the arm [kN·m] is to be obtained from the following formula:

$$M = \frac{F_C}{\sin\alpha} \cdot \left(\frac{L}{\ell} \cdot d_1 \cdot \cos\beta + L - \ell \right)$$

α = angle between the two arms

β = angle defined in Fig. 7.10

d_1 = distance [m] defined in Fig. 7.10

L, ℓ = lengths [m] defined in Fig. 7.11

It is to be checked that the bending stress σ_F, the compressive stress σ_N and the shear stress τ are in compliance with the following formula:

$$\sqrt{(\sigma_F + \sigma_N)^2 + 3 \cdot \tau^2} \le \sigma_{ALL}$$

$$\sigma_F = \frac{M}{w_A} \cdot 10^3$$

$$\sigma_N = 10 \cdot F_C \cdot \frac{L \cdot \sin\beta}{A \cdot \ell \cdot \sin\alpha}$$

$$\tau = 10 \cdot F_C \cdot \frac{L \cdot \cos\beta}{A_S \cdot \ell \cdot \sin\alpha}$$

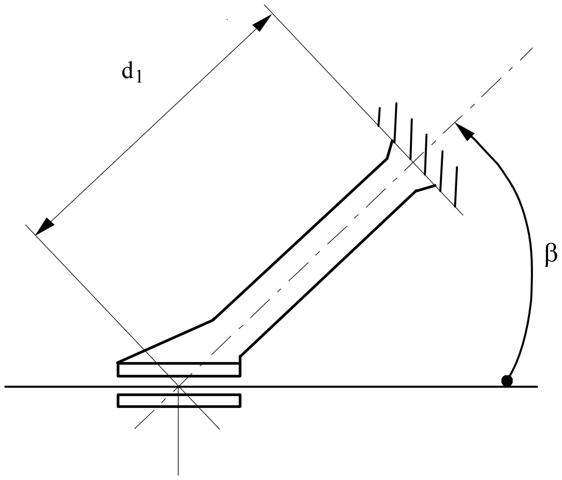


Fig. 7.10 Angle β and length d_1

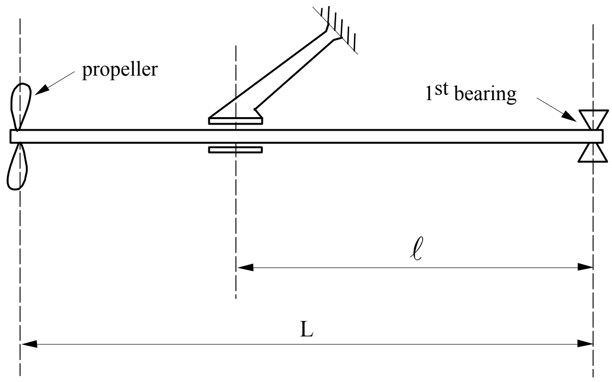


Fig. 7.11 Lengths L and ℓ

3.1.3 Scantlings of propeller shaft bossing

The length of the propeller shaft bossing is to be not less than the length of the aft sterntube bearing bushes (see GL Rules for Machinery, Systems and Electricity (I-2-3), Section 1, B.2.6.2).

The thickness of the propeller shaft bossing is to be not less than 0,33 · d_P.

3.1.4 Bracket arm attachments

The bracket arms are to penetrate the hull plating and be connected to deep floors or girders of increased thickness. Moreover, in way of the attachments, the shell plating is to be increased in thickness by 50 % or fitted with a doubling plate of same thickness, and suitably stiffened.

The securing of the arms to the hull structure is to prevent any displacement of the brackets with respect to the hull.

4. Single arm propeller shaft brackets

4.1 Scantlings

4.1.1 This type of propeller shaft bracket consists of one arm.

4.1.2 Scantlings of arms

The moment in case of a vertical single arm [kN·m] is to be obtained from the following formula:

$$M = d_2 \cdot F_C \cdot \frac{L}{\ell}$$

d_2 = length of the arm [m] measured between the propeller shaft axis and the hull

L, ℓ = lengths [m] defined in Fig. 7.11

It is to be checked that the bending stress σ_F and the shear stress τ are in compliance with the following formula:

$$\sqrt{\sigma_F^2 + 3\tau^2} \le \sigma_{ALL}$$

$$\sigma_F = \frac{M}{w_A} \cdot 10^3$$

$$\tau = 10 \cdot F_C \cdot \frac{L}{A_S \cdot \ell}$$

4.1.3 Scantlings of propeller shaft bossing

The length of the propeller shaft bossing is to be not less than the length of the aft sterntube bearing bushes (see GL Rules for Machinery, Systems and Electricity (I-2-3), Section 1, B.2.6.2).

The thickness of the propeller shaft bossing is to be not less than $0{,}33 \cdot d_P$.

4.1.4 Bracket arm attachments

The connection of bracket arms to the hull structure is to comply with 3.1.4.

5. Bossed propeller shaft brackets

5.1 General

Where bossed propeller shaft brackets are fitted, their scantlings are to be considered by GL on a case-by-case basis.

5.2 Scantling of the boss

The length of the boss is to be not less than the length of the aft sterntube bearing bushes (see GL Rules for Machinery, Systems and Electricity (I-2-3), Section 1, B.2.6).

The thickness of the boss [mm] is to be not less than $0{,}33 \cdot d_P$.

The aft end of the bossing is to be adequately supported.

5.3 Scantling of the end supports

The scantlings of end supports are to be specially considered. Supports are to be adequately designed to transmit the loads to the main structure.

End supports are to be connected to at least two deep floors of increased thickness or connected to each other within the vessel.

5.4 Stiffening of the boss plating

Stiffening of the boss plating is to be specially considered. At the aft end, transverse diaphragms are to be fitted at every frame and connected to floors of increased scantlings.

At the fore end, web frames spaced not more than four frames apart are to be fitted.

D. Equipment

1. Symbols

P = required bow anchor weight [kg]

P_i = increased required bow anchor weight [kg]

L_{OA} = length over all of the vessel [m]

B = breadth [m] defined in Section 1, A.1.

T = draught [m] defined in Section 1, A.1.

R = minimum breaking load of anchor chain cable [kN]

R_S = minimum breaking load of mooring cables [kN]

2. General

2.1 General requirements

2.1.1 The following requirements provide the equipment in anchors, chain cables and ropes for ranges of navigation **IN(0)**, **IN(0,6)**, **IN(1,2)** and **IN(2)** defined in the GL Rules for Classification and Surveys (I-2-1), Section 2.

2.1.2 The towline and the mooring lines are given as a guidance, but are not required as a condition of Classification.

2.1.3 Vessels built under GL's supervision and which are to have the character ✠ stated in their certificate and in the register book have to be equipped with anchors and chain cables complying with GL's Rules for Materials and Welding and having been tested on approved machines in the presence of a Surveyor.

2.1.4 The required equipment of anchors, chain cables, ropes and cables of the vessels trading on the inland waterways has to be determined according to 3. to 5.

Inland waterway vessels intended for use on the river Rhine and other European waterways (E.U.) shall also conform to the corresponding statutory Rules.

For vessels navigating on other inland waterways the actual Rules of the local Authority have to be observed.

2.1.5 GL, taking into account the conditions on the river concerned, may consent to a reduction in equipment for vessel intended for use only in a certain river system or area of inland water provided that a note of this river system or inland water is appended to the Character of Classification.

2.1.6 Barges to be carried aboard sea going ships

Barges to be carried aboard sea going ships are to be exempted from the anchor equipment requirements.

3. Anchors

3.1 General

3.1.1 Anchors shall be of an approved type.

3.1.2 Cast iron anchors shall not be permitted.

3.1.3 The weight of the anchors shall stand out in relief in a durable manner.

3.1.4 Anchors having a weight in excess of 50 kg shall be equipped with windlasses.

3.2 Bow anchors

3.2.1 Cargo carriers

The total weight P of the bow anchors of cargo carriers shall be calculated by the following formula:

$$P = k \cdot B \cdot T$$

$k = c \cdot \left(\frac{L_{OA}}{8 \cdot B}\right)^{0,5}$

$= c$ for pushed barges

c = coefficient defined in Table 7.5.

Table 7.5 Coefficient c

Deadweight	Coefficient c
≤ 400 t	45
> 400 t ≤ 650 t	55
> 650 t ≤ 1000 t	65
> 1000 t	70

3.2.2 Anchors for passenger vessels and other vessels without deadweight measurement

Passenger vessels and vessels not intended for the carriage of goods, apart from pushers, shall be fitted with bow anchors whose total weight P is obtained from the following formula:

$$P = k \cdot B \cdot T$$

k = coefficient corresponding to 3.2.1 but where, in order to obtain the value of the empirical coefficient c, the maximum displacement [m^3] shall be taken instead of the deadweight tonnage

3.2.3 Increased bow anchor weight

For passenger vessels and for vessels having a large windage area (container vessels) it is recommended to increase the bow anchor weight as follows:

$$P_i = P + 4 \cdot A_f$$

A_f = transverse profile view (windage area) of the hull above waterline at the draught T [m^2]

For calculating the area A_f all superstructures, deckhouses and cargoes (e.g. containers) having a breadth greater than B/4 are to be taken into account.

3.2.4 For vessels navigating in **IN(0)** and **IN(0,6)**, where the current velocity is lower than 6 km/h, the anchor weights according to 3.2.1 to 3.2.3 may be reduced by 13 %.

3.3 Stern anchors

3.3.1 The vessels referred to in 3.2.1 shall be fitted with stern anchors whose total weight is equal to 25 % of the weight P calculated in accordance with that figure.

3.3.2 Vessels whose maximum length exceeds 86 m shall, however, be fitted with stern anchors whose total weight is equal to 50 % of the weight P or P_i calculated in accordance with 3.2.1 to 3.2.3.

3.3.3 Pushers

Vessels intended to propel rigid convoys not more than 86 m in length shall be fitted with stern anchors whose total weight is equal to 25 % of the maximum weight P calculated in accordance with 3.2.1 for the largest formation considered as a nautical unit.

3.3.4 Vessels intended to propel downstream rigid convoys that are longer than 86 m shall be fitted with stern anchors whose total weight equals 50 % of the greatest weight P calculated in accordance with 3.2.1 for the largest formation considered as a nautical unit.

3.3.5 The following vessels are exempted from the stern anchor requirement:

– vessels for which the stern anchor weight will be less than 150 kg

– pushed lighters

3.4 Weight reduction

The anchor weights established in accordance with 3.2.1 to 3.3.4 may be reduced for certain special anchors. The following types of anchors have so far been recognised by GL as "high-holding-power anchors"; see Table 7.6.

3.5 Number of anchors

The total weight P specified for bow anchors may be distributed among one or two anchors. It may be reduced by 15 % where the vessel is equipped with only a single bow anchor and the hawse pipe is located amidships.

The required total weight of stern anchors for pushers and vessels whose maximum length exceeds 86 m may be distributed between one or two anchors.

The weight of the lightest anchor should be not less than 45 % of that total weight.

Table 7.6 Recognized types of anchors

Type of anchors	Weight reduction
HA – DU	30 %
D'Hone Special	30 %
Pool 1 (hollow)	35 %
Pool 2 (solid)	40 %
De Biesbosch – Danforth	50 %
Vicinay – Danforth	50 %
Vicinay AC 14	25 %
Vicinay Type 1	45 %
Vicinay Type 2	45 %
Vicinay Type 3	40 %
Stockes	35 %
D'Hone – Danforth	50 %
Schmitt high holding anchor	40 %

4. Chain cables

4.1 General

4.1.1 Chains true to gauge size are to be used as anchor chain cables.

4.1.2 Short-link or stud-link chain cables may be used as anchor chain cables.

4.2 Minimum breaking loads

4.2.1 The minimum breaking load of chain cables shall be calculated by the formulae given in Table 7.7.

For the breaking loads of short-link chains and stud-link chains, see Table 7.11 and Table 7.12, respectively.

4.2.2 Where the anchors have a weight greater than that required in 3.2.1 to 3.3.4, the breaking load of the anchor chain cable shall be determined as a function of the actual anchor weight.

Table 7.7 Minimum breaking loads R of chain cables

Anchor weight [kg]	R [kN]
≤ 500	$R = 0{,}35 \cdot P'$
> 500 and ≤ 2000	$R = \left(0{,}35 - \frac{P' - 500}{15000}\right) P'$
> 2000	$R = 0{,}25 \cdot P'$
P' = theoretical weight of each anchor determined in accordance with 3.2, 3.3 and 3.5	

4.2.3 The attachments between anchor and chain shall withstand a tensile load 20 % higher than the tensile strength of the corresponding chain.

4.3 Length of chain cables

4.3.1 Bow anchor chain cables

For the minimum length of bow anchor chain cables, see Table 7.8.

Table 7.8 Minimum length of bow anchor chain cables

Overall length L_{OA} of the vessel [m]	Minimum length of chain cables [m]	
	IN(0) to IN(0,6)	IN(1,2) to IN(2)
< 30	$\ell = 40$	$\ell = L_{OA} + 10$
≥ 30 and ≤ 50	$\ell = L_{OA} + 10$	
> 50	$\ell = 60$	

4.3.2 Stern anchor chain cables

The length of stern anchor chain cables is not to be less than 40 m. However, where vessels need to stop facing downstream they are to be equipped with a stern anchor chain of not less than 60 m in length.

4.3.3 Steel wire ropes

In special cases steel wire ropes may be permitted instead of anchor chain cables. The wire ropes are to have at least the same breaking strength as the required anchor chain cables, but shall be 20 % longer.

5. Mooring and towing equipment

5.1 Ropes

5.1.1 General

Steel wire ropes as well as fibre ropes from natural or synthetic fibres or ropes consisting of steel wires and fibre strands may be used for all ropes and cables.

During loading and unloading of tank vessels carrying inflammable liquids steel wire ropes only are to be used for mooring purposes.

5.1.2 Ropes and cables shall preferably be of the following type:

– 6 × 24 wires + 7 fibre cores for towing ropes and mooring lines

– 6 × 37 wires + 1 fibre core for warps

5.1.3 Pushed barges

Pushed barges are to be equipped with at least four wire ropes having a theoretical breaking load of 440 · kN instead of the towing ropes.

5.1.4 Mooring cables

It is recommended at least mooring cables as defined in Table 7.9 and Table 7.10.

Table 7.9 Mooring cables

Mooring cable	Minimum length of cable [m]
1st cable	$\ell' = \text{MIN}(\ell_1; \ell_2)$ $\ell_1 = L_{OA} + 20$ $\ell_2 = \ell_{max}$
2nd cable	$\ell'' = 2/3 \cdot \ell'$
3rd cable [1]	$\ell'' = 1/3 \cdot \ell'$
ℓ_{max} = 100 m [1] This cable is not required on board of vessels whose L_{OA} is less than 20 m.	

Table 7.10 Minimum breaking load R_S of mooring

$L_{OA} \cdot B \cdot T$	R_S [kN]
≤ 1000 m³	$R_S = 60 + \frac{L_{OA} \cdot B \cdot T}{10}$
> 1000 m³	$R_S = 150 + \frac{L_{OA} \cdot B \cdot T}{100}$

Note

For vessels navigating on the river Rhine, a declaration certificate in accordance with European standard EN 10204: 1991 is required on board.

5.1.5 Towing cables

Self propelled barges and pushers that are also able to tow shall be equipped with an at least 100 m long towing cable whose tensile strength [kN] is not less than one quarter of the total power [kW] of the power plant(s).

5.1.6 Tugs are to be equipped with a number of cables that are suitable for their operation. However, the most important cable shall be at least 100 m long and have a tensile strength [kN] not less than one third of the total power [kW] of the power plant(s).

5.2 Bollards

5.2.1 Every vessel has to be equipped with one double bollard each on the fore and after body on port and starboard side. In between, depending on the vessel’s size, one to three single bollards have to be arranged on either side of the vessel.

For larger vessels (as from L = 70 m) it is recommended to mount a triple bollard on the fore body and two double bollards on the after body on port and starboard side.

5.2.2 The bollards have to be led through the deck and below be attached to a horizontal plate spaced at least one bollard diameter from the deck. Said plate being of the same thickness as the bollard wall has to be connected to the side wall and adjacent beam knees. Should this be impossible, the bollards have to be constrained in a bollard seat on deck.

6. Hawse pipes and chain lockers

6.1 Arrangements

6.1.1 Hawse pipes are to be of substantial construction. Their position and slope are to be arranged so as to facilitate housing and dropping of the anchors and avoid damage to the hull during these operations. The parts on which the chains bear are to be rounded to a suitable radius.

6.1.2 The fore ship of the vessels shall be built in such a way that the anchors do not stick out of the side shell.

6.1.3 All mooring units and accessories, such as timbler, riding and trip stoppers, are to be securely fastened to the Surveyor’s satisfaction.

6.1.4 Where two chains are used, the chain locker is to be divided into two compartments, each capable of housing the full length of one line.

6.2 Hawse pipe scantlings

The gross thickness of the hawse pipes is not to be less than:

– for t_0 <10 mm

$t = \text{MIN}(t_0 + 2; 10)$

– for $t_0 \geq 10$ mm

$t = t_0$

t_0 = gross thickness of adjacent shell plating [mm]

Table 7.11 Breaking loads [kN], for short-link chain cables

Chain diameter [mm]	Grade K_1		Grade K_2		Grade K_3	
	Proof load	Breaking load	Proof load	Breaking load	Proof load	Breaking load
10	20	40	28	56	40	80
13	32	63	45	90	63	125
16	50	100	71	140	100	200
18	63	125	90	180	125	250
20	80	160	110	220	160	320
23	100	200	140	280	200	400
26	125	250	180	360	250	500
28	140	280	200	400	280	560
30	180	360	250	500	360	710
33	200	400	280	560	400	800
36	250	500	360	710	500	1000
39	280	560	400	800	560	1100
42	320	630	450	900	630	1250
Grades K_1, K_2 and K_3 are equivalent to grades Q_1, Q_2 and Q_3						

Table 7.12 Breaking loads [kN] for stud-link chain cables

Chain diameter [mm]	Grade K_1		Grade K_2		Grade K_3	
	Proof load	Breaking load	Proof load	Breaking load	Proof load	Breaking load
12,5	46	66	66	92	92	132
14	58	82	82	116	116	165
16	76	107	107	150	150	216
17,5	89	127	127	179	179	256
19	105	150	150	211	211	301
20,5	123	175	175	244	244	349
22	140	200	200	280	280	401
24	167	237	237	332	332	476
26	194	278	278	389	389	556
28	225	321	321	449	449	642
30	257	368	368	514	514	735
32	291	417	417	583	583	833
34	328	468	468	655	655	937
36	366	523	523	732	732	1050
38	406	581	581	812	812	1160
40	448	640	640	896	896	1280
42	492	703	703	981	981	1400
44	538	769	769	1080	1080	1540
46	585	837	837	1170	1170	1680
48	635	908	908	1270	1270	1810
Grades K_1, K_2 and K_3 are equivalent to grades Q_1, Q_2 and Q_3, respectively.						

E. Cranes and Bunker Masts

1. General

1.1 Application

1.1.1 The lifting appliances are not covered by Classification. Therefore, the following rules are to be considered as recommendations. However, they are to comply with national and/or international Regulations.

1.1.2 The fixed parts of lifting appliances, considered as an integral part of the hull, are the structures permanently connected by welding to the vessel's hull (for instance crane pedestals, masts, derrick heel seatings, etc., excluding cranes, derrick booms, ropes, rigging accessories, and, generally, any dismountable parts). The shrouds of masts embedded in the vessel's structure are considered as fixed parts.

1.1.3 The fixed parts of lifting appliances and their connections to the vessel's structure are covered by the Rules, even when the certification of lifting appliances is not required.

1.2 Arrangement

It is to be possible to lower the crane boom or the derrick structure and to secure them to the vessel during the voyage.

2. Hull girder strength

2.1 General

The hull girder strength is to be checked when the lifting appliance is operated, taking into account the various loading conditions considered, through criteria to be agreed with GL.

3. Hull scantlings

3.1 Loads transmitted by the lifting appliances

The forces and moments transmitted by the lifting appliances to the vessel's structures, during both lifting service and navigation, are to be submitted to GL.

3.2 Vessel's structures

The vessel's structures, subjected to the forces transmitted by the lifting appliances, are to be reinforced to GL's satisfaction.

F. Barge Coupling Devices

1. General

1.1 Application

1.1.1 Pushed barges and pushers/self-propelled vessels intended to push other vessels are to comply with the following requirements.

2. Pushing arrangements

2.1 Hull strengthening

2.1.1 The bow of the pusher and the stern of the barge are to be reinforced in order to withstand the connection forces (see 3.1).

The structural reinforcements are to be continued in aft and fore directions in order to transmit the connection forces to the hull structure of pusher and barge.

2.1.2 Pushers

Pushers are to be arranged with a device, having a width not smaller than two thirds of its breadth.

2.2 Pushing transoms

Pushing transoms, at the stem of the pushing vessel and the stern of the barge, are to be arranged as a box securely attached to the vessel structure by means of horizontal and vertical web plates. As a rule, the box plating thickness is not to be less than 10 mm.

These boxes are to be arranged in following way:

– exterior vertical plates: front walls with thickness not less than 18-20 mm and side walls with thickness of not less than 12 mm
– horizontal plates: 8 mm
– inner web plates: 8 mm
– strengthening of the hull by means of a doubling plate of thickness not less than 10 mm

Attention is to be paid that this box is not supported by elements thinner and of a less rigid structure.

2.3 Other structures

2.3.1 Pusher fore part

The pusher fore structure is to be aligned with the barge aft structure in way of the notch or the dock bottom.

2.3.2 Barge aft part

The barge aft structure is to be aligned with the pusher fore structure in way of the notch or the dock bottom.

3. Coupling devices

3.1 General

The coupling devices are to be fixed on deck, which is to be locally reinforced. The reinforcements are to be checked under the loads transmitted to the deck. These loads are to be indicated by the designer.

3.2 Connection force

For pushing in two positions, the horizontal load at the connection between the pusher and the barge [kN] may be obtained using the following formula:

$$R = \frac{0,266 \cdot P \cdot L}{B}$$

L = length [m] of the pusher

B = breadth [m] of the pusher

P = total break horse power [kW] of the propelling installation

3.3 Cables

3.3.1 Types

The cables are recommended to be one of the following types:

– 1370 N/mm^2 steel, 114 wires (6 × 19) with 6 strands and central fibre or metal core, for breaking loads of less than 147 kN

– 1370 N/mm^2 steel, 144 wires (6 × 24) with 6 strands and 7 fibre cores, for breaking loads between 147 kN and 490 kN included

– 1570 N/mm^2 steel, 222 wires (6 × 37) with 6 strands and central fibre core, for breaking loads greater than 490 kN

The cables are to be joined at their end or equipped with a sleeve.

3.4 Bollards

3.4.1 A safety coefficient not less than 4, considering the breaking load, is to be obtained when the bollards are subjected to the forces exerted by the cables.

Bollards supporting the cables of a convoy are never to be applied simultaneously for mooring purposes.

3.4.2 Diameter

The diameter of the bollards is to be not less than 15 times the diameter of the cable.

3.4.3 Spacing

Bollards fitted on the pusher are to be at adequate distance of the bollards fitted on the pushed vessel, namely at a distance not less than 3 m.

Section 8

Construction and Testing

A. Welding and Weld Connections

1. General

1.1 Application

1.1.1 The following requirements apply for the preparation, execution and inspection of welded connections in new construction, conversion or repair in hull structures.

If no separate requirements and remarks for welding in the individual areas as mentioned before are specified in this Rule, the requirements and conditions have to comply with the applicable requirements of GL.

The general requirements relevant to fabrication by welding and qualification of welding procedures are given in the relevant chapters of GL Rules for Materials and Welding.

1.1.2 Weld connections are to be executed according to the reviewed/approved plans. A detail not specifically represented in the plans is, if any, to comply with the applicable requirements.

All materials shall be of proven weldability. They shall be chosen in accordance with the intended application and the conditions of service. Their properties shall be documented to the specified extent by test certificates.

1.1.3 It is understood that welding of the various types of steel is to be carried out by means of welding procedures approved for the purpose, even though an explicit indication to this effect may not appear on the reviewed/approved plans.

1.1.4 The range of approval for welding applied by the Building Yard is to be submitted to GL and applies to all constructions.

1.1.5 The adoption of welding procedures is dependent on their previous qualification by GL. In addition, individual builders are to hold an authorization by GL to use these procedures, employing welders qualified by GL.

The Building Yards and the companies, including branches and suppliers, which perform welding works within the scope of these Rules, have to demonstrate the fulfilment of the welding technical quality requirements according to GL Rules. The welding technical quality requirements can be effected by evidence of fulfilment according to EN 729 / ISO 3834 in connection with a quality assurance system according to EN 29000 / ISO 9000.

1.2 Base material

1.2.1 The following requirements apply for the welding of hull structural steels or aluminium alloys of the types considered in Section 2, A. or other types accepted as equivalent by GL.

Materials to be used according to 1.1 are to be tested in compliance with the applicable provisions. Quality and testing requirements for materials covered here are outlined in GL Rules for Materials and Welding.

1.2.2 The service temperature is intended to be the ambient temperature, unless otherwise stated.

1.3 Welding consumables and procedures

1.3.1 Approval of welding consumables and procedures

Welding consumables and welding procedures adopted are to be approved by GL.

The requirements for the approval of welding consumables and welding procedures for the individual users are given in GL Rules for Materials and Welding.

The approval of the standard welding procedures is not required in the case of manual metal arc welding with approved welding consumables and auxiliaries for the steel grades A to D, except in the case of one side welding and welding in position vertical down (PG).

Standard welding procedures are: shielded metal-arc welding (SMAW) process no.111, metal-arc active gas welding (GMAW) process no.135, fluxed-cored wire metal-arc welding with active gas shield (FCAW) process no.136, submerged arc welding with wire electrode (SAW) process no.121 and tungsten inert gas arc welding (TIG) process no.141.

Note

Welding processes according to ISO 4063 and welding positions according to ISO 6947.

1.3.2 Consumables

For welding of hull structural steels, the minimum consumable grades to be adopted are specified in Table 8.1 depending on the steel grade.

It is recommended to use consumables for manual or semiautomatic welding (covered electrodes, flux-cored and fluxcoated wires) of higher strength hull structural steels which are at least of hydrogen-controlled grade H15. Where the carbon equivalent

Ceq is not more than 0,40 % and the thickness is below 50 mm, tested and approved welding consumables by GL according to Table 8.1 shall be used.

Especially, welding consumables with hydrogen-controlled grade H15 and H10 shall be used for welding hull steel forgings and castings of respectively ordinary strength level and higher strength level.

Manual electrodes, wires and fluxes are to be stored in suitable locations so as to ensure their preservation in proper condition. Especially, where consumables with hydrogen-controlled grade are to be used, proper precautions are to be taken to ensure that manufacturer's instructions are followed to obtain (drying) and maintain (storage, maximum time exposed, re-baking, ...) hydrogen-controlled grade.

The condition and remarks of welding consumables manufacturers have to be observed.

Table 8.1 Correlation of welding consumables and auxiliary materials to hull steel grades

Steel grade	Quality grades of welding consumables and auxiliary materials
A	1, 1Y, 2, 2Y, 3, 3Y
B, D	2, 2Y, 3, 3Y
AH32 - AH36	2Y, 2Y40, 3Y, 3Y40, 4Y, 4Y40
DH32 - DH36	
A40, D40	2Y40, 3Y40, 4Y40

Notes

– *Welding consumables approved for welding higher strength steels (Y) may be used in lieu of those approved for welding normal strength steels having the same or a lower grade; welding consumables approved in grade Y40 may be used in lieu of those approved in grade Y having the same or a lower grade.*

– *In the case of welded connections between two hull structural steels of different grades, as regards strength or notch toughness, welding consumables appropriate to one or the other steel are to be adopted.*

– *When joining normal to higher strength structural steel, consumables of the lowest acceptable grade for either material being joined may be used. When joining steels of the same strength level but of different toughness grade, consumables of the lowest acceptable grade for either material being joined may be used.*

– *It is recommended for welding of plates with thickness over 50 mm and up to 70 mm to use one quality grade higher and for welding of plates with thickness over 70 mm to use two quality grades higher.*

1.4 Personnel and equipment

1.4.1 Depending on the importance of the Building Yard, welding shops or branches shall have at least one fully qualified welding supervisor and one deputy welding supervisor, who are responsible for ensuring that the welding work is competently performed. The welding education of the welding supervisor has to be demonstrated to GL.

1.4.2 Welders

Manual and semi-automatic welding is to be performed by welders certified by GL. Welders for manual and semi-mechanized welding shall have passed a test which shall comply with the applicable GL Rules for Materials and Welding.

1.4.3 Automatic welding operators

Operators of fully mechanized or automatic welding equipment and of welding robots shall have been trained in the use of the equipment. They shall also be capable of setting or programming and operating the equipment in such a way that the required weld quality is achieved. The qualification of such personnel shall have passed a test which shall comply with the applicable GL Rules for Material and Welding.

1.4.4 Organisation

The internal organisation of the Building Yard, is to be such as to ensure compliance with the requirements in 1.4.2 and 1.4.3 and to provide for assistance and inspection of welding personnel, as necessary, by means of a suitable number of competent supervisors.

1.4.5 NDE operators

Non-destructive tests are to be carried out by qualified personnel, certified by GL, or by recognised bodies in compliance with appropriate standards.

The qualifications are to be appropriate to the specific applications.

1.4.6 Technical equipment and facilities

The welding equipment is to be appropriate to the adopted welding procedures, of adequate output power and such as to provide for stability of the arc in the different welding positions.

In particular, the welding equipment for special welding procedures is to be provided with adequate and duly calibrated measuring instruments, enabling easy and accurate reading, and adequate devices for easy regulation and regular feed.

1.5 Documentation to be submitted

1.5.1 The structural plans to be submitted for review/approval according to Section 1, A., are to contain the necessary data relevant to the fabrication by welding of the structures and items represented as far as Class is concerned.

For important structures, the main sequences of prefabrication, assembly and welding and non-destructive examination planned are also to be represented in the plans.

1.5.2 A plan showing the location of the various steel types is to be submitted at least for outer shell, deck and bulkhead structures.

1.6 Design

1.6.1 General

For the various structural details typical of welded construction in shipbuilding and not dealt with in the following, the rules of good practice, recognised standards and past experience are to apply as agreed by GL.

1.6.2 Plate orientation

The plates of the shell and strength deck are generally to be arranged with their length in the fore-aft direction. Possible exceptions to the above will be considered by GL on a case-by-case basis; tests as deemed necessary (for example, transverse impact tests) may be required by GL.

1.6.3 Overall arrangement

Particular consideration is to be given to the overall arrangement and structural details of highly stressed parts of the hull.

Plans relevant to the special details are to be submitted.

1.6.4 Prefabrication sequences

Prefabrication sequences are to be arranged so as to facilitate positioning and assembling as far as possible.

The amount of welding to be performed on board is to be limited to a minimum and restricted to easily accessible connections.

1.6.5 Local clustering of welds, minimum spacing, socket weldments

The local clustering of welds and short distances between welds are to be avoided.

– Adjacent butt welds should be separated from each other by a distance of at least:

  $50 \text{ mm} + 4 \cdot t$

– Fillet welds should be separated from each other and from butt welds by a distance of at least:

  $30 \text{ mm} + 2 \cdot t$,

where t is the plate thickness [mm].

The width of replaced or inserted plates (strips) should, however, be at least 300 mm or ten times the plate thickness, whichever is the greater.

Reinforcing plates, welding flanges, mountings and similar components socket welded into plating should be of the following minimum size:

$D = 120 + 3 \cdot (t - 10)$, without being less than 120 mm.

The corners of angular socket weldments are to be rounded to a radius of at least 50 mm unless the longitudinal butt welds are extended beyond the transverse butt weld as shown in Fig. 8.1. The socket welding sequence shall then comprise firstly the welding of the transverse seams (1) following by cleaning of the ends of these and then the welding of the longitudinal seams (2).

The socket welding of components with radiused corners should proceed in accordance with the relevant welding sequence description.

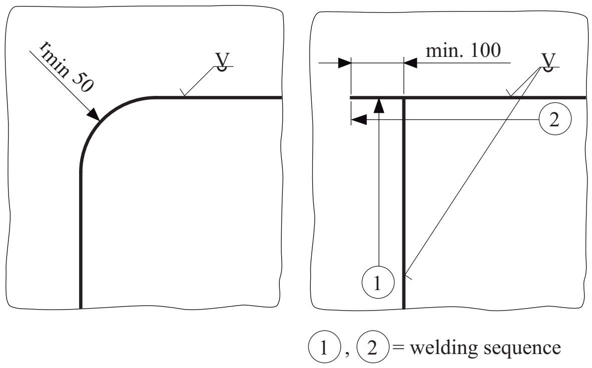


Fig. 8.1 Corners of socket weldments

2. Type of connections and preparation

2.1 General

The type of connection and the edge preparation are to be appropriate to the welding procedure adopted, the structural elements to be connected and the stresses to which they are subjected.

2.2 Butt welding

2.2.1 General

In general, butt connections of plating are to be full penetration, welded on both sides except where special procedures or specific techniques, considered equivalent by GL, are adopted.

Connections different from the above may be accepted by GL on a case-by-case basis; in such cases, the relevant detail and workmanship specifications are to be approved by GL.

2.2.2 Welding of plates with different thicknesses

In the case of welding of plates with a difference in gross thickness z equal to or greater than (see Fig. 8.2):

– 3 mm if $t_1 \leq 10$ mm

– 4 mm if $t_1 > 10$ mm,

a taper having a length of not less than 4 times the difference in gross thickness is to be adopted for connections of plating perpendicular to the direction of main stresses. For connections of plating parallel to the direction of main stresses, the taper length may be reduced to 3 times the difference in gross thickness.

The transition between different component dimensions shall be smooth and gradual.

When the difference in thickness is less than the above values, it may be accommodated in the weld transition between plates.

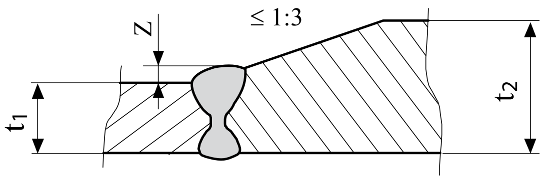


Fig. 8.2 Transition between different component dimensions

2.2.3 Butt welding edge preparation

Typical butt weld plate edge preparation for manual welding is specified in Table 8.2 and Table 8.3.

The acceptable root gap is to be in accordance with the adopted welding procedure and relevant bevel preparation.

2.2.4 Butt welding on permanent backing

Butt welding on permanent backing, i.e. butt welding assembly of two plates backed by the flange or the face plate of a stiffener, may be accepted where back welding is not feasible or in specific cases deemed acceptable by GL.

The type of bevel and the gap between the members to be assembled are to be such as to ensure a full penetration of the weld on its backing and an adequate connection to the stiffener as required.

2.2.5 Section, bulbs and flat bars

When lengths of longitudinals of the shell plating and strength deck within 0,6 · L amidships, or elements in general subject to high stresses, are to be connected together by butt joints, these are to be full penetration. Other solutions may be adopted if deemed acceptable by GL on a case-by-case basis.

The work is to be done in accordance with an approved procedure; in particular, this requirement applies to work done on board or in conditions of difficult access to the welded connection. Special measures may be required by GL.

Welding of bulbs without a doubler is to be performed by welders specifically certified by GL for such type of welding.

Table 8.2 Typical butt weld plate edge preparation (manual welding) - See Note

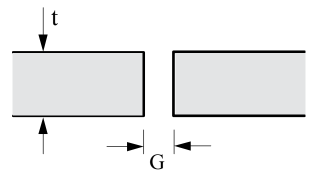
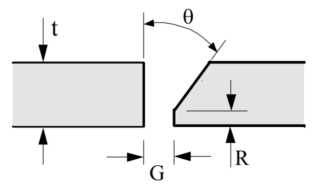
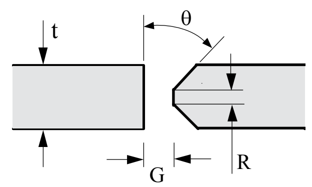
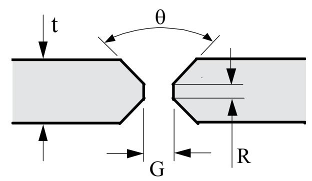
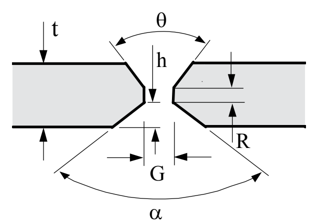
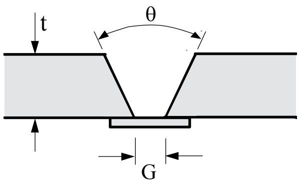
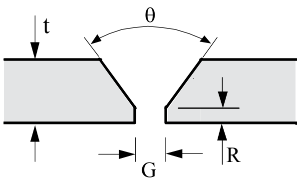
Detail	Standard
Square butt 	t ≤ 5 mm G = 3 mm
Single bevel butt 	t > 5 mm G ≤ 3 mm R ≤ 3 mm 50° ≤ θ ≤ 70°
Double bevel butt 	t > 19 mm G ≤ 3 mm R ≤ 3 mm 50° ≤ θ ≤ 70°
Double vee butt, uniform bevels 	G ≤ 3 mm R ≤ 3 mm 50° ≤ θ ≤ 70°
Double vee butt, non-uniform bevels 	G ≤ 3 mm R ≤ 3 mm 6 ≤ h ≤ t/3 mm θ = 50° α = 90°
Note *Different plate edge preparation may be accepted or approved by GL on the basis of an appropriate welding procedure specification.*	

Table 8.3 Typical butt weld plate edge preparation (manual welding) - See Note

Detail	Standard
Single vee butt, one side welding with backing strip (temporary or permanent) 	$3 \leq G \leq 9$ mm $30° \leq \theta \leq 45°$
Single vee butt 	$G \leq 3$ mm $50° \leq \theta \leq 70°$ $R \leq 3$ mm
Note *Different plate edge preparation may be accepted or approved by the Society on the basis of an appropriate welding procedure specification.*	

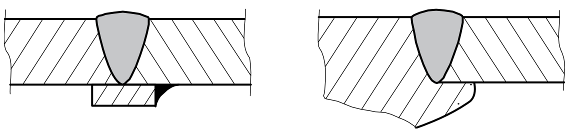


Fig. 8.3 Butt welding on permanent backing

2.3 Fillet welding

2.3.1 General

In general, ordinary fillet welding (without bevel) may be adopted for T connections of the various simple and composite structural elements, where they are subjected to low stresses (in general not exceeding 30 N/mm^2) and adequate precautions are taken to prevent the possibility of local laminations of the element against which the T web is welded.

Where this is not the case, partial or full T penetration welding according to 2.4 is to be adopted. This applies particularly to members over 12 mm in thickness constituting the whole or part of the engine seatings.

Further the special requirements in the different application range of GL have to be observed.

2.3.2 Fillet welding types

Fillet welding may be of the following types:

– continuous fillet welding, where the weld is constituted by a continuous fillet on each side of the abutting plate (see 2.3.3)

– intermittent fillet welding, which may be subdivided (see 2.3.4) into:

  – chain welding

  – scallop welding

  – staggered welding.

2.3.3 Continuous fillet welding

Continuous fillet welding is to be adopted:

– for watertight connections

– for connections of brackets, lugs and scallops

– at the ends of connections for a length of at least 75 mm

– where end brackets are fitted, in way of brackets and at least 50 mm beyond the bracket toes

– where intermittent welding is not allowed, according to 2.3.4

Continuous fillet welding may also be adopted in lieu of intermittent welding wherever deemed suitable, and it is recommended where the spacing p, calculated according to 2.3.4, is low.

2.3.4 Intermittent welding

In water and cargo tanks, in the bottom area of fuel oil tanks and of spaces where condensed or sprayed water may accumulate and in hollow components (e.g. rudders) threatened by corrosion, only continuous or intermittent scallop welding shall be used.

Where the plating is liable to be subjected to locally concentrated loads (e.g. due to grounding or impacts when berthing) intermittent welding with scallops should not be used.

The spacing p and the length d [mm] of an intermittent weld, shown in:

– Fig. 8.4 for chain welding

– Fig. 8.5 for scallop welding

– Fig. 8.6 for staggered welding,

are to be such that:

$$\frac{p}{d} \leq \varphi$$

where the coefficient φ is defined in Table 8.4 and Table 8.5 for the different types of intermittent welding, depending on the type and location of the connection.

In general, staggered welding is not allowed for connections subjected to high alternate stresses.

In addition, the following limitations are to be complied with:

– chain welding (see Fig. 8.4):

  $d \geq 75$ mm

  $p - d \leq 200$ mm

– scallop welding (see Fig. 8.5):

  $d \geq 75$ mm

  $p - d \leq 25$ t and $p - d \leq 150$ mm,

  where t is the lesser thickness of parts to be welded $v \leq 0{,}25$ b, without being greater than 75 mm

– staggered welding (see Fig. 8.6):

  $d \geq 75$ mm

  $p - 2\,d \leq 300$ mm

  $p \leq 2$ d for connections subjected to high alternate stresses.

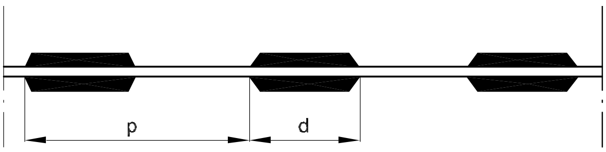


Fig. 8.4 Intermittent chain welding

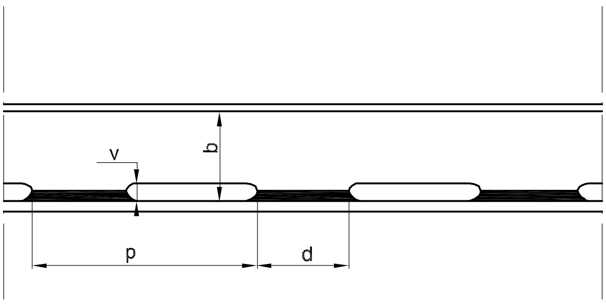


Fig. 8.5 Intermittent scallop welding

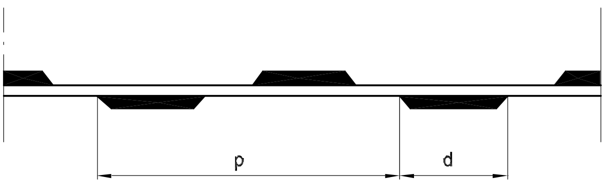


Fig. 8.6 Intermittent staggered welding

2.3.5 Throat thickness of fillet weld T connections

Fillet welds shall normally be made on both sides, and exceptions to this rule (as in the case of closed box girders and predominant shear stresses parallel to the weld) are subject to approval in each individual case.

The throat thickness of fillet weld T connections is to be obtained [mm] from the following formula:

$$t_T = w_F \cdot t \cdot \frac{p}{d}$$

w_F = welding factor, defined in Table 8.4 for the various hull structural connections; for connections of primary supporting members belonging to single skin structures and not mentioned in Table 8.4, w_F is defined in Table 8.5

t = actual gross thickness [mm] of the structural element which constitutes the web of the T connection

p, d = spacing and length [mm] of an intermittent weld, defined in 2.3.4.

For continuous fillet welds, p/d is to be taken equal to 1.

Unless otherwise agreed (e.g. for the fully mechanised welding of smaller plate thicknesses in appropriate clamping jigs), the minimum fillet weld throat thickness shall be the greater of:

– $$t_{T-min} = \sqrt{\frac{t_1 + t_2}{3}}$$

and:

– 3,0 mm, for $t_1 < 6$ mm

  3,5 mm, for $t_1 \geq 6$ mm

t_1, t_2 = thicknesses of connected plates with $t_1 < t_2$

In the case of automatic or semi-automatic deep penetration weld, the throat thickness may be reduced according to 2.3.8. Prior to start fabrication welding with deep penetration a production test has to be conducted to ensure the relevant weld quality. The kind of tests and the test scope has to be agreed with GL.

The throat thickness may be required by GL to be increased, depending on the results of structural analyses.

The leg length of fillet weld T connections is to be not less than 1,4 times the required throat thickness.

2.3.6 Throat thickness of welds between cut-outs

The throat thickness of the welds between the cut-outs in primary supporting member webs for the passage of ordinary stiffeners is to be not less than the value obtained, in [mm], from the following formula:

$$t_{TC} = t_T \cdot \frac{\varepsilon}{\lambda}$$

t_T = throat thickness defined in 2.3.5

ε, λ = dimensions [mm] to be taken as shown in:

– Fig. 8.7 for continuous welding

– Fig. 8.8 for intermittent scallop welding

2.3.7 Throat thickness of welds connecting ordinary stiffeners with primary supporting members

The throat thickness of fillet welds connecting ordinary stiffeners and collar plates, if any, to the web of primary supporting members is to be not less than $0{,}35 \cdot t_W$, where t_W is the web gross thickness [mm].

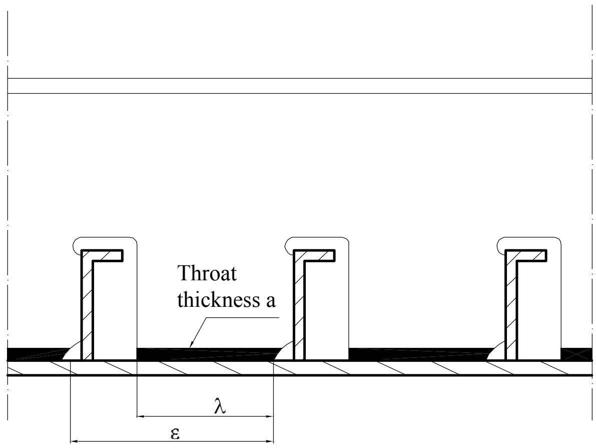


Fig. 8.7 Continuous fillet welding between cut-outs

Table 8.4 Welding factors w_F and coefficient φ for the various hull structural connections

Hull area	Connection of	Connection to		w_F [1]	φ [2 3] CH	SC	ST
General, unless otherwise specified in the table	watertight plates	boundaries		0,35			
	webs of ordinary stiffeners	plating		0,13	3,5	3,0	4,6
		face plate of fabricated stiffeners	at ends [4]	0,13			
			elsewhere	0,13	3,5	3,0	4,6
Bottom and double bottom	longitudinal ordinary stiffeners	bottom and inner bottom plating		0,13	3,5	3,0	4,6
	centre girder	keel		0,4			
		inner bottom plating		0,20	2,2	2,2	
	side girders	bottom and inner bottom plating		0,13	3,5	3,0	4,6
		floors (interrupted girders)		0,20	2,2		
	floors	bottom and inner bottom plating	in general	0,13	3,5	3,0	4,6
			at ends (20 % of span) for longitudinally framed double bottom	0,25	1,8		
		inner bottom plating in way of brackets of primary supporting members		0,25	1,8		
		girders (interrupted floors)		0,20	2,2		
		side girders in way of hopper tanks		0,35			
	partial side girders	floors		0,25	1,8		
	web stiffeners	floor and girder webs		0,13	3,5	3,0	4,6
Side and inner side	ordinary stiffeners	side and inner side plating		0,13	3,5	3,0	4,6
	girders and web frames in double hull vessels	side and inner side plating		0,35			

Table 8.4 Welding factors w_F and coefficient φ for the various hull structural connections *(continued)*

Hull area	Connection			w_F [1]	φ [2, 3]		
	of	to			CH	SC	ST
Deck	strength deck [5]	side plating		w_F = 0,45 if t ≤ 15 mm Partial penetration welding if t > 5 mm			
	non-watertight decks	side plating		0,20	2,2		
	ordinary stiffeners and intercostal girders	deck plating		0,13	3,5	3,0	4,6
	hatch coamings	deck plating	in general	0,35			
			at corners of hatchways for 15 % of the hatch length	0,45			
	web stiffeners	coaming webs		0,13	3,5	3,0	4,6
Bulkheads	tank bulkhead structures	tank bottom	plating and ordinary stiffeners (plane bulkheads)	0,45			
			vertical corrugations (corrugated bulkheads)	Full penetration welding, in general			
		Boundaries other than tank bottom		0,35			
	watertight bulkhead structures	boundaries		0,35			
	non-watertight bulkhead structures	boundaries	wash bulkheads	0,20	2,2	2,2	
			others	0,13	3,5	3,0	4,6
	ordinary stiffeners	Bulkhead plating	in general [6]	0,13	3,5	3,0	4,6
			at ends (25 % of span), where no end brackets are fitted	0,35	2,2		
Structures located forward of 0,75 · L from the AE [7]	bottom longitudinal ordinary stiffeners	bottom plating		0,20	1,8		
	floors and girders	bottom and inner bottom plating		0,25	2,2		
	side frames in panting area	side plating		0,20	1,8	1,8	
	webs of side girders in single side skin structures	side plating and face plate	A < 65 cm^2 [8]	0,25			
			A ≥ 65 cm^2 [8]	See Table 8.5			
After peak [7]	internal structures	each other		0,20			
	side ordinary stiffeners	side plating		0,20			
	floors	bottom and inner bottom plating		0,20			
Machinery space [7]	centre girder	keel and inner bottom plating	in way of main engine foundations	0,45			
			in way of seating of auxiliary machinery and boilers	0,35			
			elsewhere	0,25	1,8	1,8	
	side girders	bottom and inner bottom plating	in way of main engine foundations	0,45			
			in way of seating of auxiliary machinery and boilers	0,35			
			elsewhere	0,20	2,2	2,2	
	floors (except in way of main engine foundations)	bottom and inner bottom plating	in way of seating of auxiliary machinery and boilers	0,35			
			elsewhere	0,20	2,2	2,2	
	floors in way of main engine foundations	bottom plating		0,35			
		foundation plates		0,45			
	floors	centre girder	single bottom	0,45			
			double bottom	0,25	1,8	1,8	

Table 8.4 Welding factors w_F and coefficient φ for the various hull structural connections *(continued)*

Hull area	Connection: of	Connection: to		w_F [1]	φ [2, 3] CH	SC	ST
Super-structures and deckhouses	external bulkheads	deck	in general	0,35			
			engine and boiler casings at corners of openings (15% of opening length)	0,45			
	internal bulkheads	deck		0,13	3,5	3,0	4,6
	ordinary stiffeners	external and internal bulkhead plating		0,13	3,5	3,0	4,6
Hatch covers	ordinary stiffener	plating		0,13	3,5	3,0	4,6
Pillars	elements composing the pillar section	each other (fabricated pillars)		0,13			
	pillars	deck	pillars in compression	0,35			
			pillars in tension	Full penetration welding			
Ventilators	coamings	deck		0,35			
Rudders	horizontal and vertical webs directly connected to solid parts	each other		0,45			
	other webs	each other		0,20		2,2	
	webs	plating	in general	0,20		2,2	
			top and bottom plates of rudder plating	0,35			
		solid parts or rudder stock		According to Section 7, A.7.3 or A.7.4			

1 In connections for which $w_F \geq 0{,}35$, continuous fillet welding is to be adopted.

2 For coefficient φ, see 2.3.4. In connections for which no φ value is specified for a certain type of intermittent welding, such type is not permitted and continuous welding is to be adopted.

3 CH = chain welding, SC = scallop welding, ST = staggered welding.

4 See 3.5.

5 Fillet weld of 5 mm is acceptable for vessels of less than 90 m in length if thicknesses of strength deck and shell plating are less than 10 mm and if shell plating extends over the strength deck by more than 50 mm.

6 In tanks intended for the carriage of ballast or fresh water, continuous welding with $w_F = 0{,}35$ is to be adopted.

7 For connections not mentioned, the requirements for the central part apply.

8 A is the face plate sectional area of the side girders [cm^2].

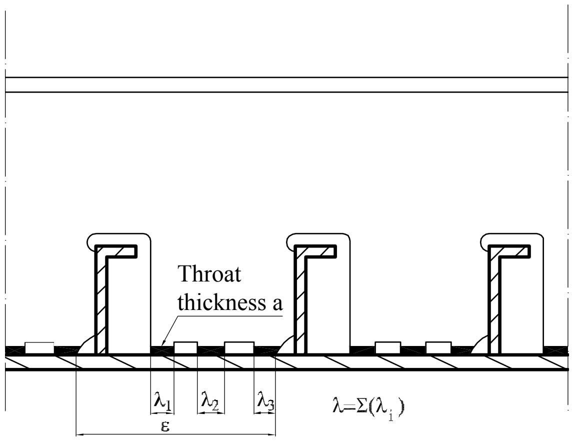


Fig. 8.8 Intermittent scallop fillet welding between cut-outs

2.3.8 Throat thickness of deep penetration fillet welding

When fillet welding is carried out with automatic welding processes, the throat thickness required in 2.3.5 may be reduced up to 15 %, depending on the penetration of the weld process. The evidence of the weld penetration is subject to a welding procedure test which has to be approved by GL. However, this reduction may not be greater than 1,5 mm.

The same reduction applies also for semi-automatic procedures.

The conditions of welding in down hand position (PG) have to comply with the applicable GL Rules for Material and Welding.

2.4 Partial and full T penetration welding

2.4.1 General

Partial or full T penetration welding is to be adopted for connections subjected to high stresses for which fillet welding is considered unacceptable by GL.

Typical edge preparations are indicated in:

– for partial penetration welds: Fig. 8.9 and Fig. 8.10, in which f [mm] is to be taken between 3 mm and t/3, and α between 45° and 60°

– for full penetration welds: Fig. 8.11 and Fig. 8.12, in which f [mm] is to be taken between 0 and 3 mm, and α between 45° and 60°.

  Back gouging is generally required for full penetration welds.

Table 8.5 Welding factors w_F and coefficient φ for connections of primary supporting members

Primary supporting Member	Connection			w_F [1]	φ [2, 3]		
	of	to			CH	SC	ST
General [4]	web, where A < 65 cm²	plating and face plate	at ends	0,20			
			elsewhere	0,15	3,0	3,0	
	web, where A ≥ 65 cm²	plating		0,35			
		face plate	at ends	0,35			
			elsewhere	0,25	1,8	1,8	
	end brackets	face plate		0,35			
In tanks, where A < 65 cm² [5]	web	plating	at ends	0,25			
			elsewhere	0,20	2,2	2,2	
		face plate	at ends	0,20			
			elsewhere	0,15	3,0	3,0	
	end brackets	face plate		0,35			
In tanks, where A ≥ 65 cm²	web	plating	at ends	0,45			
			elsewhere	0,35			
		face plate		0,35			
	end brackets	face plate		0,45			

1 In connections for which $w_F \geq 0{,}35$, continuous fillet welding is to be adopted.

2 For coefficient φ, see 2.3.4. In connections for which no φ value is specified for a certain type of intermittent welding, such type is not permitted.

3 CH = chain welding, SC = scallop welding, ST = staggered welding.

4 For cantilever deck beams, continuous welding is to be adopted.

5 For primary supporting members in tanks intended for the carriage of ballast or fresh water, continuous welding is to be adopted.

Notes

– *A is the face plate sectional area of the primary supporting member [cm²].*

– *Ends of primary supporting members means the area extended 20 % of the span from the span ends. Where end brackets are fitted, ends means the area extended in way of brackets and at least 100 mm beyond the bracket toes.*

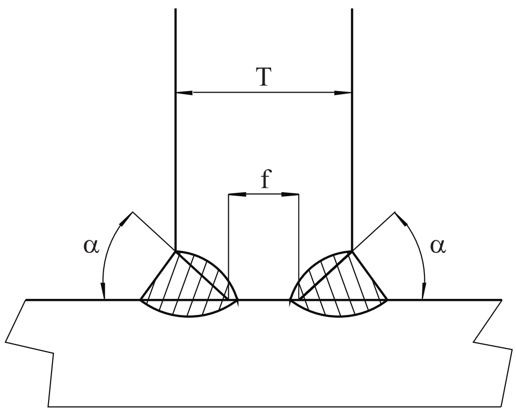


Fig. 8.9 Partial penetration weld

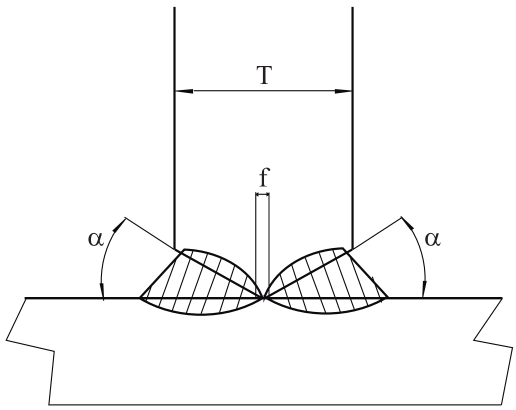


Fig. 8.11 Full penetration weld

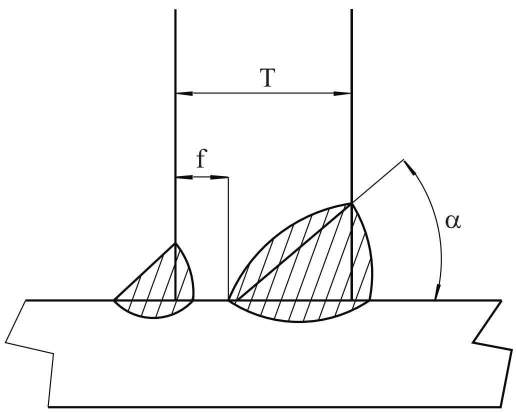


Fig. 8.10 Partial penetration weld

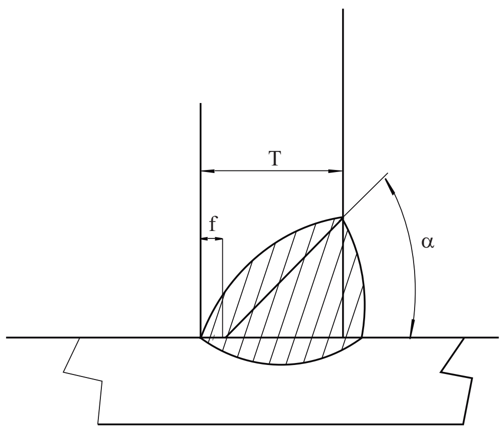


Fig. 8.12 Full penetration weld

2.4.2 Lamellar tearing

Precautions are to be taken in order to avoid lamellar tears, which may be associated with:

– cold cracking when performing T connections between plates of considerable thickness or high restraint

– large fillet welding and full penetration welding on higher strength steels

Additional provisions may be required by GL on a case-by-case basis.

2.5 Lap-joint welding

2.5.1 General

Lap-joint welding may be adopted for:

– peripheral connection of doublers

– internal structural elements subjected to very low stresses

Elsewhere, lap-joint welding may be allowed by GL on a case-by-case basis, if deemed necessary under specific conditions.

Continuous welding is generally to be adopted.

2.5.2 Gap

The surfaces of lap-joints are to be in sufficiently close contact.

2.5.3 Dimensions

The dimensions of the lap-joint are to be specified and are considered on a case-by-case basis. Typical details are given in Table 8.6.

2.6 Slot welding

2.6.1 General

Slot welding may be adopted in very specific cases subject to the special agreement of GL, e.g. for doublers according to Section 2, B.2.1.

In general, slot welding of doublers on the outer shell and strength deck is not permitted within $0{,}6 \cdot L$ amidships. Beyond this zone, slot welding may be accepted by GL on a case-by-case basis.

Slot welding is, in general, permitted only where stresses act in a predominant direction. Slot welds are, as far as possible, to be aligned in this direction.

2.6.2 Dimensions

Slot welds are to be of appropriate shape (in general oval) and dimensions, depending on the plate thickness, and may not be completely filled by the weld.

Typical dimensions of the slot weld and the throat thickness of the fillet weld are given in Table 8.6.

The distance between two consecutive slot welds is to be not greater than a value which is defined on a case-by-case basis taking into account:

– the transverse spacing between adjacent slot weld lines

– the stresses acting in the connected plates

– the structural arrangement below the connected plates

2.7 Plug welding

Plug welding may be adopted only when accepted by GL on a case-by-case basis, according to specifically defined criteria. Typical details are given in Table 8.6.

3. Specific weld connections

3.1 Corner joint welding

3.1.1 Corner joint welding, as adopted in some cases at the corners of tanks, performed with ordinary fillet welds, is permitted provided the welds are continuous and of the required size for the whole length on both sides of the joint.

3.1.2 Alternative solutions to corner joint welding may be considered by GL on a case-by-case basis.

3.2 Struts connecting ordinary stiffeners

In case of a strut connected by lap joint to the ordinary stiffener, the throat thickness of the weld is to be obtained [mm] from the following formula:

$$t_T = \frac{\eta \cdot F}{n_W \cdot \ell_W \cdot \tau} \cdot 10^3$$

F = maximum force transmitted by the strut [kN]

η = safety factor, to be taken equal to 2

n_W = number of welds in way of the strut axis

ℓ_W = length of the weld in way of the strut axis [mm]

τ = permissible shear stress, to be taken equal to 100 N/mm^2

3.3 Connection between propeller post and propeller shaft bossing

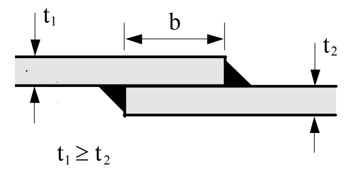
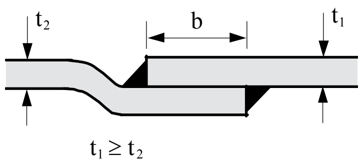
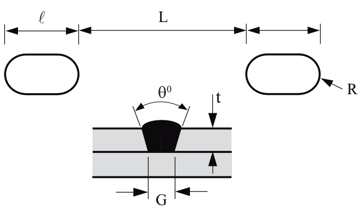
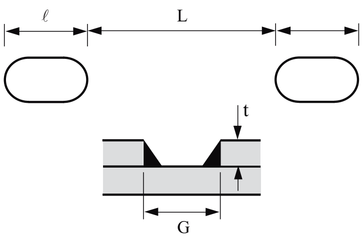
Fabricated propeller posts are to be welded with full penetration welding to the propeller shaft bossing.

3.4 Bar stem connections

The bar stem is to be welded to the bar keel generally with butt welding.

The shell plating is also to be welded directly to the bar stem with butt welding.

Table 8.6 Typical lap joint, plug and slot welding (manual welding)

Detail	Standard	Remark
Fillet weld in lap joint 	$b = 2 \cdot t_2 + 25$ mm	location of lap joint to be approved by GL
Fillet weld in joggled lap joint 	$b \geq 2 \cdot t_2 + 25$ mm	
Plug welding 	– $t \leq 12$ mm $\ell = 60$ mm R = 6 mm $40° \leq \theta \leq 50°$ G = 12 mm $L > 2 \cdot \ell$ – 12 mm $< t \leq 25$ mm $\ell = 80$ mm $R = 0{,}5 \cdot t$ [mm] $\theta = 30°$ G = t [mm] $L > 2 \cdot \ell$	
Slot welding 	– $t \leq 12$ mm G = 20 mm $\ell = 80$ mm $2 \cdot \ell \leq L \leq 3 \cdot \ell$, max 250 mm – $t > 12$ mm $G = 2 \cdot t$ $\ell = 100$ mm $2 \cdot \ell \leq L \leq 3 \cdot \ell$, max 250 mm	

3.5 Welds at the ends of structural members

3.5.1 As shown in Fig. 8.13, the web at the end of intermittently welded girders or stiffeners is to be continuously welded to the plating or the flange plate, as applicable, over a distance at least equal to the depth 'h' of the girder or stifffener, subject to a maximum of 300 mm and minimum of 75 mm.

3.5.2 The areas of bracket plates should be continuously welded over a distance at least equal to the length of the bracket plate. Scallops are to be located only beyond a line imagined as an extension of the free edge of the bracket plate.

3.5.3 Wherever possible, the free ends of stiffeners shall abut against the transverse plating or the webs of sections and girders so as to avoid stress concentrations in the plating. Failing this, the ends of the stiffeners shall be cut off obliquely and shall be continuously welded over a distance of at least $1{,}7 \cdot h$, subject to a maximum of 300 mm.

3.5.4 Where butt joints occur in flange plates, the flange shall be continuously welded to the web on both sides of the joint over a distance at least equal to the width of the flange.

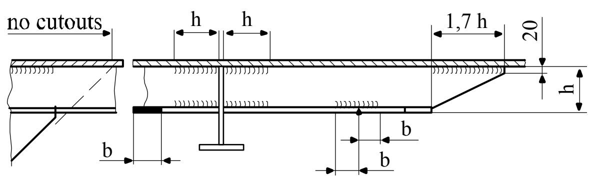


Fig. 8.13 Welds at the ends of girders and stiffeners

3.6 Joints between section ends and plates

3.6.1 Welded joints uniting section ends and plates (e.g. at lower ends of frames) may be made in the same plane or lapped.

Where no design calculations have been carried out or stipulated for the welded connections, the joints may be made analogously to those shown in Fig. 8.14.

If the thickness t_1 of the section web is greater than the thickness t of the plate to be connected, the length of the joint d shall be increased in the ratio t_1/t.

3.6.2 Where the joint lies in the plane of the plate, it may conveniently take the form of a single-bevel butt weld with fillet. Where the joint between the plate and the section end overlaps, the fillet weld shall be continuous on both sides and shall meet at the ends. The necessary 'a' dimension is to be calculated in accordance with 4.7 but need not exceed 0,6·t. The fillet weld throat thickness shall not be less than the minimum specified in 2.3.5.

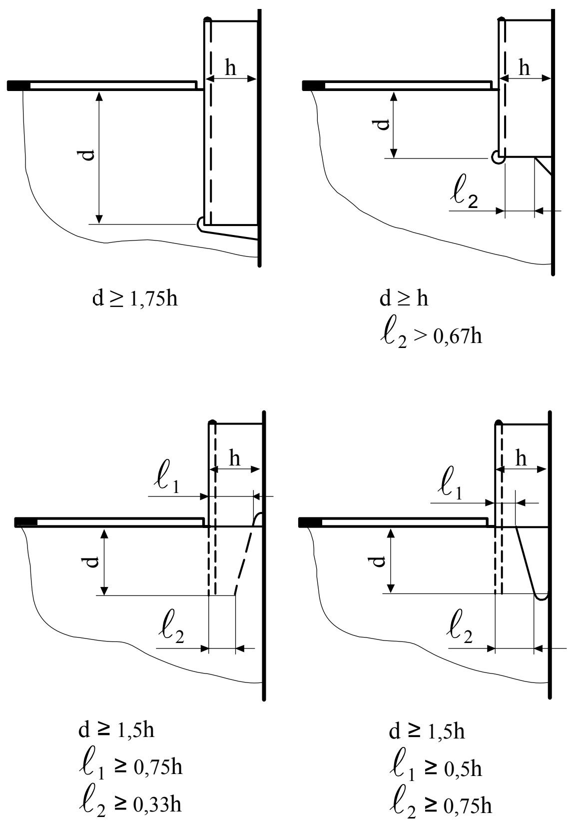


Fig. 8.14 Joints between section ends and plates

3.7 Welded joint between wale plate (sheerstrake) and side plating

If the difference in thickness between the wale plate and the side plating is at least 5 mm but not more than 10 mm, the longitudinal seam may take the form of a partial-penetration single-bevel butt weld with fillet, as shown in Fig. 8.15. Where the difference in thickness exceeds 10 mm, the proud edge is to be bevelled at an angle ≤ 45°.

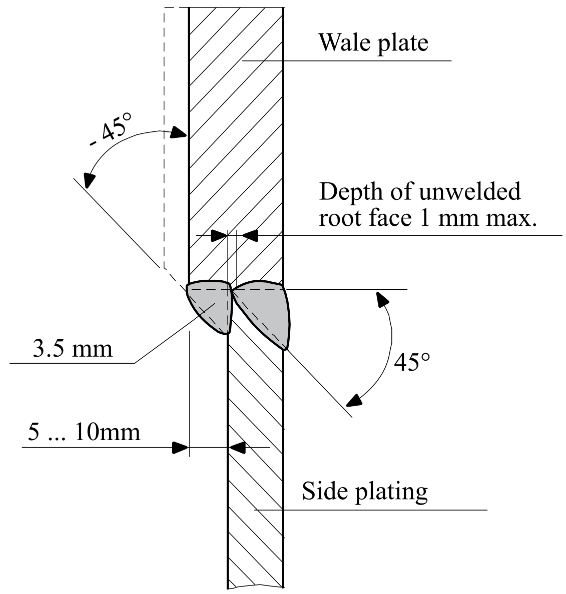


Fig. 8.15 Welded joint between wale plate and side plating

3.8 Welded shaft bracket joints

3.8.1 Unless cast in one piece and provided with integrally cast welding flanges (see Fig. 8.16), strut barrel and struts are to be connected to each other and to the shell plating in the manner shown in Fig. 8.17.

3.8.2 In the case of single-strut shaft brackets no welding may be performed on the arm at or close to the position of constraint. Such components shall be provided with integrally forged or cast welding flanges in the manner shown in Fig. 8.16.

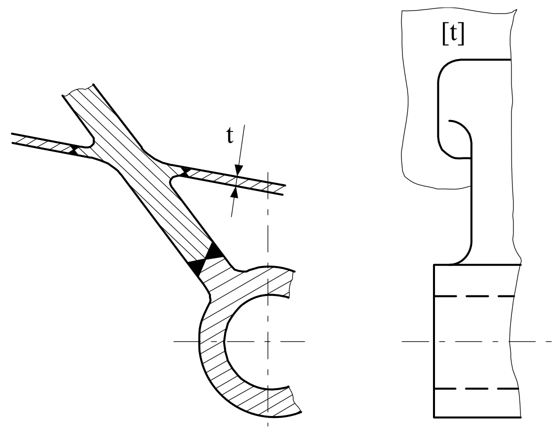
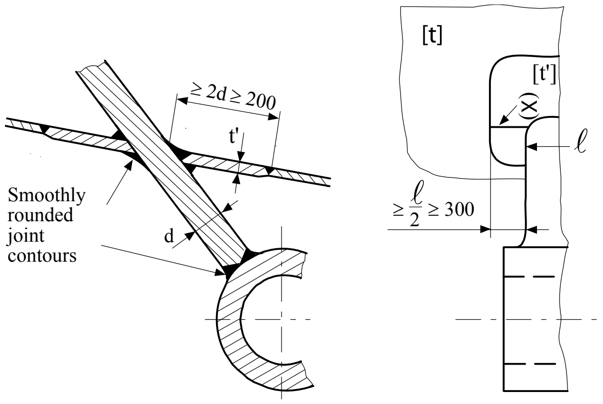


Fig. 8.16 Shaft bracket with integrally cast welding flanges

3.9 Rudder coupling flanges

3.9.1 Unless forged or cast steel flanges with integrally forged or cast welding flanges are used, horizontal rudder coupling flanges are to be joined to the rudder body by plates of graduated thickness and full penetration single or double-bevel welds as prescribed in 2.4 (see Fig. 8.18).



t = shell plating thickness

t' = d/3 + 5 mm, where d < 50 mm

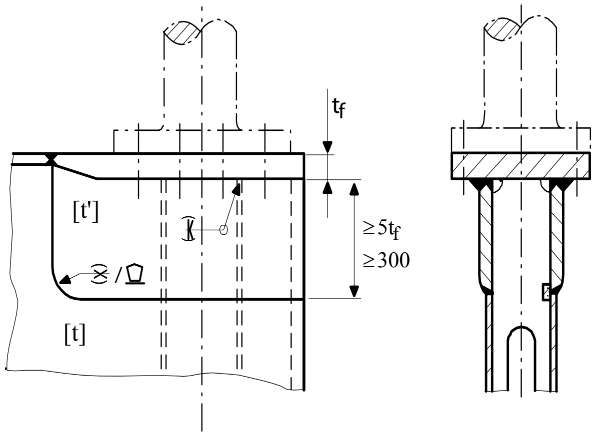
= $3 \cdot d^{0,5}$ mm, where d ≥ 50 mm

Fig. 8.17 Shaft bracket without integrally cast welding flanges

3.9.2 Allowance shall be made for the reduced strength of the coupling flange in the thickness direction (see Note). It is recommended that a material with guaranteed properties in the thickness direction (Z grade) should be used for this purpose. In case of doubt, proof by calculation of the adequacy of the welded connection shall be produced.

Note

Special characteristics peculiar to the material such as the (lower) strength values of rolled material in the thickness direction or the softening of cold hardened aluminium as a result of welding are factors which have to be taken into account when designing and dimensioning welded joints.



t = rudder plating thickness [mm]

t_f = actual flange thickness [mm]

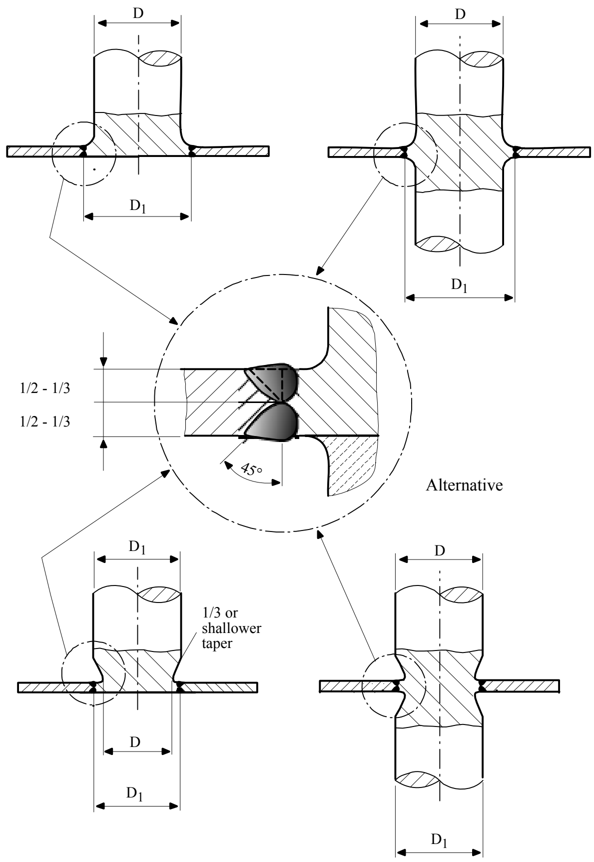
t′ = 1,25 t

Fig. 8.18 Horizontal rudder coupling flanges

3.10 Welded joints between rudder stock and rudder body

Where rudder stocks are welded into the rudder body, a thickened collar of the type shown in Fig. 8.19 shall be provided at the upper mounting (top edge of rudder body). The welded joint between the collar and the top rib is to take the form of a full penetration single or doublebevel weld in accordance with 2.4.

The transitions from the weld to the collar are to be free from notches. The collar radii shall be kept free from welds in every case.



D_1 = 1,1 · D without being less than D + 20 mm

$D_{1\,min}$ = D + 10 mm (applies only to alternative solution)

D = rudder stock diameter [mm]

Fig. 8.19 Rudder stock welded to rudder body

4. Direct calculation of fillet welds

4.1 General

4.1.1 As an alternative to the determination of the necessary fillet weld throat thicknesses in accordance with 2.3, a mathematical calculation may be performed, e.g. in order to optimize the weld thicknesses in relation to the loads. In the following a general stress analysis for mainly static loads is described. For welded joints subjected to loads dynamic in character, e.g. those at the shell connection of single-strut shaft brackets, proof of fatigue strength in compliance with GL Rules is to be submitted where necessary.

4.1.2 Definitions

For the purposes of calculation, the following stresses in a fillet weld are defined (see also Fig. 8.20):

$\sigma_{\perp}$ = normal stress perpendicular to direction of seam

$\tau_{\perp}$ = shear stress perpendicular to direction of seam

$\tau_{\parallel}$ = shear stress parallel to seam

Normal stresses parallel to the seam are disregarded in the calculation.

The calculated weld seam area is ($a \cdot \ell$).

For reasons of equilibrium, for the flank of the weld lying vertically to the shaded calculated weld seam area:

$\tau_{\perp} = \sigma_{\perp}$

For a composite stress the equivalent stress is to be calculated by the following formula:

$$\sigma_V = \sqrt{\sigma^2_{\perp} + \tau^2_{\perp} + \tau^2_{\parallel}}$$

Fillet welds are to be so dimensioned that the stresses determined by the formulae do not exceed the permissible stresses stated in Table 8.7.

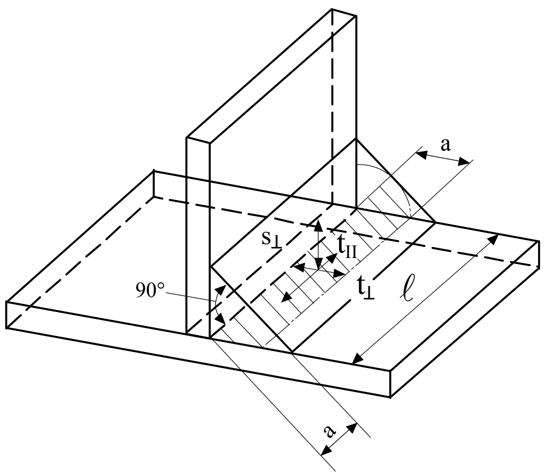


Fig. 8.20 Definition

4.2 Fillet welds stressed by normal and shear forces

Flank and frontal welds are regarded as being equal for the purposes of stress analysis. In view of this, normal and shear stresses [N/mm^2] are calculated as follows:

$$\sigma = \tau = \frac{P}{\Sigma a \cdot \ell}$$

a, ℓ = thickness and length [mm] of the fillet weld

P = force acting on the weld joint [N].

– For a joint as shown in Fig. 8.21, this produces:

– stresses in frontal fillet welds [N/mm^2]:

$$\tau_{\perp} = \frac{P_1}{2 \cdot a \cdot (\ell_1 + \ell_2)}$$

$$\tau_{\parallel} = \frac{P_2}{2 \cdot a \cdot (\ell_1 + \ell_2)} \pm \frac{P_2 \cdot e}{2 \cdot a \cdot F_t}$$

– stresses in flank fillet welds:

$$\tau_{\perp} = \frac{P_2}{2 \cdot a \cdot (\ell_1 + \ell_2)}$$

$$\tau_{\parallel} = \frac{P_1}{2 \cdot a \cdot (\ell_1 + \ell_2)} \pm \frac{P_2 \cdot e}{2 \cdot a \cdot F_t}$$

F_t = parameter [mm^2] equal to:
= $(\ell_2 + a) \cdot (\ell_1 + a)$

P_1, P_2 = forces [N]

a_1, ℓ_1, ℓ_2 = weld joint dimensions [mm]

– Equivalent stresses for frontal and flank fillet welds:

$$\sigma_V = \sqrt{\sigma^2_{\perp} + \tau^2_{\parallel}} \le \sigma_{Vzul}$$

– For a joint as shown in Fig. 8.22, this produces:

$$\tau_{\perp} = \frac{P_2}{2 \cdot a \cdot \ell} + \frac{3 \cdot P_1 \cdot e}{a \cdot \ell^2}$$

$$\tau_{\parallel} = \frac{P_1}{2 \cdot a \cdot \ell}$$

– Equivalent stress:

$$\sigma_V = \sqrt{\sigma^2_{\perp} + \tau^2_{\parallel}} \le \sigma_{Vzul}$$

where σ_{Vzul} is given in Table 8.7

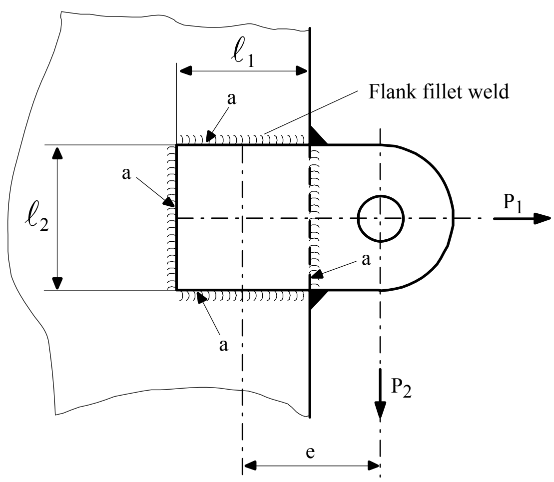


Fig. 8.21 Fillet welds stressed by normal and shear forces

Table 8.7 Permissible stresses in fillet welded joint

Material		R_{eH} or $R_{P\,0,2}$ [N/mm²]	Permissible stresses equivalent stress, shear stress $\sigma_{V\,zul}$, τ_{zul} [N/mm²]
Normal hull structural steel	A, B, D [1]	235	115
Higher tensile hull structural steel	AH 32 / DH 32 AH 36 / DH 36 [2]	315 355	145 160
High tensile steel	St E 460 St E 690	460 685	200 290
Austenitic stainles steels	1.4306/304L 1.4404/316L 1.4435/316L 1.4438/317L 1.4541/321 1.4571/316 Ti	180 190 190 195 205 215	110
Aluminium alloys	Al Mg 3 Al Mg 4,5 Al Mg Si 0,5 Al Mg Si 1	80 [3] 125 [3] 65 [4] 11 [4]	35 [5] 56 [6] 30 [7] 45 [8]

1 Also applies to structural steel S 235 JR according to EN 10025-2, rimming steel not permitted
2 Also applies to structural steel S 355 J2 according to EN 10025-2
3 Plates, soft condition
4 Profiles, cold hardened
5 Welding consumables: S-Al Mg 3, S-Al Mg 5 or S-Al Mg 4,5 Mn
6 Welding consumables: S-Al Mg 4,5 Mn
7 Welding consumables: S-Al Mg 3, S-Al Mg 5, S-Al Mg 4,5 Mn or SAl Si 5
8 Welding consumables: S-Al Mg 5 or S-Al Mg 5, S-Al Mg 4,5 Mn

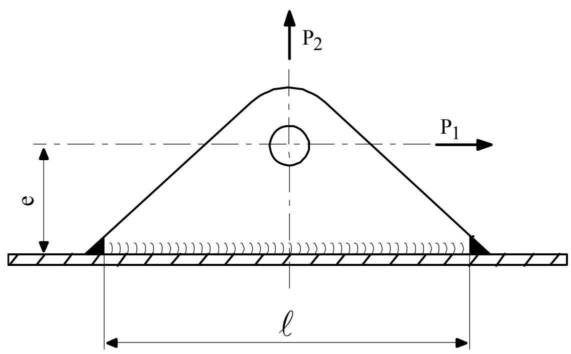


Fig. 8.22 Fillet welds stressed by normal and shear forces

4.3 Fillet welds stressed by bending moments and shear forces

The stresses at the fixing point of a girder (a cantilever beam is given as an example in Fig. 8.23) are calculated as follows:

a) Normal stress due to bending [N/mm²]:

$$\sigma_{\perp}(z) = \frac{M}{J_S} \cdot z$$

$$\sigma_{\perp max} = \frac{M}{J_S} \cdot e_u \quad \text{for}\, e_u > e_0$$

$$\sigma_{\perp max} = \frac{M}{J_S} \cdot e_0 \quad \text{for}\, e_u < e_0$$

b) Shear stress due to shear force [N/mm²]:

$$\tau_{\parallel}(z) = \frac{Q \cdot S_{S(z)}}{10 \cdot J_S \cdot \sum a}$$

$$\tau_{\parallel}(z) = \frac{Q \cdot S_{S(z)}}{10 \cdot J_S \cdot 2 \cdot a}$$

c) Equivalent stress:

It has to be proved that neither $\tau_{\perp\,max}$ in the region of the flange nor $\tau_{\parallel\,max}$ in the region of the neutral axis nor the equivalent stress σ_V exceed the permitted limits given in Table 8.7 at any given point. The equivalent stress σ_V should always be calculated at the web-flange connection.

$$\sigma_V = \sqrt{\sigma^2_{\perp} + \tau^2_{\parallel}}$$

M = bending moment at the point of the welded joint [N·m]

Q = shear force at the point of the welded joint [N]

J_S = moment of inertia of the welded joint relative to the x-axis [cm^4]

$S_{S(z)}$ = first moment of the connected weld section at the point under consideration [cm^3]

z = distance from the neutral axis [cm]

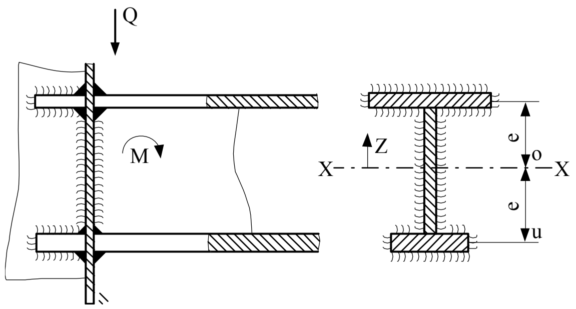


Fig. 8.23 Fillet welds stressed by bending moments and shear forces

4.4 Fillet welds stressed by bending and torsional moments and shear forces

For the normal and shear stresses [N/mm^2], resulting from bending, see 4.3. Torsional stresses resulting from the torsional moment M_T are to be calculated as follows:

$$\tau_T = \frac{M_T \cdot 10^3}{2 \cdot a_m \cdot A_m}$$

M_T = torsional moment [N·m]

a_m = mean fillet weld throat thickness [mm]

A_m = mean area enclosed by weld seam [mm^2].

The equivalent stress composed of all three components (bending, shear and torsion) is calculated by the following formulae:

– where $\tau_{\parallel}$ and $\tau_{\perp}$ do not have the same direction:

$$\sigma_V = \sqrt{\sigma^2{}_{\perp} + \tau^2{}_{\perp} + \tau^2{}_{\parallel}}$$

– where $\tau_{\parallel}$ and $\tau_{\perp}$ have the same direction:

$$\sigma_V = \sqrt{\sigma^2{}_{\perp} + \left(\tau_{\perp} + \tau_{\parallel}\right)^2}$$

4.5 Continuous fillet welded joints between web and flange of bending girders

The stress analysis has to be performed in the area of maximum shear forces.

In the case of continuous double fillet weld connections, the shear stress [N/mm^2] is to be calculated as follows:

$$\tau_{\parallel} = \frac{Q \cdot S}{10 \cdot J \cdot 2 \cdot a}$$

Q = shear force at the point considered [N]

S = first moment of the cross sectional area of the flange connected by the weld to the web in relation to the neutral beam axis [cm^3]

J = moment of inertia of the girder section [cm^4]

a = thickness of the fillet weld [mm]

The fillet weld thickness required [mm] is:

$$a_{erf} = \frac{Q \cdot S}{10 \cdot J \cdot 2 \cdot \tau_{zul}}$$

4.6 Intermittent fillet welded joints between web and flange of bending girders

The shear stress [N/mm^2] is to be calculated as follows:

$$\tau_{\parallel} = \frac{Q \cdot S \cdot \alpha}{10 \cdot J \cdot 2 \cdot a} \cdot \frac{b}{\ell}$$

ℓ = length of the fillet weld

b = interval

α = stress concentration factor which takes into account increases in shear stress at the ends of the lengths of fillet weld seam ℓ

= 1,1

The fillet weld thickness required [mm] is:

$$a_{erf} = \frac{1{,}1 \cdot Q \cdot S}{10 \cdot J \cdot 2 \cdot \tau_{zul}} \cdot \frac{b}{\ell}$$

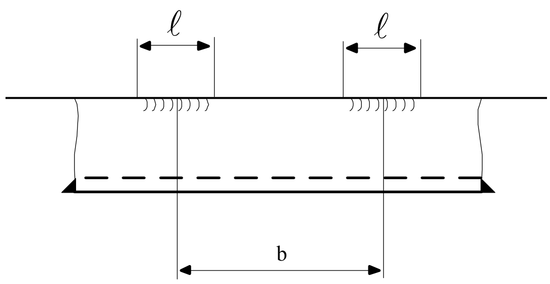


Fig. 8.24 Intermittent fillet welded joints between web and flange of bending girders

4.7 Fillet weld connections on overlapped profile joints

4.7.1 Profiles joined by means of two flank fillet welds (see Fig. 8.25):

$$\tau_{\perp} = \frac{Q}{2 \cdot a \cdot d}$$

$$\tau_{\parallel} = \frac{M \cdot 10^3}{2 \cdot a \cdot c \cdot d}$$

The equivalent stress is:

$$\sigma_V = \sqrt{\tau^2_{\perp} + \tau^2_{\parallel}}$$

Q = shear force to be transmitted [N]

M = bending moment to be transmitted [N·m]

c, d, ℓ_1, ℓ_2, r = dimensions [mm], defined in Fig. 8.25

$$c = r + \frac{(3 \cdot \ell_1 - \ell_2)}{4}$$

As the influence of the shear force can generally be neglected, the required fillet weld thickness [mm] is:

$$a_{erf} = \frac{M \cdot 10^3}{2 \cdot c \cdot d \cdot \tau_{zul}}$$

or

$$a_{erf} = \frac{w \cdot 10^3}{1{,}5 \cdot c \cdot d}$$

w = section modulus of the joined profile [cm^3]

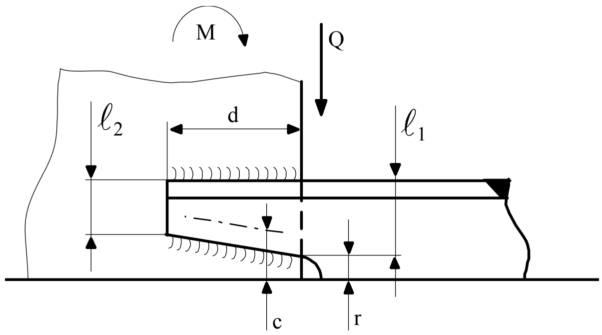


Fig. 8.25 Fillet weld connections on overlapped profile joints: case a

4.7.2 Profiles joined by means of two flank and two front fillet welds (all-round welding as shown in Fig. 8.26):

$$\tau_{\perp} = \frac{Q}{a(2 \cdot d + \ell_1 + \ell_2)}$$

$$\tau_{\parallel} = \frac{M \cdot 10^3}{a \cdot c(2 \cdot d + \ell_1 + \ell_2)}$$

The equivalent stress is:

– where $\tau_{\parallel}$ and $\tau_{\perp}$ do not have the same direction:

$$\sigma_V = \sqrt{\tau^2_{\perp} + \tau^2_{\parallel}}$$

– where $\tau_{\parallel}$ and $\tau_{\perp}$ have the same direction:

$$\sigma_V = \tau_{\perp} + \tau_{\parallel}$$

As the influence of the shear force can generally be neglected, the required fillet weld thickness [mm] is:

$$a_{erf} = \frac{M \cdot 10^3}{2 \cdot c \cdot d \cdot \left(1 + \frac{\ell_1 + \ell_2}{2 \cdot d}\right) \cdot \tau_{zul}}$$

or

$$a_{erf} = \frac{W \cdot 10^3}{1{,}5 \cdot c \cdot d \cdot \left(1 + \frac{\ell_1 + \ell_2}{2 \cdot d}\right)}$$

c, d, ℓ_1, ℓ_2, r = Dimensions [mm] defined in Fig. 8.26.

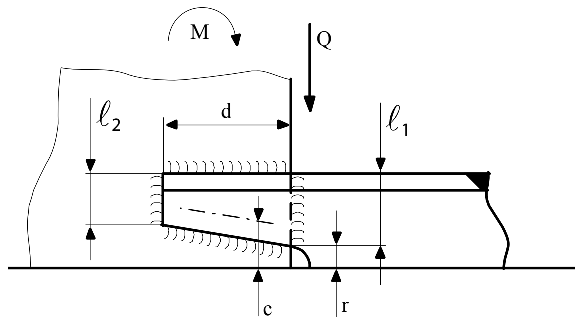


Fig. 8.26 Fillet weld connections on overlapped profile joints: case b

4.8 Bracket joints

Where profiles are joined to brackets as shown in Fig 8.27 the average shear stress [N/mm^2] is:

$$\tau = \frac{3 \cdot M \cdot 10^3}{4 \cdot a \cdot d^2} + \frac{Q}{2 \cdot a \cdot d}$$

M = moment of constraint [N·m]

Q = shear force [N]

d = length of overlap [mm]

The required fillet weld thickness [mm] is to be calculated from the section modulus of the profile, w, as follows:

$$a_{erf} = \frac{w \cdot 10^3}{d^2}$$

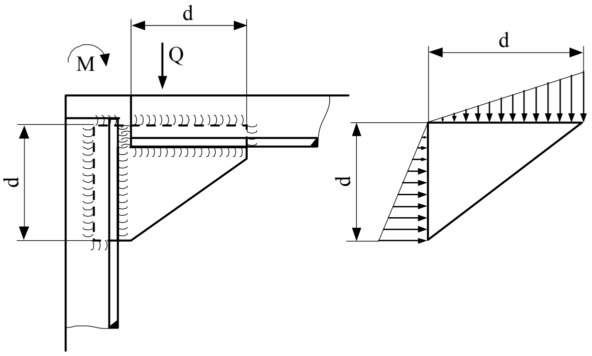


Fig. 8.27 Bracket joint with idealized stress distribution resulting from moment M and shear Q

4.9 Admissible stresses

Both, the individual and the reference stresses calculated in accordance with the formulae in 4.1.2 and 4.2 to 4.8, shall not exceed the admissible stresses as indicated in Table 8.7 for various materials mainly exposed to static loading. The values stated for high tensile steels, stainless austenitic steels and aluminium alloys are applicable only if the strength properties of the weld material employed are at least equal to those of the base material. Where this is not the case, the "a"-values calculated are to be increased accordingly.

5. Workmanship

5.1 Welding procedures and consumables

The various welding procedures and consumables are to be used within the limits of their approval and in accordance with the conditions of use specified in the respective approval documents.

Welding may only be performed on materials whose identity and weldability under the given fabricating conditions can be unequivocally established by reference to markings, certificates, etc. Only welding consumables and auxiliary materials tested and approved according to GL Rules and of a quality grade standards recognized by GL appropriate to the base material to be welded may be used.

5.2 Welding operations

5.2.1 Weather protection

The area in which welding work is performed (particularly outside) is to be sheltered from wind, damp and cold. Where gas-shielded arc welding is carried out, special attention is to be paid to ensuring adequate protection against draughts. When working in the open under unfavourable weather conditions it is advisable to dry welding edges by heating.

5.2.2 Butt connection edge preparation

The edge preparation is to be of the required geometry and correctly performed. In particular, if edge preparation is carried out by flame, it is to be free from cracks or other detrimental notches.

Seam edges (groove faces) prepared by thermal cutting shall be finished by machining (e.g. grinding) if a detrimental effect on the welded joint as a result of the cutting operation cannot be ruled out. Welding edges of steel castings and forgings shall always be ground as a minimum requirement; roll scale or casting skin is to be removed.

5.2.3 Surface condition

The surfaces to be welded are to be free from rust, moisture and other substances, such as mill scale, slag caused by oxygen cutting, grease or paint, which may produce defects in the welds.

Effective means of cleaning are to be adopted particularly in connections with special welding procedures; flame or mechanical cleaning may be required.

The presence of a shop primer may be accepted, provided it has been approved by GL.

Shop primers are to be approved by GL for a specific type and thickness according to GL Rules for Materials and Welding.

5.2.4 Assembling and gap

The setting appliances and system to be used for positioning are to ensure adequate tightening adjustment and an appropriate gap of the parts to be welded, while allowing maximum freedom for shrinkage to prevent cracks or other defects due to excessive restraint.

The gap between the edges is to comply with the required tolerances or, when not specified, it is to be in accordance with normal good practice.

When preparing and assembling components, care shall be taken to ensure compliance with the weld shapes and root openings (air gaps) specified in the manufacturing documents. With single and double bevel butt welds in particular, care shall be taken to make an adequate root opening to achieve sufficient root penetration. Moisture or dirt shall be carefully removed before welding.

5.2.5 Gap in fillet weld T connections

In fillet weld T connections, a gap g, as shown in Fig. 8.28, may not be greater than 2 mm. In the case of a gap greater than 2 mm, the throat thickness shall be increased accordingly, or a single or double-bevel weld shall be made, subject to the consent of the Surveyor. Inserts and wires may not be used as fillers.

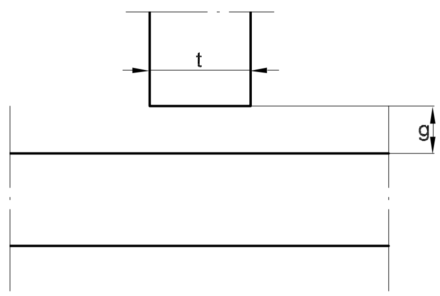


Fig. 8.28 Gap in fillet weld T connections

5.2.6 Plate misalignment in butt connections

The misalignment m, measured as shown in Fig. 8.29, between plates with the same gross thickness t is to be less than 0,15 t, without being greater than 3 mm.

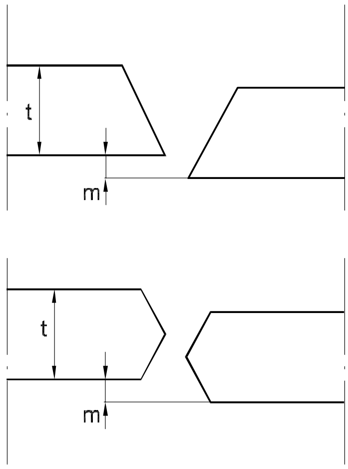


Fig. 8.29 Plate misalignment in butt connections

5.2.7 Misalignment in cruciform connections

The misalignment m in cruciform connections, measured on the median lines as shown in Fig. 8.30, is to be less than:

– t/2, in general, where t is the gross thickness of the thinner abutting plate for steel grade A, B and D

– t/3, where t is the gross thickness of the thinner abutting plate for steel grade AH 32 to DH 40

GL may require lower misalignment to be adopted for cruciform connections subjected to high stresses.

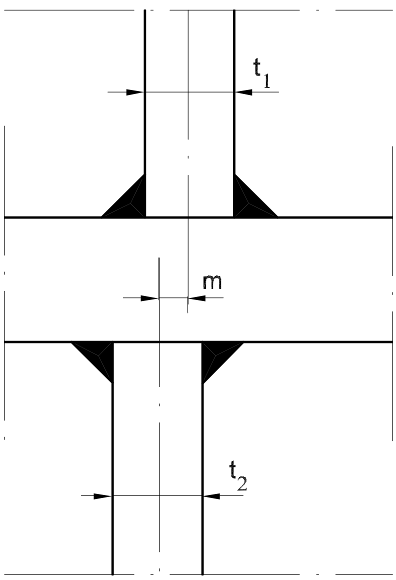


Fig. 8.30 Misalignment in cruciform connections

5.2.8 Assembling of aluminium alloy parts

When welding aluminium alloy parts, particular care is to be taken so as to:

– reduce as far as possible restraint from welding shrinkage, by adopting assembling and tack welding procedures suitable for this purpose

– keep possible deformations within the allowable limits

Further specifications may be required by GL on a case-by-case basis.

5.2.9 Preheating and interpass temperatures, welding in cold conditions

The need for and degree of preheating is determined by various factors, such as chemical composition, plate thickness, two or three-dimensional heat dissipation, ambient and work piece temperatures, or heat input during welding.

At low (subzero) temperatures, suitable measures shall be taken to ensure the satisfactory quality of the welds. Such measures include the shielding of components, large area preliminary warming and preheating, especially when welding with a relatively low heat input, e.g. when laying down thin fillet welds or welding thick-walled components. Wherever possible, no welding should be performed at temperatures below −10 °C.

Normal-strength hull structural steels do not normally require preheating. In the case of corresponding thick-walled steel castings and forgings, gentle preheating to approximately 80 – 120 °C is advisable. The necessary preheating temperatures of other materials (e.g. thick-walled higher tensile steels) have to comply with the applicable GL Rules for Material and Welding.

Suitable preheating, to be maintained during welding, and slow cooling may be required by GL on a case-by-case basis.

The preheating and interpass temperatures are to be shown in the welding procedures which have to be approved by GL.

5.2.10 Welding sequences

Welding sequences and direction of welding are to be determined so as to minimise deformations and prevent defects in the welded connection.

All main connections are generally to be completed before the vessel is afloat.

Departures from the above provision may be accepted by GL on a case-by-case basis, taking into account any detailed information on the size and position of welds and the stresses of the zones concerned, both during vessel launching and with the vessel afloat.

5.2.11 Interpass cleaning

After each run, the slag is to be removed by means of a chipping hammer and a metal brush; the same precaution is to be taken when an interrupted weld is resumed or two welds are to be connected.

5.2.12 Stress relieving

It is recommended and in some cases it may be required that special structures subject to high stresses, having complex shapes and involving welding of elements of considerable thickness (such as rudder spades and stern frames), are prefabricated in parts of adequate size and stress-relieved in the furnace, before final assembly, at a temperature within the range 550 ÷ 620 °C, as appropriate for the type of steel.

Further specifications may be required by GL on a case-by-case basis.

Welding may be performed at the cold formed sections and adjacent areas of hull structural steels and comparable structural steels provided that the minimum bending radius is not less than those specified in Table 8.8

Table 8.8 Minimum bending radius of welding of cold formed sections

Plate thickness [mm]	Minimum inner bending radius [r]
up to 4	1,0·t
up to 8	1,5·t
up to 12	2,0·t
up to 24	3,0·t
over 24	5,0·t

5.3 Crossing of structural elements

In the case of T crossing of structural elements (one element continuous, the other physically interrupted at the crossing) when it is essential to achieve structural continuity through the continuous element (continuity obtained by means of the welded connections at the crossing), particular care is to be devoted to obtaining the correspondence of the interrupted elements on both sides of the continuous element. Suitable systems for checking such correspondence are to be adopted.

6. Modifications and repairs during construction

6.1 General

Deviations in the joint preparation and other specified requirements, in excess of the permitted tolerances and found during construction, are to be repaired as agreed with GL on a case-by-case basis.

6.2 Gap and weld deformations

Welding by building up of gaps exceeding the required values and repairs of weld deformations may be accepted by GL upon special examination.

6.3 Defects

Defects and imperfections on the materials and welded connections found during construction are to be evaluated for possible acceptance on the basis of the applicable requirements of GL.

Where the limits of acceptance are exceeded, the defective material and welds are to be discarded or repaired, as deemed appropriate by the Surveyor on a case-by-case basis.

When any serious or systematic defect is detected either in the welded connections or in the base material, the manufacturer is required to promptly inform the Surveyor and submit the repair proposal.

The Surveyor may require destructive or non-destructive examinations to be carried out for initial identification of the defects found and, in the event that repairs are undertaken, for verification of their satisfactory completion.

6.4 Repairs on structures already welded

In the case of repairs involving the replacement of material already welded on the hull, the procedures to be adopted are to be agreed with GL on a case-by-case basis.

7. Inspections and checks

7.1 General

7.1.1 Materials, workmanship, structures and welded connections are to be subjected, at the beginning of the work, during construction and after completion, to inspections by the Building Yard suitable to check compliance with the applicable requirements, reviewed/approved plans and standards.

7.1.2 The manufacturer is to make available to the Surveyor a list of the manual welders and welding operators and their respective qualifications.

The manufacturer's internal organisation is responsible for ensuring that welders and operators are not employed under improper conditions or beyond the limits of their respective qualifications and that welding procedures are adopted within the approved limits and under the appropriate operating conditions.

7.1.3 The manufacturer is responsible for ensuring that the operating conditions, welding procedures and work schedule are in accordance with the applicable requirements, reviewed/approved plans and recognised good welding practice.

7.1.4 The necessary quality of the welds is to be proved by non-destructive tests of at least the number N_P defined below, carried out at testing positions on the welded joints:

$$N_P = c_P \cdot L/3$$

N_P = number of test positions using radiographic methods with a 480 mm film length or ultrasonic methods with 1 m long test sections

L = Rule length [m] of the vessel, defined in Section 1, A.1.2.1

c_P = coefficient defined as

= 0,8 for transverse framing

= 1,0 for longitudinal and combined construction

7.1.5 Test schedule, evaluation of results, test reports

A test schedule shall be compiled covering the tests to be performed. This schedule shall contain details of the materials used and their thicknesses and the method to be applied. The positions at which the various tests are to be performed will be designated by the Surveyor on completion of the welded joints. This shall later be clearly specified in the test schedule. The evaluation of weld defects identified according to their nature, location, size and distribution shall take due account of the requirements applicable to the welded joints (position and loading of the weld), e.g ISO 5817 categories C. The test results shall be evaluated by the testing department and/or the welding supervisory staff.

7.2 Visual and non-destructive examinations

7.2.1 After completion of the welding operation and workshop inspection, the structure is to be presented to the Surveyor for visual examination at a suitable stage of fabrication. For this purpose, welds shall be readily accessible and shall normally be uncoated. Wherever possible, the results of non-destructive tests shall be presented at this juncture.

7.2.2 Non-destructive examinations are to be carried out with appropriate methods and techniques suitable for the individual applications, to be agreed with GL.

7.2.3 Radiographic examinations are to be carried out on the welded connections of the hull in accordance with 7.3. The Surveyor is to be informed when these examinations are performed. The results are to be made available to GL.

7.2.4 GL may allow radiographic examinations to be replaced by ultrasonic examinations.

7.2.5 When the visual or non-destructive examinations reveal the presence of unacceptable indications, the relevant connection is to be repaired to sound metal for an extent and according to a procedure agreed with the Surveyor. The repaired zone is then to be submitted to nondestructive examination, using a method deemed suitable by the Surveyor to verify that the repair is satisfactory.

Additional examinations may be required by the Surveyor on a case-by-case basis.

7.2.6 Ultrasonic and magnetic particle examinations may also be required by the Surveyor in specific cases to verify the quality of the base material.

7.3 Radiographic inspection

7.3.1 A radiographic inspection is to be carried out on the welded butts of shell plating, strength deck plating as well as of members contributing to the longitudinal strength. This inspection may also be required for the joints of members subject to heavy stresses.

The requirements 7.3.2 to 7.3.5 constitute general rules: the number of radiographs may be increased where requested by the Surveyor, mainly where visual inspection or radiographic soundings have revealed major defects, specially for butts of sheerstrake, stringer plate, bilge strake or keel plate.

Provisions alteration to these rules may be accepted by GL when justified by the organisation of the Building Yard or of the inspection department; the inspection is then to be equivalent to that deduced from 7.3.2 to 7.3.5.

7.3.2 As far as automatic welding of the panels butt welds during the premanufacturing stage is concerned, the Building Yard is to carry out random non-destructive testing of the welds (radiographic or ultrasonic inspection) in order to ascertain the regularity and the constancy of the welding inspection.

7.3.3 In the midship area, radiographies are to be taken at the joining butts of panels.

Each radiography is situated in a butt joint at a cross-shaped welding.

In a given vessel cross-section bounded by the panels, a radiography is to be made of each butt of sheerstrake, stringer, bilge and keel plate; furthermore, in the same section, on average of two radiographies is to be taken on all the butts of bottom, deck and side shell platings. This requirement remains applicable where panel butts are shifted or where some strakes are built independently from the panels. It is recommended to take most of these radiographies at the intersections of butt and panel seams.

Still in the midship area, a radiographic inspection is to be taken at random of the following main members of the structure:

– butts of continuous longitudinal bulkheads

– butts of longitudinal stiffeners, deck and bottom girders contributing to the overall strength

– assembly joints of insert plates at the corners of the openings

Moreover, a radiographic inspection is to be taken at random of the weldings of the bilge keel and of intermediate flat.

7.3.4 Outwards the midship area, a programme of radiographic inspection at random is to be set up by the Building Yard in agreement with the Surveyor for the major points. It is further recommended:

– to take a number of radiographies of the very thick parts and those comprising restrained joint, such as sternframes, shaft brackets, masts

– to take a complete set of radiographies or to increase the number of radiographies for the first joint of a series of identical joints. This recommendation is applicable not only to the assembly joints of prefabricated members completed on the slip, but also to joints completed in the workshop to prepare such prefabricated members.

7.3.5 Where a radiography is rejected and where it is decided to carry out a repair, the Building Yard is to determine the length of the defective part, then a set of inspection radiographies of the repaired joint and of adjacent parts is to be taken. Where the repair has been decided by the inspection office of the Building Yard, the film showing the initial defect is to be submitted to the Surveyor together with the film taken after repair of the joint.

B. Protection of Hull Metallic Structures

1. Symbols

L = Rule length [m] defined in Section 1, A.1.

t = thickness [mm]

2. Corrosion protection

2.1 Protection by coating

2.1.1 All areas endangered by corrosion are to be protected by a suitable corrosion protective coating.

2.1.2 All brackish water ballast spaces with boundaries formed by the hull envelope are to have a corrosion protective coating, epoxy or equivalent, applied in accordance with the manufacturer's requirements.

2.2 Cathodic protection

2.2.1 Ballast water tanks or other internal spaces endangered by corrosion due to brackish or harbour water need to be protected by sacrificial anodes.

2.2.2 Uncoated stainless steels are not protected cathodically if they are suitable for withstanding the corrosion stress.

Coated stainless steels shall be cathodically protected in the submerged zone.

2.2.3 Details concerning the type of anodes used and their location and attachment to the structure are to be submitted to GL for review/approval.

2.3 Protection against galvanic corrosion

Suitable protection measures shall take place, where the danger of galvanic corrosion exists.

3. Protection of bottom by ceiling

3.1 General

3.1.1 In single bottom vessels, ceiling is to be laid on the floors from side to side up to the upper bilge.

3.1.2 In double bottom vessels, ceiling is to be laid over the inner bottom and lateral bilges, if any.

Ceiling on the inner bottom is not required where the thickness of the inner bottom is increased in accordance with the GL Additional Requirements for Notations (I-2-4), Section 1, A.4.4 and Section 1, B.4.4

3.2 Arrangement

3.2.1 Planks forming ceiling over the bilges and on the inner bottom are to be easily removable to permit access for maintenance.

3.2.2 Where the double bottom is intended to carry fuel oil, ceiling on the inner bottom is to be separated from the plating by means of battens 30 mm high, in order to facilitate the drainage of oil leakages to the bilges.

3.2.3 Where the double bottom is intended to carry water, ceiling on the inner bottom may lie next to the plating, provided a suitable corrosion protection is applied beforehand.

3.2.4 The Building Yard is to take care that the attachment of ceiling does not affect the tightness of the inner bottom.

3.2.5 In single bottom vessels, ceiling is to be fastened to the reversed frames by galvanised steel bolts or any other equivalent detachable connection.

A similar connection is to be adopted for ceiling over the lateral bilges in double bottom vessels.

3.3 Scantling

3.3.1 The thickness of ceiling boards is to be at least equal to the smaller of the following values:

– vessels intended to carry ore or concentrated loads, and not fitted with a double bottom:

$t = 50$

$= 0{,}45 \cdot s \cdot (L + 160)$

– other vessels:

$t = 25$

$= 0{,}3 \cdot s \cdot (L + 160)$

s being the floor spacing [m].

Where the floor spacing is large, the thicknesses may be considered by GL on a case-by-case basis.

Under cargo hatchways, the thickness of ceiling is to be increased by 15 mm.

3.3.2 Where a side ceiling is provided, it is to be secured every 4 frame spacings to the side frames by an appropriate system. Its thickness may be taken equal to 0,7 times that of the bottom ceiling, without being less than 20 mm.

The batten spacing is not, as a rule, to exceed 0,2 m.

4. Protection of decks by wood sheathing

4.1 Deck not entirely plated

4.1.1 The wood used for sheathing is to be of good quality dry teak or pine, without sapwood or knots. The sheathing thickness is not to be less than:

– teak $t = (L + 55)/3 \geq 40$

– pine $t = (L + 100)/3$

4.1.2 The width of the planks is not to exceed twice their thickness. Their butts are to be adequately shifted so that, if two butts occur in the same frame spacing, they are separated by at least three planks.

Planks are to be secured to every other frame by means of 12 mm bolts. On small vessels, galvanized steel screws are permitted.

4.1.3 Wooden decks are to be carefully caulked, to the satisfaction of the Surveyor.

4.2 Wood sheathed plate deck

4.2.1 As far as practicable, plate decks above passenger or crew cabins are to be sheathed with wood planks.

4.2.2 The plank thickness is not to be less than 40 mm nor than:

– teak $t = (L + 40)/3$

– pine $t = (L + 85)/3$

C. Testing

1. Symbols

p = maximum design pressure [kPa]

p_{S1} = leak test pressure [kPa]:

= MIN (10; p)

p_{S2} = leak test pressure [kPa]:

= MIN (15; p)

2. General

2.1 Application

2.1.1 The following requirements determine the testing conditions for:

– gravity tanks, including independent tanks of 5 m^3 or more in capacity

– watertight or weathertight structures

The purpose of these tests is to check the tightness and/or the strength of structural elements.

2.1.2 Tests are to be carried out in the presence of the Surveyor at a stage sufficiently close to completion so that any subsequent work would not impair the strength and tightness of the structure.

In particular, tests are to be carried out after air vents and sounding pipes are fitted.

2.2 Definitions

2.2.1 Shop primer

Shop primer is a thin coating applied after surface preparation and prior to fabrication as a protection against corrosion during fabrication.

2.2.2 Protective coating

Protective coating is a final coating protecting the structure from corrosion.

2.2.3 Structural testing

Structural testing is a hydrostatic test carried out to demonstrate the tightness of the tanks and the structural adequacy of the design. Where practical limitations prevail and hydrostatic testing is not feasible (for example when it is difficult, in practice, to apply the required head at the top of the tank), hydropneumatic testing may be carried out instead.

Structural testing is to be carried out according to 3.2.

2.2.4 Hydropneumatic testing

Hydropneumatic testing is a combination of hydrostatic and air testing, consisting in filling the tank to the top with water and applying an additional air pressure.

Hydropneumatic testing is to be carried out according to 3.3.

2.2.5 Leak testing

Leak testing is an air or other medium test carried out to demonstrate the tightness of the structure.

Leak testing is to be carried out according to 3.4.

2.2.6 Hose testing

Hose testing is carried out to demonstrate the tightness of structural items not subjected to hydrostatic or leak testing and of other components which contribute to the watertight or weathertight integrity of the hull.

Hose testing is to be carried out according to 3.5.

2.2.7 Sister vessel

See GL Rules for Classification and Surveys (I-2-1), Section 1, A.1.2.20

3. Watertight compartments

3.1 General

3.1.1 The requirements in 3.1 to 3.6 intend generally to verify the adequacy of the structural design of gravity tanks, excluding independent tanks of less than 5 m^3 in capacity, based on the loading conditions which prevailed when determining the tank structure scantlings.

3.1.2 General requirements for testing of watertight compartments are given in Table 8.9, in which the types of testing referred to are defined in 2.2.

3.2 Structural testing

3.2.1 Structural testing may be carried out before or after launching.

3.2.2 Structural testing may be carried out after application of the shop primer.

3.2.3 Structural testing may be carried out after the protective coating has been applied, provided that one of the following two conditions is satisfied:

– all the welds are completed and carefully inspected visually to the satisfaction of the Surveyor prior to the application of the protective coating

– leak testing is carried out prior to the application of the protective coating

In the absence of leak testing, protective coating is to be applied after the structural testing of:

– all erection welds, both manual and automatic

– all manual fillet weld connections on tank boundaries and manual penetration welds

3.3 Hydropneumatic testing

When a hydropneumatic testing is performed, the conditions are to simulate, as far as practicable, the actual loading of the tank.

The value of the additional air pressure is at the discretion of GL, but is to be at least as defined in 3.4.2 for leak testing.

The same safety precautions as for leak testing (see 3.4.2) are to be adopted.

3.4 Leak testing

3.4.1 An efficient indicating liquid, such as a soapy water solution, is to be applied to the welds.

3.4.2 Where leak testing is carried out in accordance with Table 8.9, an air pressure p_{S1} is to be applied during the test.

Prior to inspection, it is recommended that the air pressure in the tank should be raised to p_{S2} and kept at this level for approximately 1 hour to reach a stabilised state, with a minimum number of personnel in the vicinity of the tank, and then lowered to the test pressure.

The test may be conducted after the pressure has reached a stabilised state at p_{S2}, without lowering the pressure, provided GL is satisfied of the safety of the personnel involved in the test.

3.4.3 A U-tube filled with water up to a height corresponding to the test pressure is to be fitted to avoid overpressure of the compartment tested and verify the test pressure.

The U-tube is to have a cross-section larger than that of the pipe supplying air.

In addition, the test pressure is also to be verified by means of one master pressure gauge.

Alternative means which are considered to be equivalently reliable may be accepted at the discretion of the Surveyor.

3.4.4 Leak testing is to be carried out, prior to the application of a protective coating, on all fillet weld connections on tank boundaries, and penetration and erection welds on tank boundaries excepting welds made by automatic processes.

Selected locations of automatic erection welds and preerection manual or automatic welds may be required to be similarly tested to the satisfaction of the Surveyor, taking into account the quality control procedures operating in the Building Yard.

For other welds, leak testing may be carried out after the protective coating has been applied, provided that such welds have been carefully inspected visually to the satisfaction of the Surveyor.

3.4.5 Any other recognised method may be accepted to the satisfaction of the Surveyor.

3.5 Hose testing

When hose testing is required to verify the tightness of the structures, as defined in Table 8.9, the minimum pressure in the hose, at least equal to 200 kPa, is to be applied at a maximum distance of 1,5 m.

The nozzle diameter is to be not less than 12 mm.

Table 8.9 Watertight compartments – General testing requirements

Compartment or structure to be tested	**Type of testing**	**Structural test pressure**	**Remarks**
Double bottom tanks	Structural testing [1]	Head of water up to the top of overflow, at least 1,0 m above tank top	Tank boundaries tested from at least one side
Double side tanks	Structural testing [1]	Head of water up to the top of overflow, at least 1, 0 m above tank top	Tank boundaries tested from at least one side
Tank bulkheads, deep tanks	Structural testing [1]	The greater of the following [2]: – head of water up to the top of overflow, at least 1, 0 m above tank top – testing pressure defined in Section 2, D., Table 2.13	Tank boundaries tested from at least one side
Fuel oil bunkers	Structural testing		
Fore and after peaks used as tanks	Structural testing	head of water up to the top of overflow, at least 1,0 m above tank top	Test of the after peak carried out after the sterntube has been fitted
Fore peak not used as tank	Structural testing	Head of water up to bulkhead deck	
After peak not used as tank	Leak testing		
Cofferdams	Structural testing [3]	head of water up to the top of overflow, at least 1,0 m above cofferdam top	
Watertight bulkheads	Hose testing [4]		
Watertight doors below freeboard or bulkhead deck [5]	Structural testing	Head of water up to the bulkhead deck	Test to be carried out before the vessel is put into service, either before or after the door is fitted on board
Double plate rudders	Leak testing		
Shaft tunnel clear of deep tanks	Hose testing		
Shell doors	Hose testing		
Weathertight hatch covers and closing appliances	Hose testing		
Chain locker (if aft of ollision bulkhead)	Structural testing	Head of water up to the top	
Independent tanks not used as cargo tanks	Structural testing	Head of water up to the top of overflow, but not less than 2,4 m	

1 Hydropneumatic or leak testing may be accepted under the conditions specified in 3.3 and 3.4.

2 Where applicable, the highest point of the tank is to be measured to deck and excluding hatches. In holds for liquid cargo or ballast with large hatch covers, the highest point of tanks is to be taken at the top of the hatch.

3 Hydropneumatic or leak testing may be accepted under the conditions specified in 3.3 and 3.4, respectively, when, at the GL's discretion, it is considered significant also in relation to the construction techniques and the welding procedures adopted.

4 When a hose test cannot be performed without damaging possible outfitting (machinery, cables, switchboards, insulation, etc...) already installed, it may be replaced, at the GL's discretion, by a careful visual inspection of all the crossings and welded joints. Where necessary, a dye penetrant test or ultrasonic leak test may be required.

5 The means of closure are to be subjected to a hose test after fitting on board.

3.6 Other testing methods

Other testing methods may be accepted, at the discretion of GL, based upon equivalency considerations. As far as applicable, GL reserves the right, on the request of the Prospective Owner or the Building Yard to accept any other equivalent testing methods as defined in other Society's Rules.

Referring to the testing of tanks, this may in particular be effected by a combination of a leak test by means of air pressure and an operational test by means of water or of the liquid for which the tanks are intended to be used. The operational test may be carried out when the vessel is afloat or during the trial trip. For all tanks the proper functioning of filling and suction lines and of the valves as well as the functioning and tightness of the vent, sounding and overflow pipes is to be tested.

4. Miscellaneous

4.1 Doors in bulkheads above the bulkhead deck

Doors are to be designed and constructed as weathertight doors and, after installation, subjected to a hose test from each side for weathertightness.

4.2 Steering nozzles

Upon completion of manufacture, the nozzle is to be subjected to a leak test.