CHINA CLASSIFICATION SOCIETY

RULES FOR CLASSIFICATION OF MOBILE OFFSHORE UNITS

PART TWO STRUCTURES AND EQUIPMENT

CONTENTS

CHAPTER 1 GENERAL

Section 1 GENERAL PROVISIONS

1.1.1 Application

1.1.1.1 Except as stated otherwise, this part applies to steel units of all welded construction.

1.1.1.2 For units of a unusual type or novel configuration, their structural scantlings are to be specially considered and with the consent of CCS.

1.1.1.3 In addition, the structure and arrangement of the main structure is to comply with the applicable requirements in PART EIGHT of the Rules.

1.1.2 Structural members

1.1.2.1 For attached plating, span points and details of structural members as well as primary and secondary member end connections, refer to the relevant provisions in Section 2, Chapter 1 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

1.1.2.2 For the structures not expressly specified in this part, including ventilators, air pipes, watertight/weathertight doors and covers etc., their scantlings are to comply with the relevant provisions in PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

Section 2 DEFINITIONS

1.2.1 Main scantlings of the unit

1.2.1.1 Length of the unit L (m)

(1) Self-elevating units

L is the horizontal distance measured on the centerline of the unit between the inside surfaces of fore and aft shell plating at 0.85 D (D is defined in 1.2.1.3), without taking the well slot into account.

(2) Column-stabilized units and submersible units

L is the extreme horizontal length of the unit on a projection of the centerline.

(3) Surface-type units

L means 96% of the total length on a waterline at 85% of D (for D, see 1.2.1.3), or the length from the foreside of the stem to the axis of the rudder stock on that waterline, whichever is greater. In units designed with a rake of keel, the waterline on which this length is measured is to be parallel to the designed waterline.

1.2.1.2 Breadth B of the unit (m)

(1) Self-elevating units, column-stabilized units and submersible units

B is the maximum horizontal distance measured perpendicular to centerline between the inside surfaces of shell plating at both sides.

(2) Surface-type units

B is the horizontal distance measured over the main frames at the widest part of the unit.

1.2.1.3 Moulded depth D (m)

D is the vertical distance measured at the middle of the length L from the moulded baseline to the lower edge of the freeboard deck.

1.2.1.4 Draught d (m)

d is the vertical distance measured from the moulded baseline to the assigned load line. Certain components or parts of a unit's structure, machinery or equipment may extend below the moulded baseline.

1.2.1.5 Water depth h (m)

The water depth *h* as used herein is the vertical distance from the seabed to the mean low water level plus the height of astronomical and storm tides.

1.2.1.6 Moulded baseline

The moulded baseline is a horizontal line extending through the upper surface of the bottom plating.

1.2.1.7 Freeboard deck

The freeboard deck is normally the uppermost complete deck exposed to weather and sea, which has permanent means of closing all openings in the weather part thereof, and below which all external openings are fitted with permanent means of watertight closing. As to column-stabilized units, the freeboard deck refers to the lowest complete deck exposed to weather and sea, below which all external openings are capable of being closed watertight.

1.2.1.8 Bulkhead deck

The bulkhead deck is the continuous deck to which the transverse watertight bulkheads extend.

1.2.2 Structures

1.2.2.1 The hull structure of a self-elevating unit means the upper platform structure of the unit, the equipment and installations mounted on which are above sea level during operation.

1.2.2.2 Legs are tubular or truss-type structures of a self-elevating unit, capable of relatively moving with the hull in a pre-set manner by means of electrical or hydraulic devices or both, and of penetrating into seabed, supporting the hull and enabling it to rise to a predetermined elevation over the sea surface.

1.2.2.3 Mat is an integral watertight box-type structure supported by soft seabed and connected to the bottoms of legs of a self-elevating unit.

1.2.2.4 Spudcans are separate watertight structures connected to the bottom of each leg of a self-elevating unit.

1.2.2.5 Upper hull is the upper platform structure of a column-stabilized unit or submersible unit.

1.2.2.6 Lower hulls are the continuous buoyant structures below the columns of a column-stabilized unit or submersible unit.

1.2.2.7 Columns are the tubular structural members of a column-stabilized unit or submersible unit, with which the upper hull and lower hulls or spudcans are connected.

1.2.2.8 Footings are separate buoyant structures connected to the bottom of each column of a column-stabilized unit.

1.2.2.9 Bracing members are connecting members of a tubular form or some other forms, by which the major structures (i.e. upper hull, columns, and lower hulls) of a column-stabilized unit or submersible unit are connected into an integral structure.

1.2.2.10 Critical fatigue nodes are locations which have been identified from calculations to require monitoring or from the service history of similar units to be sensitive to cracking, and specified to do fatigue check by the rules.

1.2.3 Modes of operation

1.2.3.1 A mode of operation is a condition or manner in which a unit may operate or function while on location or in transit. The approved five modes of operation for a unit stipulated in the Rules are as follows:

(1) Normal operating condition: A condition wherein a unit is on location for purposes of drilling or other operations, and combined environmental and operational loadings are within the appropriate design limits established for such operations.

(2) Survival condition: A condition wherein a unit is subjected to the most severe environmental loadings for which the unit is designed and drilling or other operations have been discontinued to maximize the capability of surviving such environmental loadings.

(3) Transit condition: a condition wherein a unit moves from one geographical location to another.

(4) Jacking condition: A condition wherein a self-elevating unit lowers its legs and raises its hull structure or

lowers its hull structure and raises its legs.

(5) Descending and ascending condition: A complete process during which the condition of a submersible unit resting on the seabed is changed from floating to resting on seabed, or vice versa.

1.2.4 Miscellaneous

1.2.4.1 Wellhead refers to the opening for drilling / production units.

1.2.4.2 Pile hole refers to the platform opening at the pile leg enclosure on the Jack-up units.

1.2.4.3 Lightweight is defined as the weight of the complete unit with all its permanently installed machinery, equipment and outfit, including permanent ballast, spare parts normally retained on board and liquids in machinery and piping to their normal working levels, but does not include liquids in storage or reserve supply tanks, items of consumable or variable loads, stores or crew and their effects.

1.2.4.4 Weathertightness means that in any sea conditions water will not penetrate into the unit.

1.2.4.5 Watertightness means the capability of preventing the passage of water through the buoyant structure in any direction under a head of water for which the surrounding structure is designed.

1.2.4.6 Downflooding means any flooding of the interior of any part of the buoyant structure of a unit through openings which cannot be closed weathertight or watertight, as appropriate, in order to meet the intact or damage stability criteria, or which are required for operational reasons to be left open.

1.2.4.7 Operating conditions are a combination of specific environmental conditions and loading conditions.

1.2.4.8 Design conditions are the typical operating conditions selected for structural design.

Section 3 PLANS AND INFORMATION

1.3.1 General requirements

1.3.1.1 For any new unit intended to be classed with CCS, the following plans and information are to be submitted in quadruplicate to CCS for approval before commencement of construction. Additional plans and information may be required for approval if considered necessary by CCS. These drawings are to clearly indicate scantlings, structural arrangements, types and grades of materials, joint details, welding, or other methods of connection:

(1) General arrangement;

(2) Summary of distributions of fixed and variable weights;

(3) Specifications or plans of deck load;

(4) Construction profile, including buttock, deck and flat for each layer, inner bottom structure, superstructure and deckhouse;

(5) Main transverse section;

(6) Oiltight and watertight bulkheads;

(7) Shell expansion;

(8) Fore and aft end construction, if applicable;

(9) Structural plans, including strength calculations, of legs, spudcans or mats, leg wells, supporting and jacking devices of legs, for self-elevating units;

(10) Structural plans, including strength calculations, of moveable cantilevers/skid beams and their supporting structures;

(11)Structural plans and strength calculations of the sliding locking system of the unit’s cantilever;

(12)Structural plans and strength calculations of the openings and reinforcements of the unit hull;

(13) Structural plans of columns, footings or lower hulls, bracing members, for column-stabilized units;

(14) Structural plans of columns, lower hulls, bracing members and anti-slip spuds, for submersible units;

(15) Structural plans, including strength calculations, of foundations for vital machinery and their supporting structures;

(16) Structural plans, including strength calculations, of propeller bracket together with rudder, stock and tiller, for self-propelled units;

(17) Masts, derrick foundations and their supporting structures;

(18) Ice strengthening (if applicable);

(19) Corrosion control arrangements, including coating and cathodic protection;

(20) Instructions of construction procedures and principles, including welding details and specifications, non-destructive testing and tightness testing;

(21) Arrangement of temporary anchoring and towing equipment, including calculation of equipment number and calculations of towing equipment strength;

(22) Global strength calculations;

(23) Calculations of resultant forces and moments from wind, waves, current, mooring and other environmental loadings and if applicable, including effects of icing;

(24) Fatigue strength calculations;

(25) Calculations substantiating adequacy of structure to transmit forces between legs and hull through the jacking or other elevating system;

(26) Calculations of significant operational loads from drilling derrick, tensioners and upper structures, and other similar significant loadings;

(27) Longitudinal strength calculations and loading manual for surface-type units;

(28) Specifications or plans of critical fatigue nodes

(29) Operating manual;

(30) Construction booklet;

(31) The following plans and information are to be submitted for information:

① design specification, if necessary;

② specifications of structures and equipment;

③ lines plan and table of offsets;

④ frame lines;

⑤ capacity plan;

⑥ tank sounding tables.

1.3.1.2 In addition to the plans and information specified in 1.3.1.1 as appropriate, the applicant is to submit additional plans and information as specified in PART EIGHT of the Rules to CCS for approval, regardless of the type of the unit.

Section 4 STRUCTURAL STEELS

1.4.1 General requirements

The chemical composition, mechanical properties, manufacturing and testing of the steels used in the construction of the unit are to comply with the requirements in PART ONE of CCS Rules for Materials and Welding in respect to steels for hull structure and high strength quenched and tempered steels for welded structures. Steel forgings and castings for unit structure are also to comply with the relevant requirements in CCS Rules for Materials and Welding. Steels for which provision is not made therein may be accepted, provided that submitted documents on their chemical composition, mechanical properties and heat treatment procedures are approved and such steels found satisfactory at surveys by CCS according to applied standards or technical specifications, giving due consideration to the ratio of yield to tensile strength, intended structural location and design temperature.

1.4.2 Categories of structural members

1.4.2.1 All structural members of the unit may be divided into the following categories according to applied loading, stress level and associated stress pattern, critical load transfer points and stress concentrations, and consequences of failure:

(1) Special structural members: Those portions of primary structural members which are in way of critical load transfer points, stress concentrations, etc.

(2) Primary structural members: Structural members essential to the overall integrity of the unit.

(3) Secondary structural members: Structural members of minor importance, failure of which is unlikely to affect the overall integrity of the unit.

1.4.2.2 Self-elevating units

(1) Special structural members

① vertical leg structures in way of intersections with individual spudcans or with the mat structure;

② intersection of lattice type leg structures which incorporate novel construction, including the use of steel castings or forgings.

(2) Primary structural members

① external plating of cylindrical legs;

② plating of all components of lattice type legs;

③ combination of bulkhead, deck, side and bottom plating within the upper hull which form a “box” or “I” type main supporting structure;

④ jack-house supporting structure;

⑤ external shell plating of spudcans or mats, and structural members which receive initial transfer of loads from the legs;

⑥ internal bulkheads and framing of supporting structures of spudcans or mats which are designed to distribute major concentrated or uniform loads into the structure;

⑦ primary supporting structures of helicopter decks and lifeboat platforms;

⑧ heavy substructures and equipment supports, e.g. drill floor substructure, drilling cantilevers and crane pedestals including their supporting structures and supporting structures of risers;

⑨ raw water towers.

(3) Secondary structural members:

① internal framing, including bulkheads and girders, of cylindrical legs;

② internal bulkheads and framing members of upper hull structure except where the structural members are considered as primary ones;

③ internal bulkheads and framing members of spudcans or bottom mat supporting structures except where the structural members are considered as primary or special ones;

④ deck, side and bottom plating of upper hull except where the structural members are considered as primary ones;

⑤ helicopter platforms and deckhouses;

⑥ lifeboat platforms;

⑦ pipe racks.

1.4.2.3 Column-stabilized units

(1) Special structural members

① shell plating in way of the intersections of vertical columns with platform decks and upper and lower hulls;

② portions of deck plating, heavy flanges, shell boundaries and bulkheads within the upper hull or platform which form a “box” or “I” type supporting structure which receive major concentrated loads;

③ major intersections of bracing members;

④ external brackets, portions of bulkheads, flats and frames which receive concentrated loads at intersections of major structural members;

⑤ “through” material used at connections of vertical columns, upper platform decks and upper or lower hulls which provide proper alignment and adequate load transfer;

⑥ anchor line fairleads and their supporting structure.

(2) Primary structural members

① shell plating of vertical columns, lower and upper hulls, and diagonal and horizontal braces except where the structural members are considered as special ones;

② deck plating, heavy flanges and bulkheads within the upper hull or platform which form a “box” or “I” type supporting structure except where the structural members are considered as special ones;

③ bulkheads, decks or flats and framing which provide local reinforcement or continuity of structure in way of intersections, except where the structural members are considered as special ones;

④ primary supporting structures of helicopter decks and lifeboat platforms;

⑤ heavy substructures and equipment supports, e.g. drill floor substructure, crane pedestals and supporting structures of risers.

(3) Secondary structural members:

① internal structures including bulkheads, stiffeners, flats or decks and girders in vertical columns, upper hull or platform, lower hulls, diagonal and horizontal braces, except where the structural members are considered as primary or special ones;

② upper platform decks or decks of upper hull except where the structural members are considered as primary or special ones;

③ certain large-diameter vertical columns with low length-to-diameter ratios, except in intersections;

④ helicopter platforms and deckhouses;

⑤ pipe racks;

⑥ lifeboat platforms.

1.4.2.4 Submersible units

(1) Special structural members

① shell plating in way of the intersections of large-diameter vertical columns with platform decks or upper and lower hulls;

② deck plating, heavy flanges, shell boundaries and bulkheads within the upper hull or platform which form a “box” or “I” type supporting structure which receive major concentrated loads;

③ portions of bulkheads, flats and framing which receive concentrated loads at intersections of major structural members;

④ "through" material used at connections of vertical columns, upper platform decks and upper or lower hulls which provide proper alignment and adequate load transfer.

(2) Primary structural members

① shell plating of vertical columns, lower and upper hulls, and diagonal braces and anti-slip spuds, except where the structural members are considered as special ones;

② deck plating, heavy flanges and bulkheads within the upper hull or platform which form a "box" or "I" type supporting structure, except where the structural members are considered as special ones;

③ bulkheads, flats or decks and framing which provide local reinforcement or continuity of structure in way of intersections, except where the structural members are considered as special ones;

④ primary supporting structures of helicopter decks and lifeboat platforms;

⑤ heavy substructures and equipment supports, e.g. drill floor substructure, drilling cantilever and crane pedestals with their supporting structures, and supporting structures of risers.

(3) Secondary structural members:

① internal structure including bulkheads, stiffeners, flats or decks and girders in vertical columns, upper hull or platform decks and lower hulls, except where the structural members are considered as primary or special ones;

② upper platform decks or decks of upper hull except where the structural members are considered as primary or special ones;

③ certain large-diameter vertical columns with low length-to-diameter ratios, except in intersections;

④ helicopter platforms and deckhouses;

⑤ pipe racks;

⑥ lifeboat platforms.

1.4.2.5 Surface-type units

(1) Special structural members:

① sheer strake at strength deck within 0.4*L* amidships;

② stringer plate in strength deck within 0.4*L* amidships;

③ deck strake at longitudinal bulkhead within 0.4*L* amidships;

④ deck plating or inner bottom plating at corners of the opening of the moon pool;

⑤ bilge strakes within 0.4*L* amidships;

⑥ continuous longitudinal hatch coaming having a length of more than 0.15*L*.

(2) Primary structural members:

① bottom plating, including keel plate within 0.4*L* amidships;

② strength deck plating within 0.4*L* amidships, except where the structural members are considered as special ones;

③ continuous longitudinal members above strength deck, excluding hatch coamings, within 0.4*L* amidships;

④ uppermost strake in longitudinal bulkhead within 0.4*L* amidships;

⑤ sheer strake at strength deck outside 0.4*L* and within 0.6*L* amidships;

⑥ stringer plate in strength deck outside 0.4*L* and within 0.6*L* amidships;

⑦ deck strake at longitudinal bulkhead outside 0.4*L* and within 0.6*L* amidships;

⑧ bilge strakes outside 0.4*L* and within 0.6*L* amidships;

⑨ inner bottom plating at corners of the opening of the moon pool

⑩ moon pool coamings;

⑪ primary supporting structures of helicopter decks and lifeboat platforms;

⑫ heavy substructures and equipment supports, e.g. drill floor substructure, crane pedestals, propeller base, anchor line fairleads and their supporting structures, and supporting structures of risers;

⑬ supporting structures of risers;

⑭ supporting structure of burner boom;

⑮ primary girder in the truss-type module;

⑯ upper module deck plating and girders;

⑰ upper module side plating and girders.

(3) Secondary structural members:

① bulkhead plating, stiffeners within 0.4*L* amidships areas except where the structural members are considered as primary or special ones;

② deck plating exposed to weather within 0.4*L* amidships, including forecastle and poop decks except where the structural members are considered as primary or special ones;

③ side plating;

④ sheer strake at strength deck outside 0.6*L* amidships;

⑤ stringer plate in strength deck outside 0.6*L* amidships;

⑥ deck strake at longitudinal bulkhead outside 0.6*L* amidships;

⑦ bilge strakes outside 0.6*L* amidships;

⑧ lifeboat platforms;

⑨ pipe racks;

⑩ module deck plating and girders, except the structural members are considered as primary ones;

⑪ module deck stiffeners;

⑫ upper module side stiffeners;

⑬ tween decks and platforms in upper structure;

⑭ deck plating and girders on the top of the superstructure;

⑮ helicopter platforms and deckhouses.

1.4.3 Minimum design temperature of steel

1.4.3.1 The minimum design temperature of steel is a reference temperature used as a criterion for the selection of steel grades to be used in the structure and is to be assumed equal to the average minimum daily atmospheric temperatures per annum during the designed service period (at least 20 years) of the unit, based on meteorological data for any anticipated area of operation.

1.4.3.2 A design temperature of 0℃ is generally acceptable for determining the steel grades for underwater structures.

1.4.3.3 The internal structure of all units is normally assumed to have the same design temperature as the adjacent external structure unless defined otherwise. However, internal structures of permanently heated compartments normally need not be designed for temperatures lower than 0℃.

1.4.4 Selection of steels for unit structures

1.4.4.1 In order to determine the steel grades for unit structures, consideration is to be given not only to chemical composition and mechanical properties of the material, but also to stress pattern associated with the location of structures, the plate thickness of structural members, the design temperature of working environment as well as the fracture toughness, fatigue property and resistance to lamellar tearing of the material.

1.4.4.2 The steel grades for structures of surface-type (ship-type or barge-type) units are to be selected in accordance with the relevant requirements in PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

1.4.4.3 The steel grades for structures of self-elevating units, column-stabilized units and submersible units are to be selected from Table 1.4.4.3 as appropriate, according to structural categories, minimum design temperature and plate thickness.

Thickness Limitations (Mm) Regarding Structural Steel Grades for Various Structural Categories and Minimum Design Temperatures **Table 1.4.4.3**

Structural members	Minimum Design Temperature						
	Steel Grade	0℃	-10℃	-20℃	-30℃	-40℃	-50℃
Secondary structural members	A	30	20	10	×	×	×
	B	40	30	20	10	×	×
	D	100	100	45	35	25	15
	E	100	100	100	100	45	35
	A32~A40	40	30	20	10	×	×
	D32~D40	100	100	45	35	25	15
	E32~E40	100	100	100	100	45	35
	F32~F40	100	100	100	100	100	100
	AH420~AH690	40	25	10	×	×	×
	DH420~DH690	70	45	35	25	15	×
	EH420~EH690	70	70	70	45	35	25
	FH420~EH690	70	70	70	70	70	45
Primary structural members	A	20	10	×	×	×	×
	B	25	20	10	×	×	×
	D	45	40	30	20	10	×
	E	100	100	100	40	30	20
	A32~A40	25	20	10	×	×	×
	D32~D40	45	40	30	20	10	×
	E32~E40	100	100	100	40	30	20
	F32~F40	100	100	100	100	100	40
	AH420~AH690	20	×	×	×	×	×
	DH420~DH690	45	35	25	15	×	×
	EH420~EH690	70	70	45	35	25	15
	FH420~FH690	70	70	70	70	45	35
Special structural members	A	×	×	×	×	×	×
	B	15	×	×	×	×	×
	D	30	20	10	×	×	×
	E	70	45	35	25	15	×
	A32~A40	20	×	×	×	×	×
	D32~D40	30	20	10	×	×	×
	E32~E40	70	45	35	25	15	×

	F32~F40	70	70	70	70	40	30
	AH420~AH690	15	×	×	×	×	×
	DH420~DH690	25	15	×	×	×	×
	EH420~EH690	70	40	30	20	10	×
	FH420~FH690	70	70	70	40	30	20

Notes: (1) "X" for not applicable.

(2) Thicknesses greater than shown in the Table will be specially considered by CCS.

(3) Substitution of materials by those considered equivalent to the grades shown in the Table or by those of different strength levels will be specially considered by CCS.

(4) Interpolation of thicknesses for intermediate temperatures may be considered.

(5) Steel grades and supply status are to comply with CCS Rules for Materials and Welding. H means higher strength hull structural steel; Q means high strength quenched and tempered steel for welded structures.

1.4.4.4 A lower service temperature than specified in the Table for the relevant steel grade may be considered, subject to agreement of CCS, for improving the toughness of steels:

(1) when a stress relieving heat treatment is employed; or

(2) when a steel manufacturing process, such as normalizing, thermo-mechanical controlled processing, or grain refinement, is utilized when not specifically required by CCS Rules for Materials and Welding.

1.4.4.5 In order to prevent lamellar tearing, Z-direction steel plates complying with Section 10, Chapter 3 of PART ONE of CCS Rules for Materials and Welding are to be used at primary connections where principal tensile stresses are imposed perpendicular to the plate thickness.

1.4.4.6 Table 1.4.4.3 specifies the thickness limits corresponding to the member class, steel grade and minimum design temperature of the member under consideration. When the material grade specified by the owner or designer exceeds the grade shown in table 1.4.4.3 (and when the material has been approved), the material of lower grade shall not be approved without the written consent of the owner or designer.

1.4.5 Additional requirements for high-strength quenched and tempered steels used for welded structures

1.4.5.1 For high-strength quenched and tempered steels that are used for welded structures and have a yield strength of 420~690MPa, the requirements on the average impact energy of Charpy V-notch impact test are to be in accordance with the requirements prescribed in CCS Rules for Materials and Welding.

1.4.5.2 For materials with thickness specifications that exceed the applicable requirements of CCS Rules for Materials and Welding regarding the thickness of high-strength quenched and tempered steels used for welded structures, the Charpy V-notch impact test is to be carried out as per the following requirements:

(1) Test temperatures are to be in accordance with Table 1.4.5.2.

Required Impact Test Temperatures for High-strength Quenched and Tempered Extra-thick Steel Plate Used for Welded StructuresTable 1.4.5.2

Minimun design temperature	Test temperature		
	Secondary structural menbers	Primary structural menbers	Special structural menbers
0 oC	-10 °C	-20 °C	-30 °C
-10 oC	-20 °C	-30 °C	-40 °C
-20 oC	-30 °C	-40 °C	-50 °C
-30 oC	-40 °C	-50 °C	-60 °C
-40 oC	-50 °C	-60 °C	-70 °C
-50 oC	-60 °C	-70 °C	-80 °C

(2) In addition, for high-strength quenched and tempered steels that are used for welded structures and have a thickness of more than 70mm, the Charpy V-notch impact test specimens are to be taken respectivelyat the 1/4 and 1/2 thickness of the steel materials and comply with the following requirements:

① The requirements for test specimens with their axis at 1/4 thickness of the steel materials are to be in accordance with the requirements contained in Table 3.4.4.4, Chapter 3, Part One of CCS Rules for Materials and Welding;

② For test specimens with their axis at 1/2 thickness of the steel materials, 2/3 of the specified values listed in Table 3.4.4.4, Chapter 3, Part One of CCS Rules for Materials and Welding may be taken as the value of impact energy for the test. Alternatively, the values specified in Rules for Materials and Welding may be taken as the value of impact energy for the test, but the test temperature can be 10 oC higher than the temperature values specified in Table 1.4.5.2.

1.4.5.3 Steels with a thickness in excess of 200mm are to be approved by CCS.

1.4.5.4Where the administration of the flag state has more stringent requirements than those described in the Rules, the corresponding material requirements of the flag state are to be complied with.

Section 5 WELD DESIGN FOR STRUCTURES

1.5.1 General requirements

1.5.1.1 This Section applies to the weld design for structures and components for normal units, special structures will be subject to individual consideration. Welding procedures for the construction of main structure are to comply with the relevant requirements of CCS Rules for Materials and Welding.

1.5.1.2 The arrangement of welds in structures is to be such as will allow adequate access for the welders to complete all welding operations. Welded joints are to be so arranged as to facilitate the use of downhand welding, as far as practicable.

1.5.1.3 Where welding is used for structures, care is to be taken to avoid the arrangement of welded joints in positions of stress concentration. Adequate transition is to be made in way of the abrupt changes of shape or section, and excessive concentration of welds over such positions is to be avoided.

1.5.1.4 Parallel welded seams in main structures are to be spaced an adequate distance apart. The distance between two parallel butt welded seams is not to be less than 100 mm, and these seams are not to be intersected with an acute angle. Where a butt welded seam is in parallel with a fillet welded seam, the distance between them is not to be less than 50 mm.

1.5.1.5 The shell plating, deck plating, inner bottom plating and bulkhead plating are all to be connected by butt welds.

1.5.1.6 Overlaps are generally not to be used to connect plates in structures, especially for plates which may be subjected to high tensile or compressive loading.

1.5.1.7 The use of permanent backing bars in highly stressed welds in structures is to be avoided as far as possible.

1.5.1.8 Double continuous fillet welding is to be adopted in the following locations:

(1) boundaries of weathertight decks and erections, including hatch coamings, companionways and other openings;

(2) boundaries of tanks and watertight cofferdams;

(3) connections of foundations and supporting structures for machinery;

(4) all structures in the aft peak (including bulkhead stiffeners);

(5) all lap welds in tanks;

(6) primary and secondary members to bottom shell within 0.25*L* forward;

(7) centreline girder to keel plate;

(8) boundaries of galleys, pantries, laundry rooms, bathrooms, toilets and storage battery rooms, etc.;

(9) end connections of all primary and secondary members to plating, and bracket ends to plating in the case of lap connections;

(10) other special connections or attachments, and in particular the attachment of minor fittings to higher tensile steel plating, will be specially considered.

1.5.1.9 Where higher tensile steel is used, double continuous fillet welds are normally to be adopted.

1.5.1.10 Details of the welded connections of main structural members including type and size of welds, are to be clearly indicated on the plans submitted for approval. The extent to which automatic welding is used is to be indicated on the plans.

1.5.1.11 When arranging side joints of shell plating, the arrangement of longitudinal members such as deck plating, longitudinals and inner bottom margin plates are to be taken into account, avoiding coincidence of the side joints and fillet welds of longitudinal members or their intersection to an excessively small angle. The butt welds of end joint of the shell are to avoid the toes of internal longitudinal members and the fillet welding of transverse members as far as practicable.

1.5.2 Welding consumables

1.5.2.1 Welding consumables used for structures are to comply with CCS Rules for Materials and Welding. The grade of welding consumables selected is to be suitable for the grade of structural steel, and is to comply with Table 1.5.2.1.

Selection of Welding Consumables Table 1.5.2.1

Grade of welding consumables	Steel grade for unit structures														
	A	B	D	E	AH32	DH32	EH32	FH32	AH36	DH36	EH36	FH36	AH40 DH40	EH40	FH40
1	×														
2	×	×	×												
3	×	×	×	×											
1Y	O				×				×						
2Y	O	O	O		×	×			×	×					
3Y	O	O	O	O	×	×	×		×	×	×				
4Y	O	O	O	O	×	×	×	×	×	×	×	×			
2Y40	/	/	/		O	O			O	O			×		
3Y40	/	/	/	/	O	O	O		O	O	O		×	×	
4Y40	/	/	/	/	O	O	O	O	O	O	O	O	×	×	×

Notes:

(1) "×" means applicable.

(2) "O" means permissible.

(3) "/" means not recommended.

(4) Void box means not applicable.

Selection of Welding Consumables Table 1.5.2.1 (continued)

Grade of welding consumables	High strength quenched and tempered steel for welded structures																	
	A420 D420	E420	F420	A460 D460	E460	F460	A500 D500	E500	F500	A550 D550	E550	F550	A620 D620	E620	F620	A690 D690	E690	F690
3Y42	×																	
4Y42	×	×																
5Y42	×	×	×															
3Y46	O			×														
4Y46	O	O		×	×													
5Y46	O	O	O	×	×	×												

3Y50	O			O			×											
4Y50	O	O		O	O		×	×										
5Y50	O	O	O	O	O	O	×	×	×									
3Y55	/			O			O			×								
4Y55	/	/		O	O		O	O		×	×							
5Y55	/	/	/	O	O	O	O	O	O	×	×	×						
3Y62	/			/			O			O			×					
4Y62	/	/		/	/		O	O		O	O		×	×				
5Y62	/	/	/	/	/	/	O	O	O	O	O	O	×	×	×			
3Y69	/			/			/			O			O			×		
4Y69	/	/	/	/	/	/	/	/		O	O		O	O		×	×	
5Y69	/	/	/	/	/	/	/	/	/	O	O	O	O	O	O	×	×	×

Notes:

(1) “×” means applicable.

(2) “O” means permissible.

(3) "/" means not recommended.

(4) Void box means not applicable.

1.5.2.2 For the joining of steels of different strength levels, the welding consumables in general may be of a type suitable for the lower strength level except at structural discontinuities or areas of stress concentration.

For the joining of steels of the same strength level but of different toughness grades, the welding consumables in general may be of a type suitable for the lower toughness grade except for the structural members subjected to complicated forces or severe construction conditions.

1.5.2.3 Low hydrogen electrodes are to be used for the welding of the following structural members and components:

(1) circumferential butt welds in the joining of the block sections and butt welds of main girders;

(2) end and side joints of the shell in way of ice strengthening;

(3) masts, derricks, boat davits, bollards and other outfits subject to heavy loads and their highly stressed fittings;

(4) components for which high rigidity is required, such as stem, stern frame, propeller shaft bracket, and joints between them and shell plating and the hull framing;

(5) main seating and the associated structural members.

1.5.2.4 It is recommended that low hydrogen type welding consumables be used for the joining of higher strength structural steels or of steels with carbon equivalent over 0.41%. However, such welding consumables are to be used for the joining of higher strength structural steels having yield strength of 390 N/mm^2 or over.

1.5.2.5 Low hydrogen type electrodes are usually to be used for manual welding to ensure the quality of deposited metal.

1.5.3 Butt, lap and plug welds

1.5.3.1 Where plates of different thicknesses are to be butt welded and the difference in thicknesses is equal to or greater than 4 mm, the edge of the thicker plate is to be tapered so as to ensure a uniform transition. The width of taper is not to be less than 4 times the difference in thickness. Where the difference in thickness is less than 4 mm, a smooth taper may be achieved within the width of the weld.

1.5.3.2 Where lap welding is necessary the width of the overlap is to be about 3 to 4 times the thickness of the thinner plate, but need not exceed 50 mm. The faying surfaces of the lap joints are to be in close contact and both edges of the overlap are to have continuous fillet welds.

1.5.3.3 For the connection of shell plating to internal webs, where access for fillet welding is not practicable, the closing plating is to be attached by continuous full penetration or slot welds to flat bars fitted to the webs. Slots are to have a minimum length of 90 mm and a minimum width of twice the plating thickness, with well rounded ends, and spaced not more than 150 mm apart. Slots are normally not to be filled with welding.

1.5.4 Fillet welds

1.5.4.1 Fillet welds of structures are generally to be welded on both sides of the abutting plate. The types and application of fillet welds are to be as shown in Table 1.5.4.1.

1.5.4.2 The size of fillet welds for structural connections is to be determined as follows:

(1) The throat thickness h of fillet welds is to be determined from the following formula:

$$h = w_\tau t_p \frac{d}{l} \quad \text{mm}$$

where: t_p — thickness of the thinner plate of the abutting plates, in mm, e.g., t_1 or t_2 in item 1 of Table 1.5.4.1(1), whichever is the lesser;

d — distance between weld fillets, in mm, i.e. the distance between start positions of successive weld fillets for intermittent welding, as shown in items 4, 5 and 6 of Table 1.5.4.1; where the fillet weld is continuous, d/l is to be equal to l;

l — the length of successive weld fillet, in mm, and is not to be less than 75 mm;

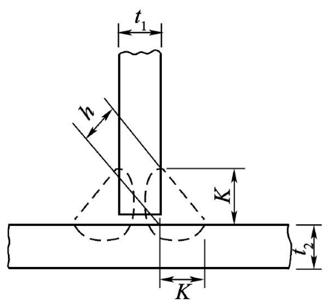
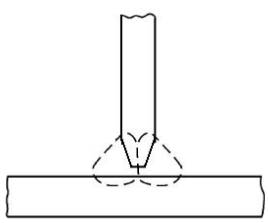
w_τ — weld factor. The weld factors used for structures are as specified in Table 1.5.4.2. Where an approved automatic deep penetration procedure is used, w_τ may be 85% of the value given in the table.

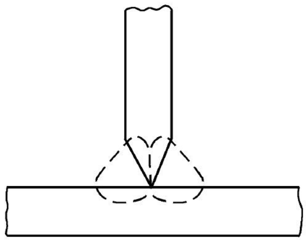
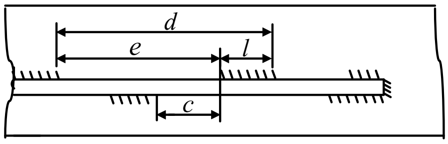
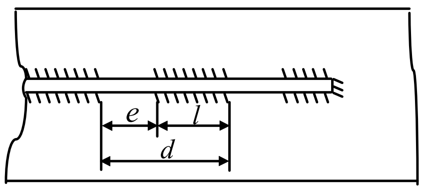
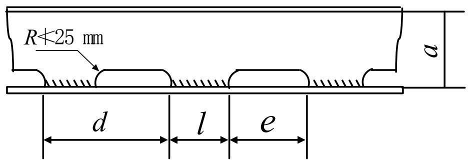
(2) The fillet leg length K is not to be less than the value obtained from the following formula:

$$K = \sqrt{2} w_\tau t_p \frac{d}{l} \quad \text{mm}$$

where: t_p, w_τ, d and l are the same as defined in (1) above.

Type of Fillet Welds **Table 1.5.4.1**

Item	Fillet weld	Type	Remarks
1	Double continuous		One type of double continuous fillet welding used for ordinary connection K — leg length h — throat thickness t_1, t_2 — thickness of plates
2	Double deep penetration		One type of double continuous fillet welding used for significantly stressed connection

3	Double full penetration		One type of double continuous fillet welding used for highly stressed connection
4	Staggered intermittent	 $c \le 150$ mm	Welding to be carried out round ends of plating l — length of weld e — spacing of welds d — distance between welds
5	Chain intermittent	 $e \le 150$ mm	Welding to be carried out round ends of plating l — length of weld e — spacing of welds d — distance between welds
6	Scalloped construction	 $e \le 150$ mm Depth of scallop ≯ 0.25 a or 75 mm, whichever is less	Welding to be carried out round ends of plating l — length of weld e — spacing of welds d — distance between welds

Weld Factors Table 1.5.4.2

Item	Weld factor	Remarks
1 General application (except as required below)		
(1) Watertight or oiltight plate boundaries	0.34	
(2) Non-tight plate boundaries	0.13	
(3) Longitudinals, frames, beams, and other secondary members to shell, deck or bulkhead plating	0.10 0.13 0.21	 In tanks In way of end connections
(4) Panel stiffeners (i.e. small stiffeners)	0.10	
(5) Overlap welds	0.27	
(6) Longitudinals of flat-bar type to plating	0.21	Double continuous
(7) Shell boundaries of columns to lower and upper hulls	Full penetration	Compliance with item 4(1)"strength deck plating to shell" may be considered for certain areas
2 Bottom construction in general		
(1) Tight centre girder to keel; to inner bottom	0.44 0.44	
(2) Non-tight centre girder (or centre keelson) to keel; to inner bottom (or face plate of centre keelson)	0.27 0.21	 No scallops
(3) Tight boundaries of floors, girders	0.39	
(4) Non-tight boundaries of floors, girders (or side keelson) and brackets	0.16 0.21 0.27	 In way of 0.2×span at ends In way of brackets at lower end of main frame

(5) Inner bottom longitudinals or reverse frames to inner bottom	0.13	Under areas strengthened for heavy cargoes
(6) Floors supporting plane, corrugated, double plate bulkheads and bulkhead stools to inner bottom	0.44	Double continuous
3 Hull framing		
(1) Self-elevating and surface-type units		
① Webs of web frames and stringers to shell ② Webs of web frames and stringers to face plate ③ Tank side brackets to shell or inner bottom	0.16 0.13 0.34	
(2) Column-stabilized units or submersible units		
Primary hull framing and girders on lower hulls, columns and footings		See Table 1.5.4.8
4 Decks and supporting structure		
(1) Strength deck plating to shell	0.44 Deep penetration	For $t \leq 15$ mm If $t > 15$ mm, single (weld factor being 0.39) or double sides beveled, with remainder $\leq t/3$ or 10 mm, whichever is the less, for deck stringers; or full penetration may be required
(2) Other decks to shell and bulkheads (except where forming tank boundaries)	0.21	Generally double continuous
(3) Webs of cantilevers to deck and to shell in way of root bracket	0.44	
(4) Webs of cantilevers to face plate	0.21	
(5) Pillars: end connection end connection (tubular)	0.34 0.44	
(6) Girder web connections and brackets in way of pillar heads and heels	0.21	
(7) Deck main girders and connections between primary members of column-stabilized units		Generally comply with Table 1.5.4.8, but full penetration welding may be required
5 Bulkheads and tank construction		
(1) Watertight plane, corrugated and double plate bulkheads to bottom, inner bottom, bilge plating, decks and bulkhead stool shelf plating	0.44	
(2) Upper and lower bulkhead stool plates to their shelf plates	0.44	Full penetration welding in way of lower stool
(3) Bulkhead stool plates to inner bottom, deck and bilge	0.44	
(4) Bulkhead plating to side shell	0.34	
(5) Bulkhead plating to secondary members where acting as pillars	0.13	
(6) Non-watertight bulkhead boundaries	0.13	
(7) Boundaries of swash bulkhead and perforated flats	0.10	
6 Self-elevating units		
(1) Leg construction (excluding inner stiffeners of cylindrical legs)	Full penetration	For tubular members, also see 1.5.5
(2) Leg connection to spudcans or mats	Full penetration	
(3) Internal webs, girders and bulkheads in spudcans and mats	0.44	Full penetration welding may be required
(4) Internal stiffeners in spudcans and mats	0.34	
(5) Jack house (general)	0.44	Full penetration welding may be required
(6) Bulkheads and primary structures in way of leg wells	0.44	Full penetration welding may be required
7 Main bracings and “K” joints, etc.		
(1) Ring frames, girders and stiffeners, general	Full penetration	Other proposals may be considered
(2) Shell boundaries and end connections including brackets, gussets and cruciform plates	Full penetration	
8 Structures in machinery spaces		
(1) Non-watertight centre girder (or centre keelson) to keel and inner bottom (or face plate of centre keelson)	0.27	No scallops to inner bottom
(2) Non-watertight floors to centre girder (or centre keelson) in way of engine, thrust and boiler bearers	0.27	
(3) Non-watertight floors and side girders (or side keelson) to shell and inner bottom	0.21	

(4) Main engine foundation girder web to top plate Main engine foundation girders to shell and inner bottom Floors to main engine foundation girders Brackets to main engine foundation girders	Full penetration Full penetration 0.44 0.44	Double sides beveled for girder web with remainder ≤ $t_p/3$ Double sides beveled for girder web with remainder ≤ $t_p/3$ See 5.2.6 of PART THREE of CCS Rules for Materials and Welding See 5.2.6 of PART THREE of CCS Rules for Materials and Welding
(5) Transverse or longitudinal framing to shell	0.13	
9 Construction within 0.25*L* forward (surface-type units)		
(1) Floor or girders (or centre keelson, etc.) to shell and inner bottom	0.21	
(2) Bottom longitudinal to shell	0.13	
(3) Transverse and longitudinal side framing to shell	0.13	
(4) Tank side brackets to shell and frames	0.34	
(5) Panting stringers to shell and frames	0.34	
(6) All internal structure in forepeak	0.13	Unless a greater weld factor is required
10 Aft peak construction: all internal structures including stiffeners on after peak bulkhead (surface-type units)	0.21	Unless a greater weld factor is required
11 Superstructures and deckhouses		
(1) Connection of external bulkheads to deck	0.34 0.21	1st and 2nd tier erections Elsewhere
(2) Connection of internal bulkheads to deck	0.13	
12 Hatchways and closing arrangements		
(1) Hatchway coamings to deck	0.34	0.44 at corners
(2) Hatchway coaming stays (stiffeners, brackets) to coaming; to deck	 0.13 0.21	
(3) Hatch cover rest bar	0.16	
(4) Cleats and fittings	0.44	Full penetration welding may be required
(5) Primary and secondary stiffening of hatch covers	0.10	0.13 for tank covers and where covers strengthened for loads over
13 Steering control systems		
(1) Rudder ① Fabricated main piece and main piece to side plates and webs ② Slot welds inside plates ③ Remaining construction	 0.44 0.44 0.21	
(2) Fixed and steering nozzles: Main structure Elsewhere	0.44 0.21	
(3) Thruster units, stabilizers: Main structure Elsewhere	0.44 0.21	
14 Miscellaneous fittings and equipment		
(1) Rings for manhole type covers to deck, inner bottom or bulkhead	0.34	
(2) Frames of watertight or weathertight bulkhead doors	0.34	
(3) Stiffening of watertight doors	0.21	
(4) Ventilator, air pipes, etc., coamings to deck	0.34 0.21	Load Lines (1966) positions 1 and 2 Positions other than positions 1 and 2
(5) Ventilators, etc., fittings	0.21	
(6) Scuppers and discharges, to deck	0.44	
(7) Masts, burner boom, crane pedestals, etc., to deck	Full penetration	See 5.2.7 of PART THREE of CCS Rules for Materials and Welding
(8) Deck machinery seats to deck	0.21	Special equipment subject to its design
(9) Seats of mooring equipment, fairleads and cable stoppers to deck	0.44	Full penetration welding may be required.
(10) Bulwark stays to deck	0.21	
(11) Bulwark attachment, guardrails, stanchions, etc., to deck	0.34	
(12) Bilge keel ground bars to shell	0.34	Continuous fillet welds, minimum throat thickness 4 mm
(13) Bilge keel to ground bars	0.21	Light continuous or staggered intermittent fillet welds, minimum throat thickness 3 mm
(14) Rings and coamings for manhole type covers to shell on columns and lower hulls, general	Full penetration	However, other proposals may be considered

1.5.4.3 Where in T connections the thickness of the abutting member (e.g. the web of a stiffener or longitudinal) is greater than 15 mm and exceeds the thickness of the table member (e.g. bulkhead plating, shell plating or deck plating), the welding is to be double continuous and the throat thickness *h* of the weld is to be neither less than as required in Table 1.5.4.4(2) of this Section, nor less than the greater of the following:

$$h = 0.5Ct_v \quad \text{mm}$$

$$h = 0.21t_h \quad \text{mm}$$

where: t_v — thickness of the abutting member, in mm;

t_h — thickness of the table member, in mm;

C — coefficient, 0.21 for dry spaces, or 0.27 for liquid tanks.

1.5.4.4 Except as permitted by 1.5.4.2 and 1.5.4.3 of this Section, the throat thickness of all fillet welds is to comply with the following requirements:

(1) The throat thickness limits are to be as shown in Table 1.5.4.4(1);

(2) The minimum value of throat thickness is also to comply with Table 1.5.4.4(2).

Throat Thickness Limits Table 1.5.4.4(1)

Weld type	Throat thickness limits (mm)	
	Minimum	Maximum
Double continuous fillet welding	$0.21t_p$	$0.44t_p$
Intermittent fillet welding	$0.27t_p$	$0.44t_p$

Notes:

(1) For t_p, see 1.5.4.2(1) of this Section.

(2) When the actual plate thickness t'_p exceeds 25 mm, $t_p = 0.5\,(t'_p + 25)$.

Minimum Throat Thickness Table 1.5.4.4(2)

Plate thickness t_p (mm)		≤ 7.5	> 7.5
Minimum throat thickness (mm)	Manual or automatic welding	3	3.25
	Automatic deep penetration	3	3

Note: For t_p, see 1.5.4.2(1) of this Section.

1.5.4.5 Where intermittent fillet welds are used for the connection of main structural members, double continuous fillet welding is to be carried out for a specified length of round-the-end weld in the following locations:

(1) The length of the round-the-end weld at the ends of brackets is to be not less than the depth of the connecting members, nor less than 75 mm.

(2) Where the ends of sections, particularly of short sections, are snipped off, the length of the round-the-end weld is to be not less than the depth of such sections or nor less than the length of snipping.

(3) The length of the round-the-end weld at the ends of notches, lugs and scallops as well as at the orthogonal connections with other members is to be not less than 75 mm for plate thickness > 12 mm, and not less than 50 mm for plate thickness ≤ 12 mm.

1.5.4.6 Where scallops are cut in the structural members for intermittent welding, both ends of the scallops are to be rounded and smooth. But no scallops are permitted in the following locations:

(1) in way of the ends of brackets where stress concentration occurs;

(2) in the main frames, longitudinals and stiffeners for at least 230 mm on each side of the intersection with a primary supporting member.

1.5.4.7 Where a structural member passes through a watertight or an oiltight bulkhead, in addition to the fitting of a welded collar on the bulkhead as required by relevant standards, a small semicircular notch is to be cut on one side of the passing member as shown in Fig. 1.5.4.7(1). And double continuous fillet welding is to be carried out round the end of the semicircular notch to the bulkhead so as to ensure tightness of the bulkhead.

For bulkheads adjacent to a tank, fillet welds in way of 150 mm fore and aft of oil gas-tight or watertight bulkheads are to be properly beveled and full penetration is required in order to prevent the leakage of dangerous gases or liquids into adjacent compartments, see Fig. 1.5.4.7 (2). Other equivalent means may be adopted.

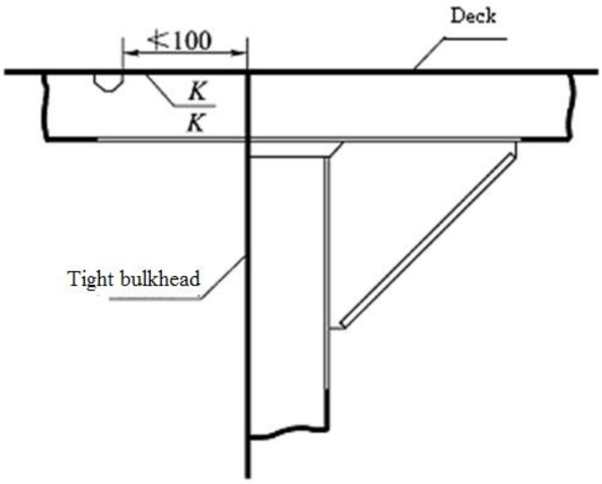


Fig. 1.5.4.7(1)

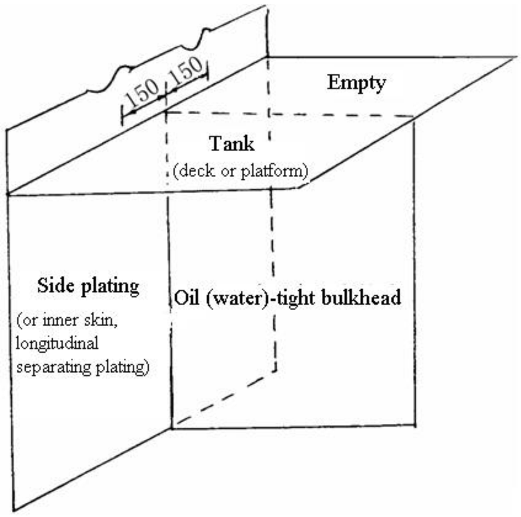


Fig. 1.5.4.7(2)

1.5.4.8 The size of fillet welds in primary members is to comply with the following:

(1) Weld factors may be obtained from Table 1.5.4.8.

(2) Where the webs of primary members are cut for the passage of secondary members and the width of the notch exceeds 15% of the stiffener spacing, the weld factor w_τ or the leg length K of the fillet weld is to be multiplied by coefficient C obtained from the following formula:

$$C = \frac{0.85 \times \text{stiffener spacing}}{\text{length of web plating between notches}}$$

(3) In calculating the throat thickness, the overall length of the weld at the end of the members may be taken into account.

Weld Factors of Primary Members Table 1.5.4.8

Cross-sectional area A of face plate of T-type members (cm^2)	Position①	In tanks		In dry spaces	
		To face plate	To plating	To face plate	To plating

		w_τ	w_τ	w_τ	w_τ
$A \le 30$	At ends	0.21	0.27	0.21	0.21
	Remainder	0.10	0.16	0.10	0.13
$30 < A \le 65$	At ends	0.21	0.34	0.21	0.21
	Remainder	0.13	0.27	0.13	0.16
$65 < A \le 95$	At ends	0.34	0.44③	0.21	0.27
	Remainder	0.27②	0.34	0.16	0.21
$95 < A \le 130$	At ends	0.34	0.44③	0.27	0.34
	Remainder	0.27②	0.34	0.21	0.27
$A > 130$	At ends	0.44	0.44③	0.34	0.44③
	Remainder	0.34	0.34	0.27	0.34

Notes:

① The weld factors "at ends" are to be applied for 0.2 × the length of the member from each end, but at least beyond the toes of the member end brackets. On vertical webs the increased welding may be omitted at the top, but is to extend at least 0.3 × length from the bottom. "Length of the member" means the overall length of the member (including end brackets).

② For crude oil storage tanks, the weld factor is to be 0.34. The final throat thickness of the weld fillet to be not less than 0.34 t_p. For *tp*, see 1.5.4.2(1) of this Section.

③ Where the web plate thickness is increased locally, the throat thickness is to be determined by 0.44 t_p or 0.34 t_c, whichever is the greater. For t_p, see 1.5.4.2(1) of this Section, and t_c is the increased thickness of plate.

1.5.4.9 The area of welding of end connections of primary members is to be not less than the cross-sectional area of the member, and the weld factor of which is not to be less than 0.34 in tanks or 0.27 elsewhere.

1.5.4.10 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the area A_w of weld is not to be less than the cross-sectional area of the strength member.

1.5.4.11 Where the secondary member passes through, and is supported by, the web of a primary member, the weld connection is to be in accordance with the following:

(1) Area A_w of weld is to be not less than $0.5\sqrt{w}$ and the weld factor not less than 0.34 in tanks or 0.27 in dry spaces, where w is the section modulus of the secondary member, in cm³.

(2) In crude oil tanks the size of weld is to be increased by 20% above that obtained from (1) above.

1.5.4.12 The fillet welding of secondary member end connections is to be as required in Table 1.5.4.12 and where two values are given, the greater is to be taken.

Weld Factors of End Connections of Secondary Members Table 1.5.4.12

Connection	Weld area A_w (cm^2)	Weld factor w_τ
1. Stiffener welded direct to deck, shell, bulkhead plating etc.	0.25 A_s or 6.5	0.34
2. Stiffener connected or lapped to bracket: (1) in dry space (2) in tank (3) main frame to tank side bracket in 0.15L forward		 0.27 0.34 0.34
3. Bracket welded to face of stiffener and bracket connection to deck, shell, bulkhead plating etc.	—	0.34
4. Stiffener to plating for 0.1 × span at ends where not fixed by welding	—	0.34

Notes:

(1) A_s — cross-sectional area of the stiffener, in cm^2.

(2) A_w — area of the weld, in cm^2, calculated as total length of the weld, in cm, × throat thickness, in cm.

1.5.5 Welding of tubular members

1.5.5.1 Welding is to comply with the relevant requirements in Chapter 6 of PART THREE of CCS Rules for Materials and Welding, or internationally or nationally recognized standards.

1.5.5.2 All welding is to conform to the following:

(1) All steels are to be joined by full penetration welds.

(2) Unless single-sided welding has been agreed for a particular weld configuration, double-sided welds are to be used, wherever practicable.

(3) In lattice type structures, a minimum weld attachment length at the cord of 1.5 times the brace wall thickness is required at all locations.

(4) Care is to be taken to ensure the weld surface profile is smooth and blends with the parent material.

(5) Backing strips are not to be used unless specially agreed by CCS.

(6) Root gaps are to be generally in the range of 3 to 6 mm.

(7) Bevels are to be such that the included angle is in the range 45°to 60°. When the dihedral angle (the angle between the brace wall and chord wall) is less than 45°, however, the included angle may be reduced appropriately as indicated for locations 4 and 5. See Fig. 1.5.5.3(5) and (6).

(8) Where saddle weld toe grinding has been agreed as a method of improving fatigue life, the grinding of the weld toe is to produce a smooth transition between the weld and the parent plate at the locations agreed. The grinding is to remove all defects, slag inclusions and any undercut. Overgrinding into the parent plate is not to exceed 2 mm or 0.05 times the plate thickness, whichever is less. The grinding tool is to preferably have a spherical head (e.g. a tungsten carbide burr) and, in general, disk-grinders are to be avoided except for initial heavy grinding. Any marks made by rotation of the grinding tool are to be aligned with the direction of stress. The surface of the main body of the weld may be dressed to produce a better concave profile if the as-welded profile is poor. See Fig. 1.5.5.2(1) and (2). Care is to be exercised in order that overgrinding does not excessively reduce the size of the attachment weld and in no case less than that required by the Rules.

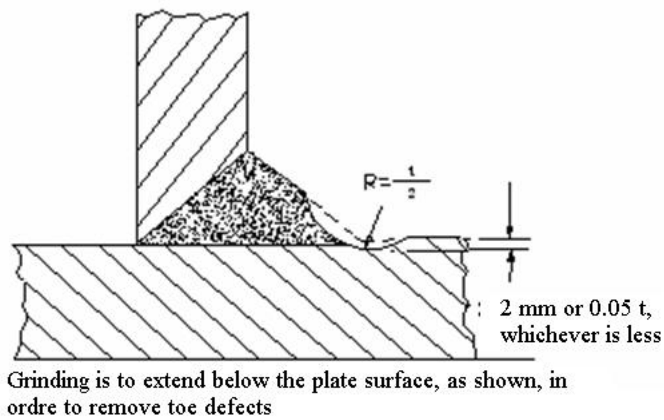


Fig. 1.5.5.2(1)

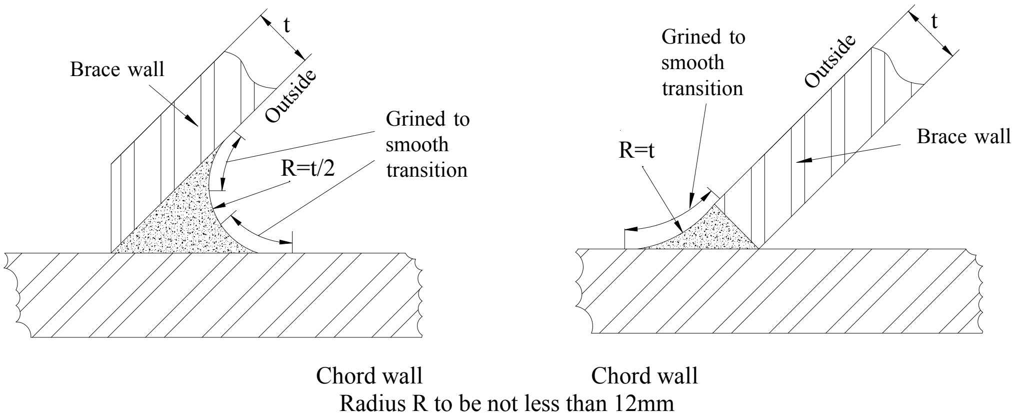


Fig. 1.5.5.2(2)

1.5.5.3 Locations 1, 2, 3, 4 and 5 are related to the local dihedral angle, see Fig. 1.5.5.3(1). Transition from one location to another is to be smooth. Required configurations of welds are shown in Fig. 1.5.5.3(2), (3), (4), (5) and (6).

Location	Applicable range of local dihedral angle	Remarks
1	180° ~ 135°	See Fig. 1.5.5.3 (2)
2	150° ~ 90°	See Fig. 1.5.5.3 (3)
3	90° ~ 50°	See Fig. 1.5.5.3 (4)
4	75° ~ 30°	See Fig. 1.5.5.3 (5)
5	40° ~ 15°	See Fig. 1.5.5.3 (6)

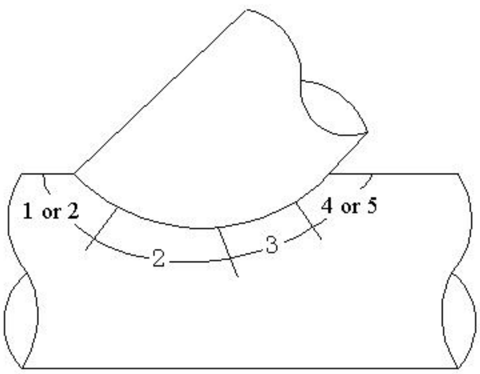


Fig. 1.5.5.3(1) Weld Location

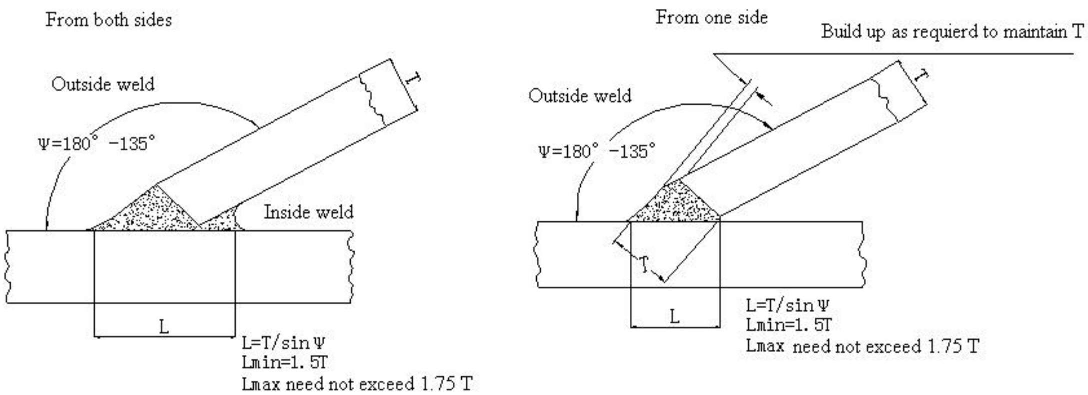


Fig. 1.5.5.3 (2) Weld Location 1

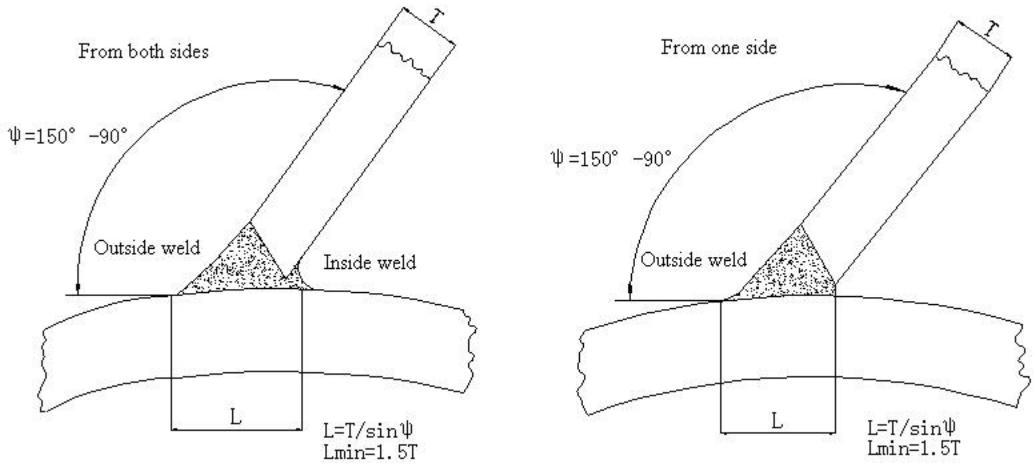


Fig. 1.5.5.3 (3) Weld Location 2

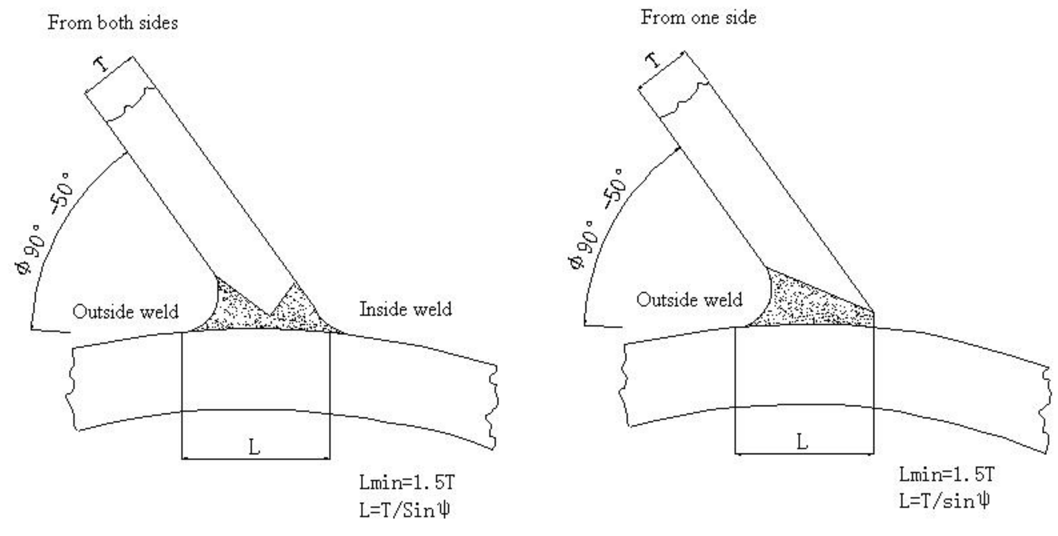


Fig. 1.5.5.3 (4) Weld Location 3

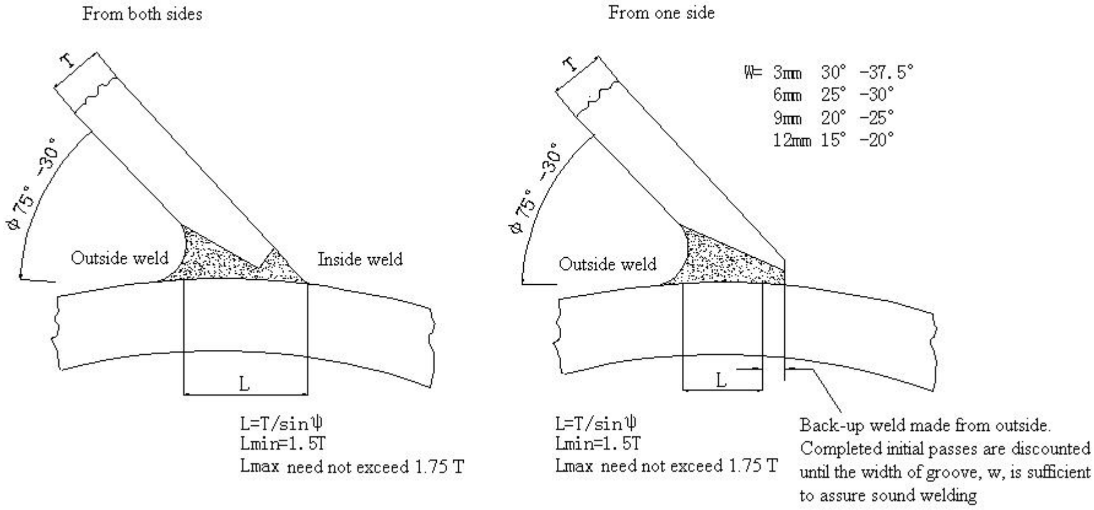


Fig. 1.5.5.3 (5) Weld Location 4

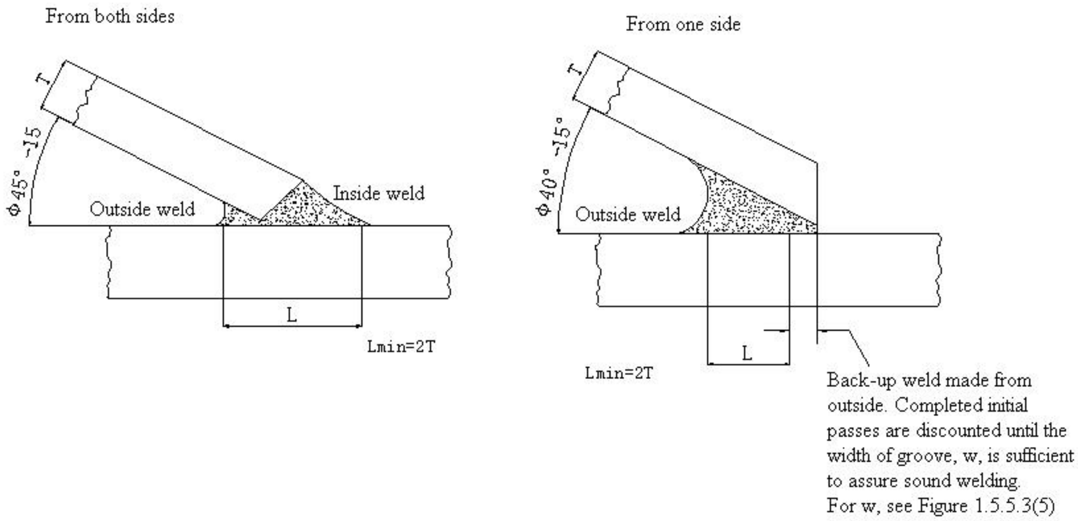


Fig. 1.5.5.3 (6) Weld Location 5

Section 6 APPLICATION OF HIGHER TENSILE STEEL

1.6.1 General requirements

1.6.1.1 The chemical composition and mechanical properties of higher tensile steel are to comply with the relevant requirements as specified in CCS Rules for Materials and Welding.

1.6.1.2 Where higher tensile steel is used in structures, its category, grade, location and extent are to be indicated on structural plans in order to facilitate repairing and maintenance.

1.6.1.3 Where higher tensile steel is used, reductions for the determination of scantlings of local structural members, e.g. plating, stiffeners and girders, will be made by applying the following material factor *K* to the formula:

$$K = \frac{235}{\sigma_s}$$

where: σ_s — yield strength of material, in N/mm^2。

1.6.1.4 The requirements in 1.6.1.3 of this Section do not apply to the minimum thickness specified in the Rules.

Section 7 CORROSION PROTECTION FOR STRUCTURES

1.7.1 General requirements

1.7.1.1 Appropriate corrosion protection means are to be provided for both outside and inside surfaces of all steel structures and for upper structures. Pain (galvanic) coating protection, cathodic protection systems or other approved corrosion protection systems may be applied. Any corrosion protection system used is to be suitable for the location and purpose of the structure.

1.7.1.2 The corrosive environments, to which steel structures are exposed at sea, are divided into: atmosphere, splash zone and underwater zone. Corrosion protection means are to be provided according to characteristics of different marine environments, service life, construction, maintenance and possibilities of renewal as well as technical and economic effects, as appropriate.

1.7.1.3 Corrosion protection of outside surfaces of steel structures

(1) For steel structures in atmosphere, painting is to be applied to prevent corrosion. For small complicated structural members or those members to which special requirements apply, galvanic coating may be accepted.

(2) For steel structures in splash zones, high-performance and enduring paint is to be applied and in addition, an appropriate corrosion allowance is recommended to be taken into account.

(3) For steel structures in underwater and sea mud zones, both cathodic protection and coating are recommended to be applied for corrosion protection. For units intended to be subject to in-water survey in lieu of drydock survey, high-performance and enduring paint is to be applied. Details of the paint are to be submitted to CCS for information.

1.7.1.4 Corrosion protection of inside surfaces of steel structures

For inside surfaces of the steel structures exposed to air, seawater or other corrosive environments, coating or cathodic protection or both are to be applied for corrosion protection.

1.7.1.5 Where bimetallic connections are made, proper measures are to be incorporated to preclude galvanic corrosion.

1.7.1.6 The cathodic protection system fitted with sacrificial anodes in tanks is to comply with paragraph 1.6.3 in Chapter 6 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

1.7.1.7 Corrosion protection for structures is to be designed, applied and inspected in accordance with CCS Guidelines for Anticorrosion Inspection of Hull Structure and/or relevant national and international standards.

1.7.2 Paints

1.7.2.1 Paints used are to be made by the manufacturers recognized by CCS. If not, it is to be agreed by CCS in advanced.

1.7.2.2 Coating is to be designed as required by 1.7.1.7 above. The coating system is to be suitable for the environment, operating conditions and service life to which the coated surfaces are subject. The primer, intermediate coat, finish coat and diluent are to be appropriate to each other.

1.7.2.3 No aluminum paint is to be used for crude oil tanks, crude oil tank deck, pump rooms, cofferdams or any other location where oil vapor may accumulate.

1.7.2.4 Where a primer is used during the construction, the primer is to be applied right after surface preparation. The composition of the primer is to be such that it will not affect the quality of welds and have no significant adverse effects on subsequent welding work and that it is compatible with the paints or other coatings subsequently applied in association with an approved system of corrosion control for structures. Primers are to be approved in accordance with the relevant requirements of CCS.

1.7.2.5 The colour of finish coat of ballast tanks in periphery of crude oil tanks is preferably to be white or light for facilitating crack and leakage inspection.

1.7.2.6 Anti-fouling paints containing TBT substance (organotin compounds) are not permitted to be applied or re-applied to the anti-fouling systems of all units. If anti-fouling systems are installed, they are to conform to the relevant requirements of the International Convention on the Control of Harmful Anti-fouling Systems on Ships, 2001.

1.7.3 Cathodic protection

1.7.3.1 The cathodic protection system is to be of the type of sacrificial anodic protection or external current protection or both.

1.7.3.2 The cathodic protection system is to be designed in accordance with 1.7.1.7 above. The cathodic protection may be combined with coating to reduce protective current density and improve current distribution. The paints used in combination with cathodic protection are to be tested for film endurance under cathodic protection in accordance with national or international standards and the test report is to be submitted to CCS for check.

1.7.4 Corrosion allowance

1.7.4.1 Except for the scantlings of bulkheads as specified in Chapter 3 of this part, the required corrosion allowances are not incorporated in the scantlings of structural members which are directly calculated in accordance with this part, and appropriate corrosion allowances are to be taken into account with regard to the environmental conditions to which they are subject in their respective areas and locations as well as the corrosion protection means provided.

1.7.4.2 The added corrosion allowances are to be indicated in plans and information.

1.7.5 Protective coatings of dedicated seawater ballast tanks

1.7.5.1 All dedicated seawater ballast tanks are to be designed, constructed and surveyed in accordance with the relevant provisions specified in CCS Interim Guidelines for Implementation of IMO Performance Standard for Protective Coatings for Dedicated Seawater Ballast Tanks in All Types of Ships and Double-Side Skin Spaces of Bulk Carriers.

1.7.5.2 For the purpose of this paragraph, pre-load tanks of self-elevating units are to be considered dedicated seawater ballast tanks. Spudcans and mat tanks of such units may not be considered dedicated seawater ballast tanks.

1.7.5.3 Maintenance of the protective coating system is to be included in the unit’s overall maintenance scheme. The effectiveness of the protective coating system is to be verified during the life period of a unit by CCS based on the Guidelines for Maintenance and Repair of Protective Coatings (MSC.1/Circ.1330) developed by IMO.

Section 8 STRUCTURAL ARRANGEMENT

1.8.1 General requirements

The section applies to structural design and analysis of the units as defined in Chapter 2 of PART ONE. In addition, the units intended for different purposes are to comply with the relevant requirements in PART EIGHT.

1.8.2 Access

1.8.2.1 Means of access

(1) Each space within the unit is to be provided with at least one permanent means of access to enable, throughout the life of a unit, overall and close-up inspections and thickness measurements of the unit’s structures to be carried out by the Administration, the company, and the unit’s personnel and others as necessary. Such means of access are to comply with the provisions of paragraph 1.8.2.3 and with the Technical Provisions for Means of Access for Inspections, adopted by the Maritime Safety Committee by resolution MSC.133(76).

(2) Where a permanent means of access may be susceptible to damage during normal operations or where it is impracticable to fit permanent means of access, CCS may allow, in lieu thereof, the provision of movable or portable means of access, as specified in the Technical Provisions, provided that the means of attaching, rigging, suspending or supporting the portable means of access forms a permanent part of the unit’s structure. All portable equipment is to be capable of being readily erected or deployed by the unit’s personnel.

(3) The construction and materials of all means of access and their attachment to the unit’s structure are to be

to the satisfaction of CCS.

1.8.2.2 Safe access to holds, tanks, ballast tanks and other spaces

(1) Safe access to holds, cofferdams, tanks and other spaces are to be direct from the open deck and such as to ensure their complete inspection. Safe access may be from a machinery space, pump-room, deep cofferdam, pipe tunnel, hold, double hull space or similar compartment not intended for the carriage of oil or hazardous materials where it is impracticable to provide such access from an open deck.

(2) Tanks, and subdivisions of tanks, having a length of 35 m or more, are to be fitted with at least two access hatchways and ladders, as far apart as practicable. Tanks less than 35 m in length are to be served by at least one access hatchway and ladder. When a tank is subdivided by one or more swash bulkheads or similar obstructions which do not allow ready means of access to the other parts of the tank, at least two hatchways and ladders are to be fitted.

(3) Each hold is to be provided with at least two means of access as far apart as practicable. In general, these accesses are to be arranged diagonally, e.g., one access near the forward bulkhead on the port side, the other one near the aft bulkhead on the starboard side.

(4) Spud can and lifting foundations of Jack-up platforms are exempt from the above provisions.

1.8.2.3 Access Manual.

(1) The access used for comprehensive inspection, close inspection and thickness measurement on the unit are described by a channel manual.The volume can be incorporated into the operation manual of the unit. The manual should be updated as needed and the latest version of the manual should be kept on the unit. The access manual should include the following information for each place:

① The map of the entrances and exits of the premises, with corresponding technical instructions and dimensions.

② Each place can carry out a comprehensive inspection of the acess map, and have the corresponding technical instructions and dimensions. The picture should indicate where each area of the premises can be inspected.

③ The access diagram of the premises where close inspection can be carried out, and the corresponding technical instructions and dimensions shall be provided. The figure should indicate the location of the critical structural area, whether the channel is fixed or portable, and where each area can be checked.

④ Instructions for the inspection and maintenance of the structural strength of all entrances and exits and ancillary equipment, in which the influence of corrosive gases in the premises shall be taken into account.

⑤ Safety precautions when using rafts for close inspection and thickness measurement.

⑥ Instructions for the safe installation and use of any portable channel.

⑦ A detailed list of all portable access.

⑧ record the regular inspection and maintenance of the unit channel.

(2) for the purposes of this paragraph, "critical structural area" means the local area to be monitored by calculation, or areas where cracks, buckling, deformation or corrosion of similar units or sister units are prone to damage the structural integrity of the unit in the history of operation .

1.8.2.4 General technical specifications

(1) For access through horizontal openings, hatches or manholes, the dimensions are to be sufficient to allow a person wearing a self-contained air-breathing apparatus and protective equipment to ascend or descend any ladder without obstruction and also provide a clear opening to facilitate the hoisting of an injured person from the bottom of a confined space. The minimum clear opening is not to be less than 600 mm × 600 mm and may have corner radii up to 100 mm maximum. Where the opening is made larger than this minimum size, the maximum corner radius is to be increased appropriately. When access to a hold is arranged through a flush manhole in the deck or a hatch, the top of the ladder is to be placed as close as possible to the deck or hatch coaming. Access hatch coamings having a height greater than 900 mm is also to have steps on the outside in conjunction with the ladder.

(2) For access through vertical openings, or manholes, in swash bulkheads, floors, girders and web frames providing passage through the length and breadth of the space, the minimum opening is not to be less than 600 mm × 800 mm at a height of not more than 600 mm from the bottom shell plating unless gratings or other footholds are provided.

(3) For small units for operations in coastal waters, openings with smaller dimensions may be accepted under special conditions with the approval of CCS, provided that these openings can allow the passage and transfer of the injured persons; however, the dimension of the openings is not to be less than 400mm×600mm or 450mm×550mm, and the structure is required to have sufficient strength after the openings are made.

(4) Spuds cans and jack cases of self-elevating units can be excluded from above mentioned clauses.

1.8.3 Protection of fuel oil tanks

For units of which the aggregate capacity of fuel oil tanks is 600 m^3 or over, delivered on or after 01 August 2010, the arrangement of fuel oil tanks are to comply with the provisions specified in Regulation 12A of Annex I to the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto.

1.8.4 Cofferdams

1.8.4.1 A cofferdam means an empty space arranged so that compartments on each side have no common boundary; a cofferdam may be located vertically or horizontally. A cofferdam is to be properly ventilated and of sufficient size to allow for inspection, maintenance and safe evacuation.

1.8.4.2 Cofferdams are to be provided between compartments intended for fuel oil and those intended for lubricating oil, and between compartments intended for fuel oil or lubricating oil and those intended for fresh water (drinking water, water for propelling machinery and boilers). Cofferdams are to be provided between compartments intended for fuel oil or lubricating oil and tanks intended for the carriage of liquid foam for fire extinguishing.

1.8.4.3 The layout requirements of the isolated empty compartments shall also meet the relevant applicable provisions of Section 2 of Chapter 1 of Part Four of the Rules..

1.8.5 Protection of crew

1.8.5.1 Guardrails or bulwarks are to be fitted around all exposed decks. The height of the guardrails or bulwarks is to be at least 1 m from the deck.

1.8.5.2 Guardrails fitted on superstructure and freeboard decks are to comply with Regulation 25(3) of the Amendment to Annex I to Annex B to the Protocol of 1988 relating to the International Convention on Load Lines, 1966. Considering the particularity of mobile offshore units, as a substitute for some technical clauses and conditions of the request, the relevant content of IACS UI LL47 may be refered to.

1.8.5.3 Safe passage of crew is to be arranged in accordance with Regulation 25-1 of the amendments to Annex I to Annex B to the Protocol of 1988 relating to the International Convention on Load Lines, 1966.

CHAPTER 2 DESIGN LOADINGS

Section 1 GENERAL PROVISIONS

2.1.1 Design loadings

2.1.1.1 The dynamic response and loadings under design conditions such as transit, operating and survival conditions for each unit are to be investigated using realistic loading conditions, including gravity and functional loads together with the relevant environmental loads.

2.1.1.2 The owner/designer is to specify design conditions and relevant environmental conditions on which the classification is to be based.

2.1.2 Environmental loadings

2.1.2.1 Environmental loadings are those which are due directly or indirectly to environmental actions, including all external forces due to environmental loads, e.g. mooring forces, inertia forces, sloshing forces.

Environmental loadings comprise generally:

(1) wind loadings;

(2) wave loadings, and

(3) current loadings.

Where deemed necessary by the owner/designer, the effects of earthquake, seabed bearing capacity, temperature, fouling, ice/snow, etc. are also to be taken into account.

2.1.2.2 Where possible, the design environmental conditions are to be determined by use of relevant statistical method based upon environmental data for the specific location and are to have a period of recurrence of at least 50 years for survival conditions and count the effects of the simultaneous occurrence of wind, wave and current with return periods of 50 years.

2.1.2.3 In addition to the methods given in this Chapter, the environmental loadings may be calculated by any other recognized method and where necessary, they are to be determined by mathematical simulations or physical model tests.

2.1.2.4 Limiting design data for each mode of operation are to be stated in the operating manual.

2.1.3 Gravity and functional loadings

2.1.3.1 Gravity and functional loadings are loadings which exist due to the unit's weight, use and operation in still water conditions.

Gravity and functional loadings comprise generally:

(1) lightweight (see 1.2.4.3);

(2) consumables like oil, water, mud and stores;

(3) Loadings due to drilling and lifting operation, e.g.: hook loadings, rotary table, set-back, tensioner and the weight of the equipment of production and processing and storage tanks,(4) deck loadings (see Section 5 of this Chapter);

(5) ballast loadings;

(6) mooring loadings;

(7) loadings of production risers (where applicable);

(8) loadings due to marine growth, ice/snow accumulated on exposed structures.

Section 2 WIND AND WIND LOADINGS

2.2.1 Wind velocity, wind pressure

2.2.1.1 When determining the wind load, the wind speed of persistent wind and gust shall be considered according to the actual situation. For units with additional signs of operating restrictions, the sustained wind speed selected by the owner or designer shall not be less than 25.8m/s (50kn). For units with unlimited operation areas, the minimum design wind speed for their structures shall be::

(1) 51.5 m/s (100 kn) for survival mode;

(2) 36 m/s (70 kn) for normal operating mode

For units with a service restriction notation, consideration is to be given to a reduced wind velocity of not less than 25.8 m/s (50 kn) under normal operating conditions.

2.2.1.2 The wind pressure P is to be obtained from the following equation:

$$P = 0.613 \times 10^{-3} V^2 \quad \text{kPa}$$

where: V — design wind velocity, in m/s.

2.2.2 Wind loadings

2.2.2.1 The wind force F acting on structural members is to be calculated according to the following formula, and the vertical height of the acting point of the resultant force is to be determined:

$$F = C_h C_s SP \quad kN$$

where: P — wind pressure, in kPa;

S — projected area of all exposed surfaces in either the upright or heeled condition of the unit, in m^2;

C_h — height coefficient from Table 2.2.2.1(a) according to the height h of the structural member exposed to the wind, the height being the vertical distance from the design waterplane to the centroid of the structural member;

C_s — shape coefficient of the structural member exposed to the wind, its value may be taken from Table 2.2.2.1(b) according to its shape, and may also be determined by wind tunnel test.

2.2.2.2 In calculating the wind forces, the following procedures are recommended:

(1) In the case of units with columns, the projected areas of all columns are to be included; i.e. no shielding allowance is to be taken.

(2) Areas exposed due to heel, such as underdecks, etc., are to be included using the appropriate shape coefficient.

(3) The block projected area of a clustering of deckhouses may be used in lieu of calculating each individual area. The shape coefficient may be assumed to be 1.1.

(4) Isolated houses, structural shapes, cranes, etc., are to be calculated individually, using the appropriate shape coefficient.

(5) Open truss work commonly used for derrick towers, booms and certain types of masts may be approximated by taking 30% of the projected block area of each side, or 60% of the projected block area of one side for double-sided truss work. An appropriate shape coefficient is to be taken from Table 2.2.2.1(b).

Height Coefficient Ch **Table 2.2.2.1(a)**

Height above sea level h (m)	Height coefficient C_h
0-15.3	1.00
15.3-30.5	1.10
30.5-46.0	1.20
46.0-61.0	1.30
61.0-76.0	1.37
76.0-91.5	1.43
91.5-106.5	1.48
106.5-122.0	1.52

122.0-137.0	1.56
137.0-152.5	1.60
152.5-167.5	1.63
167.5-183.0	1.67
183.0-198.0	1.70
198.0-213.5	1.72
213.5-228.5	1.75
228.5-244.0	1.77
244.0-259.0	1.79
Above 259	1.80

Shape Coefficient Cs **Table 2.2.2.1(b)**

Shape of members	C_S
Spherical	0.4
Cylindrical	0.5
Large flat surface (hull, deckhouse, smooth surface under deck)	1.0
Clustered deckhouses or similar structures	1.1
Wires	1.2
Drilling derrick	1.25
Exposed underdeck beams and girders	1.3
Small parts	1.4
Isolated structures (crane, beam, etc.)	1.5

2.2.2.3 The determination of pressures and resultant forces may be taken in accordance with the data derived from wind tunnel tests on a representative model of the unit by a recognized laboratory.

Section 3 WAVES AND WAVE LOADINGS

2.3.1 Design waves

Design wave criteria specified by the owner/designer may be described either by means of design wave energy spectra or deterministic design waves having appropriate shape, size and period.

2.3.2 Design wave height

2.3.2.1 The design wave height H_{max} of an individual wave with a return period can be estimated by accounting for the long-term uncertainty in the severity of the environment and the short-term uncertainty in the severity of the maximum wave of a given sea state or storm.

H_s may usually be determined from H_{max} using the generally accepted relationship as given:

for non-cyclonic areas $H_{max}=1.86H_s$

for cyclonic areas $H_{max}=1.75H_s$

2.3.2.2 Design of coastal or offshore structures in shallow water requires a reliable estimation of maximum wave height.

2.3.3 Wave period

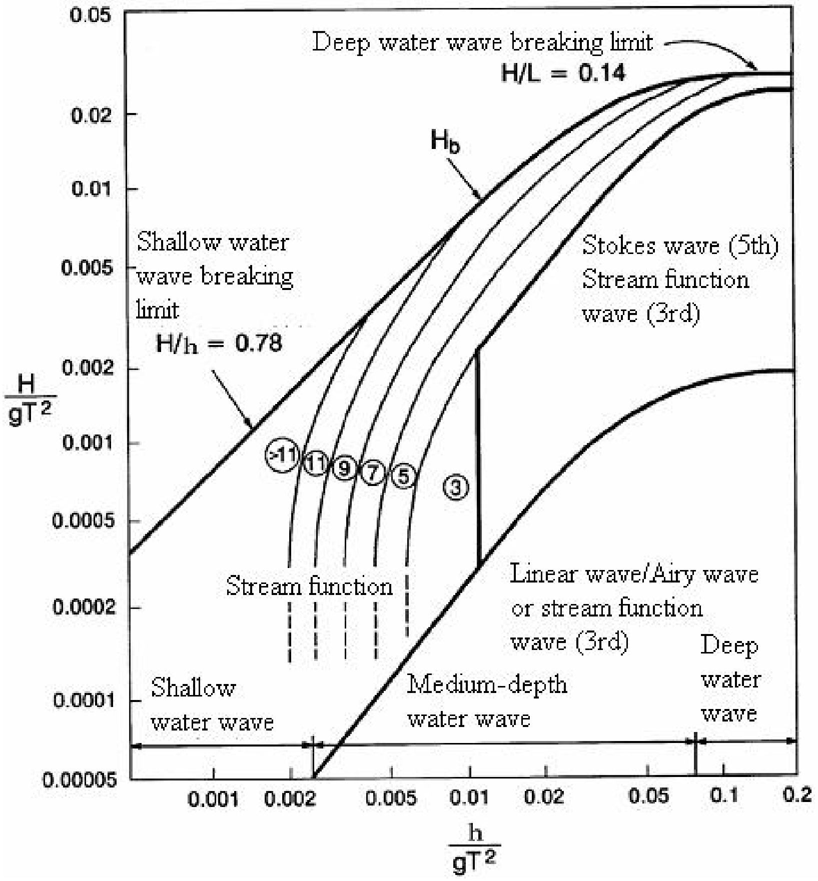
2.3.3.1 Where the design wave height has been determined, the corresponding wave period T is to be a value that may cause the structure a maximum stress within a period range of $\sqrt{6.5H_{max}} \le T \le \sqrt{11H_{max}}$ (H_{max}, m; T, s).

2.3.3.2 Consideration is to be given to waves of a height less than H_{max}, where, due to their period, the effects on structural elements may be greater.

2.3.4 Wave theory

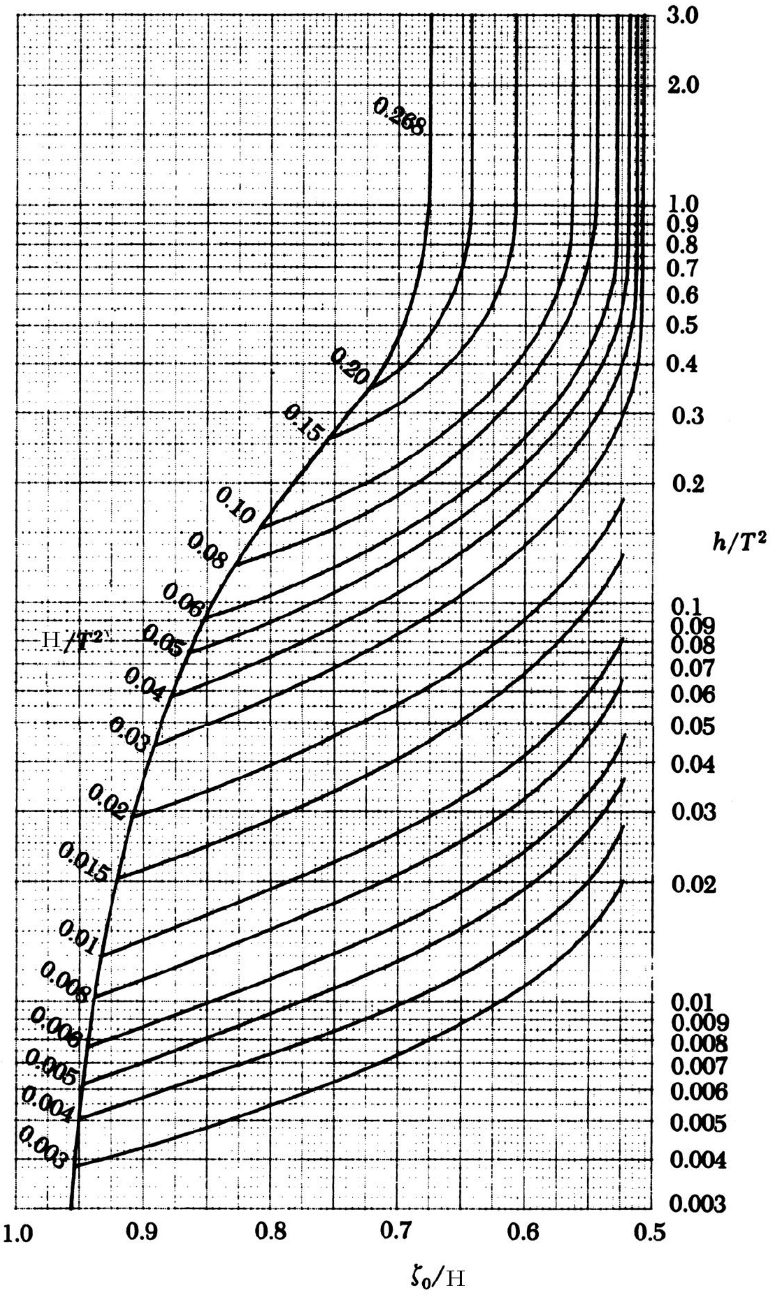
2.3.4.1 The wave pattern taken into consideration depends on the wave theory adopted, if it is not especially specified, Fig. 2.3.4.1 can be used as a reference to select an adequate wave theory.

2.3.4.2 For crest elevation above still water, refer to Fig. 2.3.4.2.



H/gT^2: dimensionless wave steepness h: mean water depth
h/gT^2: dimensionless relative water depth T: wave period
H: wave height g: acceleration of gravity
H_b: breaking wave height L: wave length

Fig. 2.3.4.1 Begions of Application of Various Wave Theories



ξ_0: crest elevation above still water *H:* wave height
T: wave period *h*: still water depth

Fig. 2.3.4.2 Wave Crest Elevation

2.3.5 Wave loadings

2.3.5.1 Wave forces acting on slender members

In general, wave loads on structures comprised of slender members with $D/L \leq 0.2$ (where D is the diameter or other projected cross-sectional dimension of a structural member and L is the wave length) may be calculated by Morison's equation.

In general, the Morison's equation can be expressed as:

$$F = F_D + F_I \qquad \text{kN/m}$$

where: F — wave force vector per unit length along the member, acting normal to the axis of the member;

F_D — drag force vector per unit length, in kN/m;

$$F_D = 1/2 \rho_W C_D A \,|u - \dot{x}|\,(u - \dot{x});$$

F_I — inertia force vector per unit length, in kN/m;

$$F_I = \rho_W C_A V(\dot{u} - \ddot{x}) + \rho_W V \dot{u}$$

$$= \rho_W V(C_M \dot{u} - C_A \ddot{x})$$

ρ_W —mass density of seawater, in t/m^3;

A — projected area per unit length along the member normal to the vector $(u - \dot{x})$, in m^2/m;

C_D — drag coefficient;

C_A — added mass coefficient;

C_M — inertia coefficient, $C_M = C_A + 1$;

V — volume of the member per unit length, in m^3/m;

u — component of the water particle velocity vector normal to the axis of the member, in m/s, and where sea current acts simultaneously with waves, u being component of the sum of wave particle velocity vector and current velocity vector normal to the member;

$\dot{u}$ — component of the water particle acceleration vector normal to the axis of the member, in m/s^2;

$\dot{x}$ — component of the velocity vector of the member normal to its axis, in m/s;

$\ddot{x}$ — component of the acceleration vector of the member normal to its axis, in m/s^2.

C_D and C_M are empirical coefficients to be determined using wave theories as appropriate. For wavy currents, C_D and C_M are related not only to Reynold's number R_e and relative surface roughness of the member, but also to Keulegan-Carpenter number.

For circular cylindrical members, $C_D = 0.6 \sim 1.2$ and $C_M = 1.3 \sim 2.0$ may be taken, and the values selected are not to be smaller than the lower limits of these ranges. For members other than circular cylindrical ones, C_D and C_M may be based on reliable data obtained from recognized literature. If necessary, C_D and C_M are to be determined by model tests.

Note: R_e number is defined as:

$$R_e = Du/V$$

K_C number is defined as:

$$K_C = uT/D$$

where: u — component of the water particle velocity at the axis of the member and normal to it, in m/s

D — characteristic dimension of the member, in m;

T — wave period, in s;

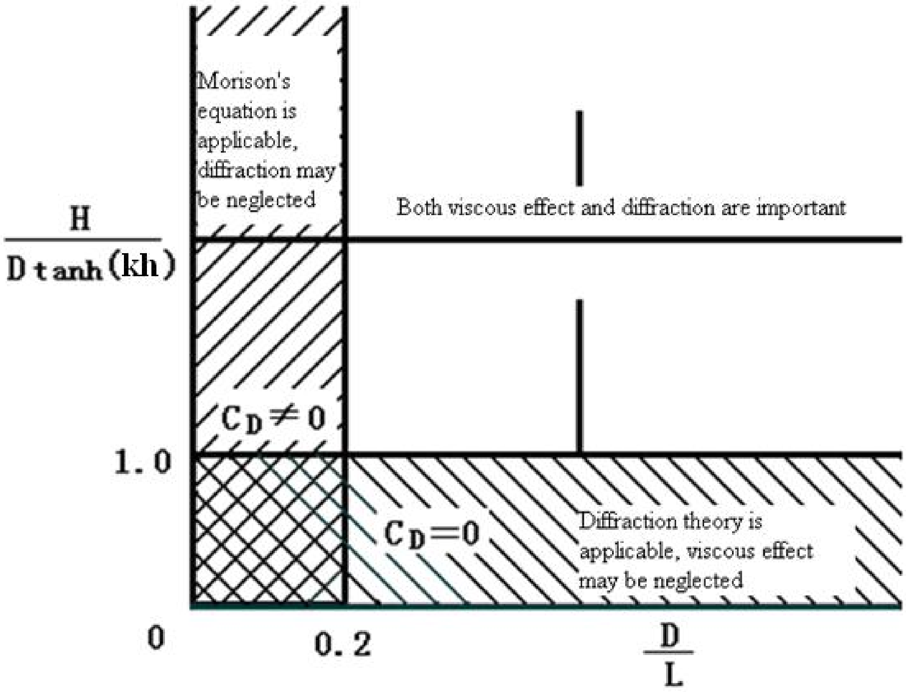
v — kinematic viscosity of seawater, in m^2/s.

2.3.5.2 Wave forces acting on large volume structures

For the large volume structures, the wave loadings may be obtained in general through integration of the total water pressure acting on wet surfaces of structures by diffraction theory.

Under diffraction theory, the flow field is described by velocity potential function. This velocity potential is to fulfill Laplace equation and the boundary conditions for surfaces of the structures, free surface, seabed and radiation condition. The total velocity potential consists of the incident wave potential, diffraction potential (restrained body assumed) and radiation potential from the oscillatory motion of the body in still water.

The application of Morison's equation and diffraction theory may be determined according to Fig. 2.3.5.2.



H – wave height; *D* – characteristic dimension of member pile; *L* – wave length; *h* – water depth; *k* – wave number

Fig. 2.3.5.2

Section 4 CURRENT AND CURRENT LOADINGS

2.4.1 Current

The design current velocity is to be taken as the maximum possible current velocity in the sea area where the unit is to operate. The current velocity is to include components due to tidal current, storm surge current and wind driven current. Consideration is to be given to the vertical distribution of current velocity in the sea area where the unit is to operate. In the presence of waves, the current velocity profile in still water is to be modified such that the current velocity at the instantaneous free surface is a constant. It is recommended that such modification may be carried out according to Fig. 2.4.1.1

$$V = V_t + V_s + V_w[(h_0 - z)/h_0] \quad \text{m/s for } z \le h_0$$

$$V = V_t + V_s \quad \text{m/s for } z > h_0$$

where: the letters are defined in Fig, 2.4.1.1.

2.4.2 Current loadings

2.4.2.1 When only current is taken into consideration, the current loadings acting on submerged members of the unit may be calculated by the following equation:

$$F = \frac{1}{2} C_D \rho_W V^2 A \quad \text{kN}$$

where: C_D — drag coefficient;

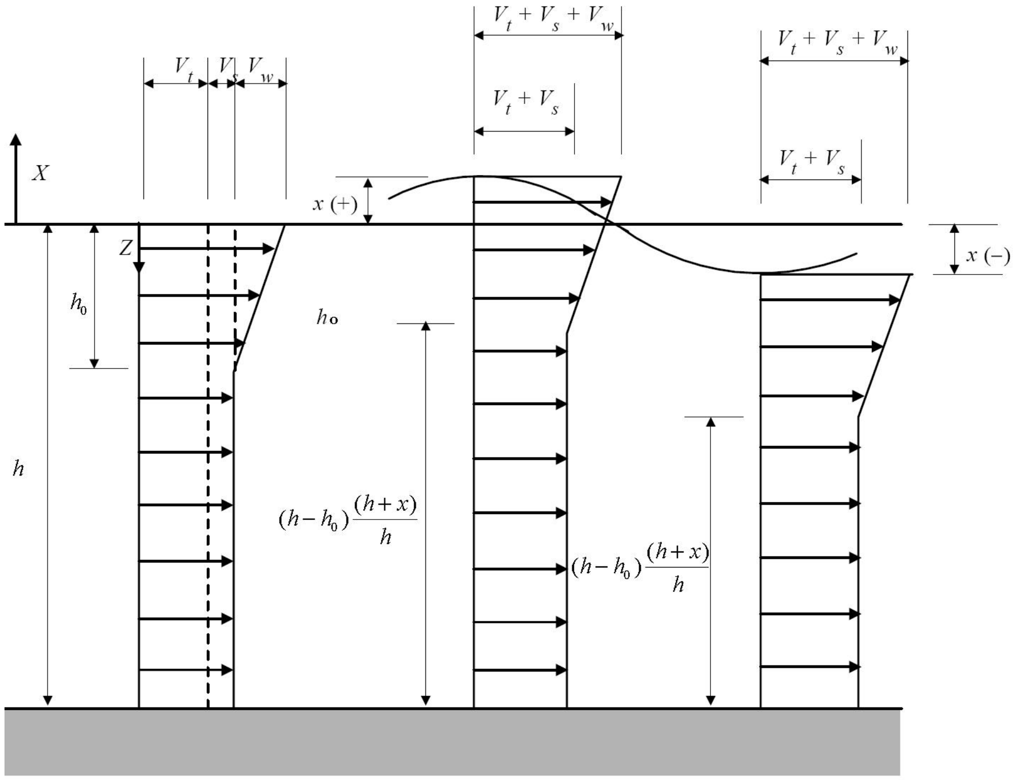
ρ_W — mass density of seawater, in t/m^3;

V — design current velocity, in m/s;

A — projected area of the member on a plane normal to the current direction, in m^2.

2.4.2.2 Consideration is to be given to the interaction of current and waves. When Morison's equation is used to calculate wave loadings, the current velocity is to be added vectorially to the wave particle velocity, see

2.3.5.1. When diffraction methods are used for calculating wave loadings, the current loading is to be calculated in accordance with 2.4.2.1 and added vectorially to the calculated wave loading.



V – design current velocity; V_t – tidal current velocity; V_s – storm surge current velocity;
V_w – wind driven current velocity; h_0 – reference depth for wind driven current;
z – vertical distance to water particle below still water level; h – still water depth

Fig. 2.4.1.1 Current Velocity Profile

Section 5 DECK LOADINGS

2.5.1 Deck loadings

2.5.1.1 The deck loading plan or specification for each unit is to show the maximum uniform and concentrated loadings to be considered for all areas for each mode of operation and each transit condition.

2.5.1.2 In the preparation of this plan or specification, the following loadings are to be considered as minimums:

crew spaces and walkways	4510 N/m^2
work areas including weather decks	9000 N/m^2
storage areas	13000 N/m^2
helicopter deck	2000 N/m^2

Section 6 VIBRATION INDUCED BY VON KARMAN VORTEX

2.6.1 General requirements

2.6.1.1 For cylindrical members, consideration is to be given to the possibility of resonance due to the frequency of variable force induced by Von Karman vortices close to the natural frequency of vibration of the structure.

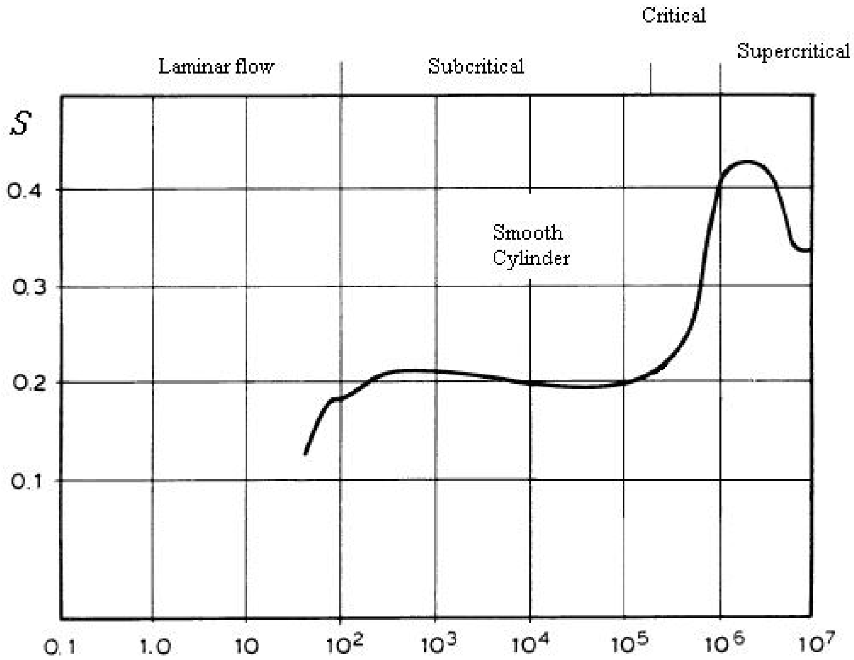
The frequency f_k of variable force can be determined by the following formula:

$$f_k = S\frac{V_n}{D} \quad 1/\mathrm{s}$$

where: V_n — water particle velocity vector or wind speed normal to the axis of the member, in m/s;

D — diameter of the cylindrical member or characteristic dimension of the member, in m;

S — Strouhal number to be determined by Reynolds R_e number from Fig. 2.6.1.1.



R_e – Reynolds number; ν – kinematic viscosity of fluid, in m²/s

Fig. 2.6.1.1

CHAPTER 3 GENERAL FOR STRUCTURAL DESIGN

Section 1 GENERAL PROVISIONS

3.1.1 General requirements

3.1.1.1 This Chapter applies to structural design and analysis of the units as defined in Chapter 2 of PART ONE. In addition, the units intended for different purposes are to comply with the relevant requirements in PART EIGHT.

3.1.2 Scantlings

3.1.2.1 The scantlings of main structural members of the unit are to comply with the relevant requirements of this Chapter and other relevant requirements of this part.

Section 2 SCANTLINGS OF STRUCTURAL MEMBERS

3.2.1 General requirements

3.2.1.1 The scantlings of main structural members of the unit are to be determined in accordance with the provisions of this Section. For the structural members subjected only to local loads and not forming an integral part of the main structure of the unit, the scantlings may be determined according to the relevant requirements of CCS Rules for Classification of Sea-Going Steel Ships.

3.2.1.2 The scantlings of surface-type units are to comply with the applicable requirements of CCS Rules for Classification of Sea-Going Steel Ships applies. In addition, the requirements in Chapter 7 of this part are to be specially considered.

3.2.1.3 The scantlings calculated according to this Section are to be the minimum structural scantlings as required in the Rules and their strength is to satisfy the overall strength requirements for the unit.

3.2.2 External boundary of units

3.2.2.1 The scantlings of the external boundary of units are to be determined in accordance with this paragraph. In addition, the scantlings are to satisfy the requirements for watertight bulkheads in 3.2.4 of this Section and calculated from pressure head to final damage waterline. The component parts of tanks are also to satisfy the requirements for watertight bulkheads in 3.2.5 of this Section.

3.2.2.2 External boundary of column-stabilized units

(1) Columns and lower hull shell

The plate thickness t is not to be less than the value obtained from the following formula, but not less than 9.0 mm:

$$t = 4sf\sqrt{Kh} + 2.5 \quad \text{mm}$$

where: s — spacing of stiffeners, in m;

f — aspect ratio coefficient of plate panel, $f = \frac{1}{\alpha}(1.21\sqrt{\alpha^2 + 0.33} - 0.69)$ and not to be more than 1.0;

α — aspect ratio of plate panel, long edge to short edge;

K — material factor, see 1.6.1.3 in Chapter 1 of this part;

h — vertical distance measured from the lower edge of the shell to 1.4 times the maximum operating draught, in m, and not to be less than 6.0m.

(2) Columns and lower hull stiffeners

The section modulus W of stiffeners is not to be less than the value obtained from the following formula:

$$W = 8.2sKhl^2 \quad \text{cm}^3$$

where: s — spacing of stiffeners, in m;

K — material factor, see 1.6.1.3 in Chapter 1 of this part;

h — vertical distance measured from the midpoint of span of stiffener to 1.4 times the maximum operating draught, in m, but not less than 6.0m;

l — span of stiffener, in m.

The inertia moment I of stiffeners is not to be less than the value obtained from the following formula:

$$I = \frac{2.3Wl}{K} \quad \text{cm}^4$$

where: W — section modulus of stiffener;

l — span of stiffener, in m;

K — material factor, see 1.6.1.3 in Chapter 1 of this part.

(3) Columns and lower hull girders

The section modulus W of girders is not to be less than the value obtained from the following formula:

$$W = 8.2bKhl^2 \quad \text{cm}^3$$

where: b — breadth of the area supported by the girder, in m;

K — material factor, see 1.6.1.3 in Chapter 1 of this part;

h — vertical distance measured from the midpoint of span of girder to 1.4 times the maximum operating draught, in m, and not to be less than 6.0m;

l — span of girder, in m.

The inertia moment I of girders is not to be less than the value obtained from the following formula:

$$I = \frac{2.5Wl}{K} \quad \text{cm}^4$$

where: W — section modulus of girders;

l — span of girder, in m;

K — material factor, see 1.6.1.3 in Chapter 1 of this part.

(4) Upper hull shell

The plate thickness t is not to be less than the value obtained from the following formula, but not less than 8mm:

$$t = 4sf\sqrt{Kh} + t_0 \quad \text{mm}$$

where: s — spacing of stiffeners, in m;

f — aspect ratio coefficient of plate panel, $f = \frac{1}{\alpha}(1.21\sqrt{\alpha^2 + 0.33} - 0.69)$ and not to be more than 1.0;

α — aspect ratio of plate panel, long edge to short edge;

K — material factor, see 1.6.1.3 in Chapter 1 of this part;

h — vertical distance measured from the lower edge of the shell to final damage waterline, and not to be less than 6.0 m;

t_0 — coefficient, 2.5 for bottom plating and 0 for side plating.

(5) Upper hull stiffeners

The section modulus W of stiffeners is not to be less than the value obtained from the following formula:

$$W = 8.2sKhl^2 \quad \text{cm}^3$$

where: s — spacing of stiffeners, in m;

K — material factor, see 1.6.1.3 in Chapter 1 of this part;

h — vertical distance measured from the midpoint of span of stiffener to final damage waterline and not to be less than 6.0m;

l — span of stiffener, in m.

The inertia moment I of stiffeners is not to be less than the value obtained from the following formula:

$$I = \frac{2.3Wl}{K} \quad \text{cm}^4$$

where: W — section modulus of stiffener;

l — span of stiffener, in m;

K — material factor, see 1.6.1.3 in Chapter 1 of this part.

(6) Upper hull girders

The section modulus W of girders is not to be less than the value obtained from the following formula:

$$W = 8.2bKhl^2 \quad \text{cm}^3$$

where: b — breadth of the area supported by the girder, in m;

K — material factor, see 1.6.1.3 in Chapter 1 of this part;

h — vertical distance measured from the midpoint of span of girder to final damage waterline and not to be less than 6.0m;

l — span of girder, in m.

The inertia moment I of girders is not to be less than the value obtained from the following formula:

$$I = \frac{2.5Wl}{K} \quad \text{cm}^4$$

where: W — section modulus of girder;

l — span of girder, in m;

K — material factor, see 1.6.1.3 in Chapter 1 of this part.

3.2.2.3 External boundary of self-elevating units

(1) Bottom plating

The plate thickness t is not to be less than the value obtained from the following formulas:

$$t_1 = 0.043s(L + 230)\sqrt{\frac{1}{K}} \quad \text{mm}$$

$$t_2 = 5.6s\sqrt{(d + h_1)K} \quad \text{mm}$$

where: s — spacing of stiffeners, in m;

L — length of unit, in m;

D — draught, in m;

h_1=0.26C, no more than 0.2d;

C — coefficient, to be taken $C = 0.0412L + 4$;

K — material factor, see 1.6.1.3 in Chapter 1 of this part.

(2) Side plating

The plate thickness t is not to be less than the value obtained from the following formulas:

$$t_1 = 0.06s(L+110)\sqrt{\frac{1}{K}} \quad \text{mm}$$

$$t_2 = 5.4s\sqrt{(d+h_1)K} \quad \text{mm}$$

where: s — spacing of stiffeners, in m;

L — length of unit, in m;

D — draught, in m;

h_1=0.26C, no more than $0.2d$;

C — coefficient, $C = 0.0412L + 4$;

K — material factor, see 1.6.1.3 in Chapter 1 of this part.

(3) Bottom plating stiffeners

The section modulus W of stiffeners is not to be less than the value obtained from the following formula:

$$W = 10.5sKDl^2 \quad \text{cm}^3$$

where: s — spacing of stiffeners, in m;

K — material coefficient, see 1.6.1.3 in Chapter 1 of this part;

D — moulded depth, in m;

l — span of stiffener, in m.

The inertia moment I of stiffeners is not to be less than the value obtained from the following formula:

$$W = 9.5bKDl^2 \quad \text{cm}^3$$

where: b — breadth of the area supported by the girder, in m;

K — material factor, see 1.6.1.3 in Chapter 1 of this part;

D — moulded depth, in m;

l — span of girder, in m.

(5) Side plating stiffeners

The section modulus W of stiffeners is not to be less than the value obtained from the following formula:

$$W = 8.0sKhl^2 \quad \text{cm}^3$$

where: s — spacing of stiffeners, in m;

K — material factor, see 1.6.1.3 in Chapter 1 of this part;

h — head taken in calculation, in m; the vertical distance measured from the midpoint of span of stiffener to deck at side and not to be less than (0.01L + 0.7), where L is the unit length (m);

l — span of stiffener, in m.

(6) Side plating girders

The section modulus W of girders is not to be less than the value obtained from the following formula:

$$W = 8.5bKhl^2 \quad \text{cm}^3$$

where: b — breadth of the area supported by the girder, in m;

K — material factor, see 1.6.1.3 in Chapter 1 of this part;

h — head taken in calculation, m; the vertical distance measured from the midpoint of span of girder to deck at side and not to be less than (0.01L + 0.7), where L is the unit length (m);

l — span of girder, in m.

3.2.2.4 Submersible units

The scantlings of the external boundary of submersible units may be referred to the applicable requirements for column-stabilized units in 3.2.2.2 of this paragraph.

3.2.3 Deck

3.2.3.1 The scantlings of tank decks are to satisfy the requirements for tank bulkheads in 3.2.5 of this Section.

3.2.3.2 Deck plating

The thickness t of deck plating is not to be less than that obtained from the following formula but not less than 7.0 mm:

$$t = 4.5sf\sqrt{Kh} + t_0 \quad \text{mm}$$

$$t = 12s \quad \text{mm}$$

where: s — spacing of stiffeners, in m;

t_0 — coefficient, 2.5 for deck comprising the external boundary of tanks; 0 for other cases;

f — aspect ratio coefficient of plate panel, $f = \frac{1}{\alpha}(1.21\sqrt{\alpha^2 + 0.33} - 0.69)$, and not to be more than 1.0;

K — material factor, see 1.6.1.3 in Chapter 1 of this part;

h — head taken in calculation, in m, equivalent to head at design loads, $h = 0.14p + 0.3$, where p is the design deck load, in kN/m^2, p taken in calculation not to be less than that specified in Section 5 of Chapter 2 of this part.

3.2.3.3 Deck stiffeners

The section modulus W of stiffeners is not to be less than the value obtained from the following formula:

$$W = 5sKhl^2 \quad \text{cm}^3$$

where: s — spacing of stiffeners, in m;

K — material factor, see 1.6.1.3 in Chapter 1 of this part;

h — head taken in calculation, in m; equivalent to head at design loads, $h = 0.14p + 0.3$, and not to be less than (0.02L + 0.76), where p is the design deck load, in kN/m^2, L is the unit length (m), p taken in calculation not to be less than that specified in Section 5 of Chapter 2 of this part;

l — span of stiffener, in m.

3.2.3.4 Deck girders

The section modulus W of girders is not to be less than the value obtained from the following formula:

$$W = 8.5bKhl^2 \quad \text{cm}^3$$

where: b — breadth of the area supported by the girder, in m;

K — material factor, see 1.6.1.3 in Chapter 1 of this part;

h — head taken in calculation, in m; equivalent to head at design loads, $h = 0.14p + 0.3$, and not to be less than (0.02L + 0.76), where p is the design deck load, in kN/m^2, L is the unit length (m), p taken in calculation not to be less than that specified in Section 5 of Chapter 2 of this part;

l — span of girder, in m.

3.2.4 Watertight bulkheads

3.2.4.1 All units are to be provided with watertight bulkheads in accordance with this Chapter. The scantlings and arrangements of watertight flats, trunks and tunnels may be equivalent to the requirements for watertight bulkheads. The scantlings of shaft tunnels will be specially considered. Additional strengthening is to be fitted to tunnels under the heels of pillars, as necessary. In all cases, the plans submitted are to clearly indicate the location and extent of the bulkheads.

3.2.4.2 The watertight bulkheads which are applied as tank bulkheads are also to comply with the relevant requirements for tank bulkheads specified in 3.2.5 of this Section.

3.2.4.3 The number and disposition of watertight bulkheads are to ensure the sufficient strength of the units and to comply with the relevant requirements for subdivision and damage stability, including related requirements of the Administration.

3.2.4.4 Where the spacing of bulkheads is unusually great due to the design, the transverse strength of the unit is to be maintained by fitting suitable web frames between the bulkheads.

3.2.4.5 Plane bulkhead plating

(1) The thickness t of the plane watertight bulkhead plating is not to be less than that obtained from the following formula, but not less than 5.5 mm:

$$t = 4sf\sqrt{Kh} \qquad \text{mm}$$

where: s — spacing of stiffeners, in m;

f — aspect ratio coefficient of plate panel, $f = \frac{1}{\alpha}(1.21\sqrt{\alpha^2 + 0.33} - 0.69)$ and not to be more than 1.0;

α — aspect ratio of plate panel, long edge to short edge;

K — material factor, see 1.6.1.3 in Chapter 1 of this part;

h — the greater of the following is to be taken, in m, but not less than 2.5 m:

① vertical distance measured from the lower edge of the plate to the bulkhead deck;

② vertical distance measured from the lower edge of the plate to the damage waterline;

(2) The thickness of plating of the lowest strake of bulkhead is to be increased by 1 mm above that obtained from calculation, and is to be increased by 2.5 mm in way of bilges or bilge wells.

(3) The lowest strake of bulkhead is not to be less than 900 mm in height measured from the inner bottom, or from the bottom in the case of single bottom. Where a double bottom is provided on one side and a single bottom on the other side of the bulkhead, the lowest strake is to extend at least 300 mm above the flat portion of the double bottom.

(4) Where the difference in thickness between the bulkhead and the web of longitudinal girders attached to the bulkhead is too great, the thickness of bulkhead plating in way is to be increased.

3.2.4.6 Plane bulkhead stiffeners

The section modulus W of bulkhead stiffeners is not to be less than that obtained from the following formula:

$$W = CsKhl^2 \qquad \text{cm}^3$$

where: C — coefficient, to be taken as follows:

C = 6, for stiffeners unattached at one or both ends;

C = 3, for stiffeners attached at both ends.

s — spacing of stiffeners, in m;

K — material factor, see 1.6.1.3 in Chapter 1 of this part;

h — the greater of the following is to be taken, in m, but not less than 2.5 m:

① vertical distance measured from the midpoint of the lower edge of the plate to the bulkhead deck;

② vertical distance measured from the lower edge of the plate to the damage waterline;

l — span of stiffener, in m.

3.2.4.7 Bulkheads with symmetrical corrugations

(1) Symbols for the dimensions of corrugations are as shown in Fig. 3.2.4.7 (1).

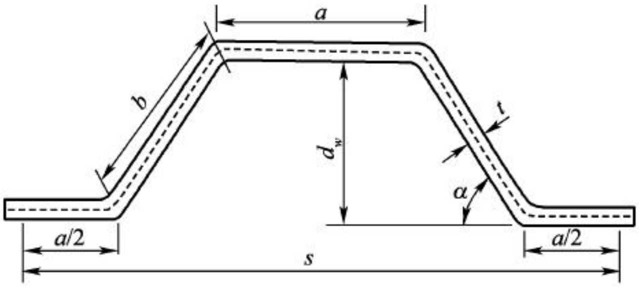


Fig. 3.2.4.7 (1) Dimensions of Corrugations

(2) The requirements for the corrugation plating are the same as 3.2.4.5 (1). *s* in the formula is to be replaced by the width a of corrugation flange or the width *b* of corrugation web, whichever is the greater, and the following formula is to be complied with:

$$t \geq \frac{a}{70} \quad \text{mm}$$

(3) The section modulus *W* of a corrugation over a spacing is not to be less than that obtained from the following formula:

$$W = CsKhl^2 \quad \text{cm}^3$$

where: *C* — coefficient, to be taken according to Table 3.2.4.7;

s — spacing of corrugations, in m;

K — material factor, see 1.6.1.3 in Chapter 1 of this part;

h — the greater of the following is to be taken, in m, but not less than 2 m:

① vertical distance measured from the mid-span of the corrugation to the bulkhead deck;

② vertical distance measured from the mid-span of the corrugation to the damage waterline.

l — span of stiffener, in m.

Value of Coefficient C **Table 3.2.4.7**

Upper end / Lower end	Directly connected to deck	As shown in Fig. 3.2.4.7(2)/(B) or (C)
As shown in Fig. 3.2.4.7 (2)/(A), (B) or (C)	5.04	3.84

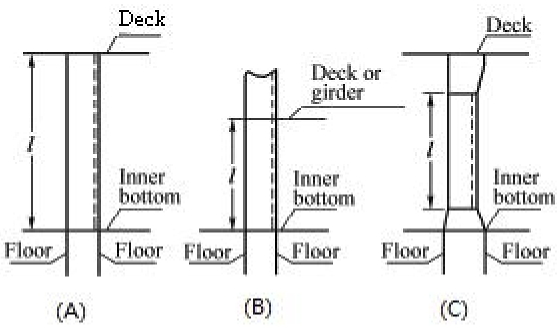


Fig. 3.2.4.7 (2) Forms of Connections

(4) The angle between web and flange of corrugations is not to be less than 40º.

(5) Where the span of corrugation exceeds 15 m, a diaphragm plate is to be arranged near the mid-span or equivalent measures for strengthening are to be taken.

3.2.4.8 Girders

(1) The section modulus W of girders is not to be less than that obtained from the following formula:

$$W = 6.6bKhl^2 \qquad \text{cm}^3$$

where: b — breadth of the area supported by the girder, in m;

K — material factor, see 1.6.1.3 in Chapter 1 of this part;

h — the greater of the following is to be taken, in m, but not less than 2 m:

① vertical distance measured from the mid-span of the girder to the bulkhead deck;

② vertical distance measured from the mid-span of the girder to the damage waterline.

l — span of stiffener, in m.

(2) The web depth of girders is not to be less than 2.5 times that of the supported bulkhead stiffeners, the web thickness of girders is not to be less than that of the bulkhead plating in way of girders, and the breadth of the face plate of girders is not to be more than the web depth or 35 times the thickness of the face plate.

(3) A tripping bracket is to be fitted for girders with spacing over 3 m and where the sectional profile is changed. When the unsupported width of the face plate is over 200 mm, a tripping bracket is also to be fitted.

3.2.5 Tank bulkheads

3.2.5.1 The tank bulkheads refer to the bulkhead structures in ballast tanks, fresh water tanks, fuel oil tanks, salt water tanks and mud tanks, etc.

3.2.5.2 The tank bulkheads are also to comply with the relevant requirements for watertight tank bulkheads specified in 3.2.4 of this Section.

3.2.5.3 Tanks, which are not entirely filled in service, are to have divisions or swash bulkheads as may be required to minimize the dynamic stress on the structure.

3.2.5.4 Fuel oil tanks, lube oil tanks and fresh/drinking water tanks are to be separated by cofferdams from one another according with the provisions of Chapter 1, Section 2, PART 4 of this RULES..

3.2.5.5 If oil fuel tanks are necessarily located within or adjacent to machinery spaces, their arrangement is to be such as to avoid direct exposure of the bottom from rising heat resulting from an engine room fire.

3.2.5.6 The scantlings of the longitudinal watertight bulkheads which are fitted for stability and subjected to equal pressure from both sides may be determined in accordance with the requirements for ordinary watertight bulkheads.

3.2.5.7 For the design of tanks, the density of the loaded liquid is to be taken into account and the density value is to be indicated in relevant plans and loading manuals as the maximum liquid density the tank can withstand.

3.2.5.8 The arrangement of all tanks, together with their intended purposes and the height of the air and overflow pipes, is to be clearly indicated on the plans submitted for approval.

3.2.5.9 Tanks are to be tested in accordance with the relevant requirements in PART ONE of the Rules.

3.2.5.10 Plane bulkheads

(1) The thickness t of plane bulkhead plating is not to be less than that obtained from the following formula:

$$t = 3.95sf\sqrt{\rho Kh} + t_0 \qquad \text{mm}$$

where: s — spacing of stiffeners, in m;

f — aspect ration coefficient of plate panel, $f = \frac{1}{\alpha}(1.21\sqrt{\alpha^2 + 0.33} - 0.69)$ and not to be more than 1.0;

α — aspect ratio of plate panel, long edge to short edge;

ρ — density of liquid, in t/m^3, and to be taken in calculation not less than 1.025;

K — material factor, see 1.6.1.3 in Chapter 1 of this part;

h — vertical distance measured from the lower edge of the plate to 2/3 of the distance from the top of the tank to the top of overflow, or to 0.9 m above the top of the tank, whichever is greater, in m;

t_0 — coefficient, taken as 3.5 for the plating thickness of tanks carrying liquids having a density equal to or more than 1.6 t/m^3, and 2.5 for tanks carrying liquids having a density less than 1.6 t/m^3.

(2) The thickness of plating of the lowest strake of bulkheads and of the bottom plate is to be increased by 1 mm.

(3) The thickness of plating of bilges and bilge wells and of the bottom plate is to be increased by 2.5 mm.

3.2.5.11 Plane bulkhead stiffeners

(1) The section modulus W of stiffeners of bulkheads is not to be less than that obtained from the following formula:

$$W = 8s\rho Khl^2 \quad \text{cm}^3$$

where: s — spacing of stiffeners, in m;

ρ — density of liquid, in t/m^3, and to be taken in calculation not less than 1.025;

K — material factor, see 1.6.1.3 in Chapter 1 of this part;

h — vertical distance measured from mid-span of the stiffener to a point in way of 2/3 of the distance from the top of the tank to the top of overflow, or to 0.9 m above the top of the tank, whichever is greater, in m;

l — span of stiffener, in m.

(2) The section moment of inertia I of stiffeners is not to be less than that obtained from the following formula:

$$I = \frac{2.3Wl}{K} \qquad \text{cm}^4$$

where: W, l, K are the same as defined above.

3.2.5.12 Bulkheads with symmetrical corrugations

(1) The requirements for the corrugation plating are the same as 3.2.5.11 (1). s in the formula is to be replaced by the width a of corrugation flange or the width b of corrugation web, whichever is the greater, and the following formula is to be complied with:

$$t \geq \frac{a}{70} \qquad \text{mm}$$

(2) The section modulus W of a corrugation over a spacing is not to be less than that obtained from the following formula:

$$W = CsKhl^2 \qquad \text{cm}^3$$

where: C — coefficient, to be taken according to Table 3.2.5.12;

s — width of a corrugation, in m;

ρ — density of liquid, in t/m^3, and to be taken in calculation not less than 1.025;

K — material factor, see 1.6.1.3 in Chapter 1 of this part;

h — vertical distance measured from mid-span of the corrugation to a point in way of 2/3 of the distance from the top of the tank to the top of overflow, or to 0.9 m above the top of the tank, whichever is greater, in m;

l — span of corrugation, in m.

Value of Coefficient C **Table 3.2.5.12**

Upper end / Lower end	Directly connected to deck	As shown in Fig. 3.2.4.7(2)/(B) or (C)
As shown in Fig. 3.2.4.7(2)/(A), (B) or (C)	13.3	10.3

(3) The angle between web and flange of corrugations is not to be less than 40º.

(4) Where the span of corrugations exceeds 15 m, a horizontal girder is to be arranged near the mid-span.

3.2.5.13 Girders

(1) The section modulus W of girders is not to be less than that obtained from the following formula:

$$W = 8b\rho Khl^2 \quad \text{cm}^3$$

where: b — breadth of the area supported by the girder, in m;

ρ — density of liquid, in t/m^3, and to be taken in calculation not less than 1.025;

K — material factor, see 1.6.1.3 in Chapter 1 of this part;

h — vertical distance measured from mid-span of the girder to a point in way of 2/3 of the distance from the top of the tank to the top of overflow, or to 0.9 m above the top of the tank, whichever is greater, in m;

l — span of girder, in m.

(2) The section moment of inertia I of girders is not to be less than that obtained from the following formula:

$$I = \frac{2.5Wl}{K} \quad \text{cm}^4$$

where: W, l, K are the same as defined above.,

(3) The web depth of girders is not to be less than 2.5 times that of the supported bulkhead stiffeners, the web thickness of girders is not to be less than that of the bulkhead plating in way of girders and the breadth of the face plate of girders is not to be more than the web depth or 35 times the thickness of the face plate.

(4) The girder ends are to be connected by brackets. The brackets are to extend to the adjacent frames or bulkhead stiffeners.

3.2.6 Pillars

3.2.6.1 Load supported by pillars

The load P supported by the pillar is to be calculated according to the following formula:

$$P = 7.06abh + P_0 \quad \text{kN}$$

where: a — length of deck area supported by the pillar, in m, as shown in Fig. 3.2.6.1;

b — mean width of deck area supported by the pillar, in m, as shown in Fig. 3.2.6.1;

h — design head of the deck supported by the pillar, equivalent to the head of the design load which is not to be less than the value specified in Section 5 of Chapter 2 of the PART, in m; h = 0.14p, where p is the design deck load, in kN/m^2;

P_0 — load transmitted from the pillar above, in kN.

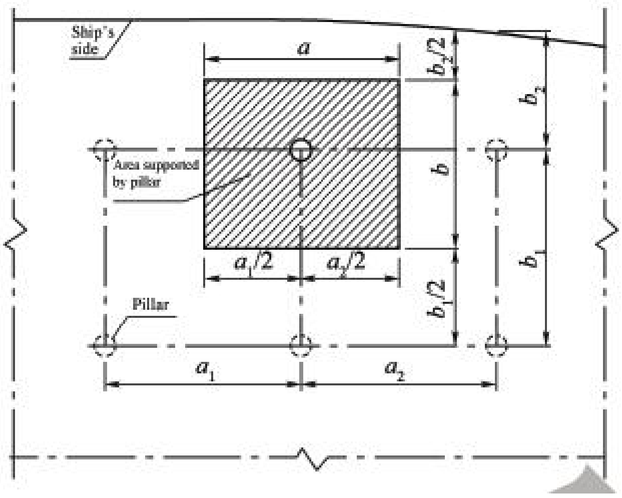


Fig. 3.2.6.1 Schematic Diagram of Pillar-supported Deck Area

3.2.6.2 Cross-sectional area of pillars

The cross-sectional area A of pillars is not to be less than that obtained from the following formula:

$$A = \frac{KP}{12.26 - 5.1\dfrac{l}{r\sqrt{K}}} \qquad \text{cm}^2$$

where: P — load, in kN, supported by the pillar, see 3.2.6.1;

l — the effective length of the pillar, in m, to be taken as 0.8 times the whole length of the pillar;

K — material factor, see 1.6.1.3 in Chapter 1 of this part;

r — minimum radius of gyration of the cross section of pillars, in cm.

3.2.6.3 Minimum wall thickness of pillars

The wall thickness t of tubular pillars is not to be less than the following but not less than 7 mm:

$$t = \frac{P}{0.392 d_P - 4.9l} \qquad \text{mm}$$

$$t = \frac{d_P}{40} \qquad \text{mm}$$

where: P — load, in kN, supported by the pillar, see 3.2.6.1;

l — the effective length of the pillar, in m, to be taken as 0.8 times the whole length of the pillar;

d_P — mean diameter of tubular pillars, in mm.

3.2.6.4 The wall thickness of the built or rolled-section pillars are to comply with the following requirements:

(1) The wall thickness t of hollow rectangular pillars or the web thickness t of I-shaped or channel-section pillars is not to be less than the lesser of the following and not less than 7 mm:

$$t = \frac{br}{60l} \qquad \text{mm}$$

$$t = \frac{b}{55} \qquad \text{mm}$$

where: b — length of hollow rectangular pillars or web depth of I-shaped or channel-section pillars, in mm;

l, r — same as defined in 3.2.6.2 of this Section.

(2) The side thickness t of angular pillars and the face plate thickness t of channel-section pillars are not to be less than the lesser of the following:

$$t = \frac{br}{20l} \quad \text{mm}$$

$$t = \frac{b}{18} \quad \text{mm}$$

where: b — side length of angular pillars and the face plate breadth of channel-section pillars, in mm;

l, r — same as defined in 3.2.6.2 of this Section.

(3) The thickness t of face plate of I-shaped pillars is not to be less than the lesser of the following:

$$t = \frac{br}{40l} \quad \text{mm}$$

$$t = \frac{b}{36} \quad \text{mm}$$

where: b — breadth of face plate of I-shaped pillars, in mm;

l, r — same as defined in 3.2.6.2 of this Section.

3.2.7 Superstructures and deckhouses

3.2.7.1 Deckhouses are to have sufficient strength for their size, function and location. Self-elevating and surface-type units are to be constructed to the scantlings as required by the Section. Column-stabilized units and submersible units are to be constructed to the scantlings required in Section 7, Chapter 5 of the PART.

3.2.7.2 The design pressure head h for end bulkheads of exposed superstructures and boundary (end and side) bulkheads of deckhouses is to be obtained as follows and not less than the minimum value in Table 3.2.7.2:

$$h = \alpha\delta(\beta\lambda - \gamma) \quad \text{m}$$

where: α, β and λ — coefficients, to be determined respectively according to 3.2.7.3, 3.2.7.4, 3.2.7.5 and 3.2.7.6 of this Section;

γ — vertical distance, in m, measured from summer loadline to mid-span of stiffener or mid-point of panel.

Minimum Design Pressure Head **le 3.2.7.2**

Lowest tier of unprotected fronts	Elsewhere
$0.01L + 2.5$	$0.005L + 1.25$

3.2.7.3 Coefficient α is to be determined as follows:

$\alpha = 0.0083L + 2.0$, lowest tier of unprotected fronts

$\alpha = 0.0083L + 1.0$, second tier of unprotected fronts

$\alpha = 0.0067L + 0.5$, third tier of unprotected fronts and above, protected fronts and sides of all tiers

$\alpha = 0.001L - 0.8(X/L) + 0.7$, aft ends of all tiers where aft of amidships

$\alpha = 0.001L - 0.4(X/L) + 0.5$, aft ends of all tiers where forward of amidship

where: L — length of unit, in m;

X — distance in metres between bulkhead considered and A.P. When determining sides of a deckhouse, the deckhouse is to be subdivided into parts of approximately equal length, not exceeding $0.15L$ each and X is to be taken as the distance between A.P. and the centre of each part considered.

3.2.7.4 Coefficient β is to be determined as follows:

$$\beta = 1.0 + (X/L - 0.45)^2 \qquad \text{for } X/L < 0.45$$

$$\beta = 1.0 + 1.5 \ \left(X / L - 0.45 \right)^2 \qquad \text{for X/L} > 0.45$$

where: L, X — same as defined in 3.2.7.3.

3.2.7.5 Coefficient λ is to be determined as follows:

$$\lambda = \frac{L}{10} e^{-L/300} - \left[1 - \left(\frac{L}{150} \right)^2 \right] \qquad \text{for } L < 150\text{m}$$

$$\lambda = \frac{L}{10} e^{-L/300} \qquad \text{for } 150 \le L < 300\text{m}$$

$$\lambda = 11.03 \qquad \text{for } L \ge 300\text{m}$$

where: L — length of unit, in m.

3.2.7.6 Coefficient δ is to be determined as follows:

$$\delta = 0.7 \frac{b}{B_1} + 0.3, \quad \text{not less than } 0.475$$

where: b — breadth of deckhouse at the position considered, in m;

B_1 — actual maximum breadth of unit on the exposed weather deck at the position considered, in m; for exposed parts of superstructures and machinery casings, δ is to be taken as 1.

3.2.7.7 The thickness t of deck plating of superstructures and deckhouses is not to be less than:

$$t = (0.02L + C)\sqrt{\frac{Ks}{s_b}} - t_0 \qquad \text{mm, and not less than 5mm}$$

where: L — length of unit, in m, not to be taken as greater than 100 m;

s — spacing of deck longitudinals or beams, in m, to be taken as not less than s_b;

s_b — standard spacing of deck longitudinals or beams, in m; $s_b = 0.0016L + 0.5$;

C — coefficient, to be taken as follows:

5.5, for the first tier;

5.0, for the second tier deck;

4.5, for the third tier deck and above;

t_0 — $t_0 = 1$ for decks of dry spaces within superstructures or deckhouses; $t_0 = 0$ in other cases.

3.2.7.8 The thickness t of end bulkhead plating of superstructures and boundary bulkhead plating of deckhouses is not to be less than:

$$t = 3s\sqrt{Kh} \qquad \text{mm}$$

$$t_{\min} = (0.01L + 5.0)\sqrt{K} \qquad \text{mm, for the lowest tier}$$

$$t_{\min} = (0.01L + 4.0)\sqrt{K} \qquad \text{mm, for other tiers, and not less than 5mm}$$

where: s — spacing of stiffeners, in m,

K — material factor, see 1.6.1.3 in Chapter 1 of this part;

h — design pressure head, in m; to be calculated according to 3.2.7.2;

L — length of unit, in m.

The scantlings of the side bulkhead of deckhouses are generally to be determined according to the requirements for their aft bulkhead. When the side bulkhead is adjacent to the side shell of the unit, however, its scantlings are to be determined in accordance with the requirements for the unsupported front bulkhead of deckhouses.

3.2.7.9 The section modulus W of end bulkhead stiffeners of superstructures and boundary bulkhead stiffeners of deckhouses is not to be less than:

$$W = 3.5Kshl^2 \quad \text{cm}^4$$

where: s, K and h are same as defined in 3.2.7.8;

l — span of stiffener, in m; to be taken as height of deckhouse, but not less than 2.0 m in any case.

3.2.7.10 The section modulus W of the deck longitudinals or beams of deckhouses is not to be less than:

$$W = 5sKhl^2 \quad \text{cm}^3\text{, and not less than 25s}$$

where: s — spacing of deck longitudinals or beams, in m;

K — material factor, see 1.6.1.3 in Chapter 1 of this part;

h — design pressure head, in m, to be determined as follows:

0.9 m, for those on first tier deck;

0.6 m, for those on second tier deck;

0.45 m, for those on third tier deck and above;

l — span of deck longitudinal or beam, in m.

3.2.7.11 The scantlings of deck girders and transverses of deckhouses are to be calculated in accordance with the relevant requirements of 3.2.3 of this Section, but the design pressure head is to be as specified in 3.2.7.10. The web thickness of girders of deckhouses is not to be less than 1% of their depth plus 2 mm, but not to be less than 4 mm.

3.2.7.12 Local strengthening of superstructures

(1) The web frames or partial bulkheads within superstructures are to be arranged, where practicable, in line with the watertight bulkheads or other strength members below.

(2) Pillars, diaphragms, bulkheads or other strength members are to be arranged under the ends of superstructures for support.

3.2.7.13 Local strengthening of deckhouses

(1) Adequate support under the ends of deckhouses is to be provided in the form of pillars, diaphragms, bulkheads or other strength members. At the corners of houses and in way of supporting structures, attention is to be given to the connection to the deck, and inserts or equivalent structures are generally to be fitted.

(2) All openings cut in the sides of long deckhouses are to be adequately strengthened and have well rounded corners. Continuous coamings with adequate height are to be fitted below and above doors or similar openings.

(3) The sides and ends of the long deckhouses on the lowest tier deck are generally to be strengthened by partial bulkheads or vertical webs spaced about 9 m apart, and these stiffening members are, as far as practicable, to be arranged in line with the strengthening members within the 'tween deck space below the deckhouse.

Section 3 STRUCTURAL ANALYSIS

3.3.1 General requirements

3.3.1.1 The methods of structural analysis covered by this part are based on the linear elastic theory. The plastic method of analysis, if used, will be specially considered by CCS.

3.3.1.2 Unless a recognized structural analysis program acceptable to CCS is used for finite element structural strength calculations, the applicant is to provide specifications for the program used, including the mechanical principles on which the program is based, computation methods and appropriate expert evidence.

3.3.1.3 The primary structure of the unit is to be analyzed using the loads and combined loading conditions specified in Chapter 2 of this part and all conditions, representative of all modes of operation, are to be considered, to enable critical design cases to be determined.

3.3.1.4 In addition to strength requirements, the arrangement of the primary structure is to prevent excessive deformation and vibration of the unit for ensuring safe operation.

3.3.2 Stresses to be considered

3.3.2.1 For each loading condition considered, the following stresses are to be determined to be not greater than the appropriate allowable stresses given in Section 4 of this Chapter:

(1) Static load stresses – stresses due to static loadings only, where the static loads include operational gravity loadings and weight of the unit, with the unit afloat or resting on the seabed in calm water, and corresponding buoyancy and/or bottom counterforce. The corresponding condition is called static loading condition;

(2) Combined stresses – stresses due to combined loadings, where the applicable static loads in (1) are combined with relevant environmental loadings, including acceleration and heeling forces. The corresponding condition is called combined loading condition.

3.3.2.2 Where applicable, local stresses of the member are to be combined with its global stress and the total stress of the member is to be determined.

3.3.2.3 When computing bending stresses, the effective flange areas are to be determined in accordance with CCS Rules for Classification of Sea-Going Steel Ships and included as eccentric beams into the finite element model.

3.3.2.4 Where appropriate, elastic deflections are to be taken into account when determining the effects of eccentricity of axial loading, and the resulting bending moments are to be superimposed on the bending moments computed for other types of loadings.

3.3.2.5 When computing shear stresses in structural members, only the effective shear area of the web of the member is to be considered.

3.3.2.6 The effect of notches, stress raisers and local stress concentrations is to be taken into account in the design of load carrying elements. When stress concentrations are considered to be of high intensity in certain elements, reference may generally be made to 3.4.2.3 of this Chapter.

Section 4 STRENGTH CHECK

3.4.1 General requirements

3.4.1.1 The design stresses of structural members are to be determined with respect to the worst stresses/stress combinations.

3.4.1.2 The yield strength and buckling strength of the primary structure of the unit under all combined loading conditions are to be checked in accordance with this Section. Other check methods are subject to the agreement of CCS.

3.4.2 Yield failure criteria

3.4.2.1 For structural members of the primary frame of the unit which are considered in structural analysis, the allowable stress [σ] is to be determined as follows:

$$[\sigma] = \sigma_s / S \quad \mathrm{N/mm^2}$$

where: σ_s — yield strength of material, in N/mm^2;

S — safety factor, to be taken from Table 3.4.2.1. For plates, the safety factor of equivalent stress is to be taken from Table 3.4.2.2.

Safety FactorTable 3.4.2.1

	Static loading condition	Combined loading condition
Axial or bending stress	1.67	1.25
Shear stress	2.50	1.88

3.4.2.2 Yield stress check of plated structures

Plated structures are to be checked for yield stress as follows:

$$\sigma_{eq} \le \frac{\sigma_s}{S}$$

where: σ_{eq} — equivalent stress, $\sigma_{eq}=\sqrt{\sigma_x^2+\sigma_y^2-\sigma_x\sigma_y+3\tau_{xy}^2}$, N/mm^2, and median plane stress (membrane stress) at centroid of plate elements is to be considered;

σ_x — element stress in the x direction, in N/mm^2;

σ_y — element stress in the y direction, in N/mm^2;

τ_{xy} — element shear stress in the xy plane, in N/mm^2;

σ_s — see 3.4.2.1 in this Section;

S — safety factor, as given in Table 3.4.2.2. The high stress produced at discontinuous structures may be considered according to 3.4.2.3.

Safety Factor of Equivalent Stress **Table 3.4.2.2**

Static loading condition	Combined loading condition
1.43	1.11

Notes:

① Static loading condition and combined loading condition are as defined in 3.3.2.1, the same below.

② In case of the stress being compressive stress, consideration is to be given to checking buckling strength of the structure in accordance with 3.4.3 as appropriate.

3.4.2.3 Yield failure criteria for local high stress areas

(1) The calculation of plating stresses is to consider the effects of notches, increased stresses and local stress concentration. Due to structural discontinuity caused great stress gradient, the stress concentrations are considered to be of high intensity in certain elements, the allowable stress may be specially considered. When fine mesh finite element analysis is applied (the mesh size of high stress areas is 50 mm × 50 mm), the equivalent stress is to be checked as follows:

$$\sigma_{eq} \le C\sigma_{yd}$$

where: σ_{eq} — equivalent stress, same as in 3.4.2.2;

C — coefficient, to be calculated as follows:

$$C=\begin{cases}1.0 & \text{for static load conditions}\\ 1.286 & \text{for combined load conditions}\end{cases}$$

σ_{yd} — specified material stress, in MPa, to be taken according to Table 3.4.2.3.

σ_{yd} Values of Different Materials in Local High Stress Check **Table 3.4.2.3**

Material yield strength (MPa)	Static loading condition	Combined condition
235	235	235
315	301	301
355	326	301
390	346	301

(2) The average value of Von Misesstress results from refined mesh analysiswith an area equivalent to the size of one mesh in the globalcoarse-mesh finite element model (one spacing of stiffener is usually taken as the basic unit) is not to exceed the allowable values listed in Table 3.4.2.2.

(3) Where a smaller mesh size is applied, the mean equivalent element stress of an area corresponding to the above mesh size can be used for comparison with the allowable stress. The mean stress in calculation can only be considered when all the boundaries of the elements are within the area of the above mesh size. The mean stress is to be calculated based on the stress at the centroid of elements, not by means of interpolation and/or extrapolation. The mean equivalent stress is to be weighted according to the element area:

$$\sigma_{vm-av}=\sum_1^n A_i\sigma_{vm-i}\Big/\sum_1^n A_i$$

where: σ_{vm-av} — mean equivalent element stress;

σ_{vm-i}— considered equivalent stress of the i[th] plating element in the area, to be taken by the same method as σ_{eq} in 3.4.2.2;

A_i — considered area of the i[th] plating element in the area;

n — considered number of elements in the area.

(4) To the local stress concentrated area, the enough fatigue strengthshall be guaranteed.

3.4.3 Buckling failure criteria

3.4.3.1 Where the structural member is subjected to compression and/or shearing (applicable to plating), the buckling strength is to be checked in addition to yield strength.

3.4.3.2 Unless specified otherwise by this Chapter, buckling stregth check of mobile units may be carried out with reference to CCS Guidelines for Buckling Strength Assessment of Offshore Engineering Structures.

3.4.3.3 The allowable critical buckling stress $[\sigma_{cr}]$ is to be determined as follows:

$$[\sigma_{cr}] = \sigma_{cr} / S_{bu} \quad \text{N/mm}^2$$

where: σ_{cr} — critical buckling strength, in N/mm^2;

S_{bu} — safety factor of buckling strength, to be taken from Table 3.4.3.2. For overall buckling of compression members, see 3.4.6.1(2).

Safety Factor of Buckling Strength **Table3.4.3.2**

Static loading condition	Combined loading condition
1.67	1.25

3.4.4 Members subjected to combined axial tension and bending

3.4.4.1 When structural members are subjected to axial tension in combination with compression due to bending, the computed stresses are to comply with the following requirements:

Tubular members:

$$\frac{\sigma_a}{[\sigma_a]} + \sqrt{\frac{\sigma_{by}^2}{[\sigma_{by}]^2} + \frac{\sigma_{bz}^2}{[\sigma_{bz}]^2}} \le 1.0$$

Non-tubular members:

$$\frac{\sigma_a}{[\sigma_a]} + \frac{\sigma_{by}}{[\sigma_{by}]} + \frac{\sigma_{bz}}{[\sigma_{bz}]} \le 1.0$$

where: σ_a — computed axial tension stress, in N/mm^2;

$[\sigma_a]$ — allowable axial tension stress, in N/mm^2;

σ_{by}, σ_{bz}— computed bending stress in respect to axes y and z of cross section of the member, in N/mm^2;

$[\sigma_{by}]$, $[\sigma_{bz}]$— allowable bending tension stress in respect to axes y and z of cross section of the member, in N/mm^2.

3.4.5 Members subjected to combined axial compression and bending

3.4.5.1 When structural members are subjected to axial compression in combination with compression due to bending, the computed stresses are to comply with the following requirements:

For tubular members:

$$\frac{\sigma_a}{[\sigma_a]} + \sqrt{\frac{\sigma_{by}^2}{[\sigma_{by}]^2} + \frac{\sigma_{bz}^2}{[\sigma_{bz}]^2}} \le 1.0 \qquad \text{for } \frac{\sigma_a}{[\sigma_a]} \le 0.15;$$

$$\frac{\sigma_a}{[\sigma_a]}+\sqrt{\left[\frac{C_{my}\sigma_{by}}{(1-\frac{\sigma_a}{\sigma'_{ey}})[\sigma_{by}]}\right]^2+\left[\frac{C_{mz}\sigma_{bz}}{(1-\frac{\sigma_a}{\sigma'_{ez}})[\sigma_{bz}]}\right]^2}\le 1.0 \qquad \text{for } \frac{\sigma_a}{[\sigma_a]}>0.15.$$

In addition, the ends of the member are to comply with the following:

$$1.67(\frac{\sigma_a}{\sigma_s})+\sqrt{\frac{\sigma_{by}^2}{[\sigma_{by}]^2}+\frac{\sigma_{bz}^2}{[\sigma_{bz}]^2}}\le 1.0 \qquad \text{for static loading condition;}$$

$$1.25(\frac{\sigma_a}{\sigma_s})+\sqrt{\frac{\sigma_{by}^2}{[\sigma_{by}]^2}+\frac{\sigma_{bz}^2}{[\sigma_{bz}]^2}}\le 1.0 \qquad \text{for combined loading condition.}$$

For non-tubular members:

$$\frac{\sigma_a}{[\sigma_a]}+\frac{\sigma_{by}}{[\sigma_{by}]}+\frac{\sigma_{bz}}{[\sigma_{bz}]}\le 1.0 \qquad \text{for } \frac{\sigma_a}{[\sigma_a]}\le 0.15;$$

$$\frac{\sigma_a}{[\sigma_a]}+\frac{C_{my}\sigma_{by}}{(1-\frac{\sigma_a}{\sigma'_{ey}})[\sigma_{by}]}+\frac{C_{mz}\sigma_{bz}}{(1-\frac{\sigma_a}{\sigma'_{ez}})[\sigma_{bz}]}\le 1.0 \qquad \text{for } \frac{\sigma_a}{[\sigma_a]}>0.15.$$

In addition, the ends of the member are to comply with the following:

$$1.67(\frac{\sigma_a}{\sigma_s})+\frac{\sigma_{by}}{[\sigma_{by}]}+\frac{\sigma_{bz}}{[\sigma_{bz}]}\le 1.0 \quad \text{for static loading condition;}$$

$$1.25(\frac{\sigma_a}{\sigma_s})+\frac{\sigma_{by}}{[\sigma_{by}]}+\frac{\sigma_{bz}}{[\sigma_{bz}]}\le 1.0 \quad \text{for combined loading condition.}$$

Where: σ_s — yield strength of material, in N/mm^2;

σ_a — computed axial compressive stress, in N/mm^2, absolute value to be taken;

σ_{by}, σ_{bz}— computed bending stress in respect to axes y and z of cross section of the member, in N/mm^2, absolute value to be taken;

$[\sigma_a]$ — allowable axial compressive stress, in N/mm^2, which is to be the least of the following:

(1) Yield strength divided by safety factor for axial compressive stress under corresponding loading condition in Table 3.4.2.1;

(2) Critical overall buckling stress obtained under 3.4.6.1 divided by safety factor S_u under corresponding loading condition in 3.4.6.1(2);

(3) Critical local buckling stress obtained under 3.4.6.2 divided by safety factor S_{bu} under corresponding condition in 3.4.3.2;

$[\sigma_{by}]$, $[\sigma_{bz}]$— allowable bending compressive stress in respect to axes y and z of cross section of the member, in N/mm^2, determined by dividing the appropriate yield stress or local buckling stress, whichever is less, by the safety factor under corresponding loading conditions in Table 3.4.2.1 and Table 3.4.3.2;

σ'_{ey} — reduced Euler stress in respect to axes y of cross section of the member, in N/mm^2;

σ'_{ez} — reduced Euler stress in respect to axes z of cross section of the member, in N/mm^2;

$\sigma'_{ey}=\dfrac{12\pi^2E}{23(K_y l_y/r_y)^2}$, may be increased 1/3 for combined loading conditions under 3.3.2.1(2);

$\sigma_{ez}^{'} = \dfrac{12\pi^2 E}{23(K_z l_z / r_z)^2}$, may be increased 1/3 for combined loading conditions under 3.3.2.1(2);

E — modulus of elasticity, $E = 2.06 \times 10^5$ N/mm²;

l_y — unsupported length in respect to plane of axe y of cross section of column, in mm;

l_z — unsupported length in respect to plane of axe z of cross section of column, in mm;

r_y — radius of gyration of cross section of column, corresponding to l_y, in mm;

r_z — radius of gyration of cross section of column, corresponding to l_z, in mm;

K_y — effective length factor of column, taken from Table 3.4.6.1(1) according to support conditions at ends of computed lengths l_y;

K_z — effective length factor of column, taken from Table 3.4.6.1(1) according to support conditions at ends of computed lengths l_z;

C_m — equivalent bending moment coefficient for calculating buckling in the plane of bending (C_{my} corresponding to XOY plane bending moment, C_{mz} corresponding to XOZ plane bending moment), to be determined as follows:

(1) For compression members in frames subject to joint translation (sideways) in the plane of bending, $C_m = 0.85$;

(2) For restrained compression members in frames braced against joint translation:

① If not subject to transverse loading between their supports:

$C_m = 0.6 - 0.4\dfrac{M_1}{M_2}$, but not less than 0.4

where: M_1 and M_2 are moments at the ends of that portion of the member unbraced in the plane of bending under consideration. The ratio M_1/M_2 is positive when the member is bent in reverse curvature (with reverse bending point) and negative when it is bent in single curvature (without reverse bending point), and $|M_2| \geq |M_1|$;

② If subject to transverse loading between their supports, in lieu of rational analysis, the following values may be used:

(a) For members whose ends are restrained, $C_m = 0.85$;

(b) For members whose ends are unrestrained, $C_m = 1.0$.

Note: ① A frame braced against joint translation (sideways) is provided with a supporting structure the rigidity of which against sideway translation is not less than 5 times that of the frame itself (excluding the supporting structure).

② A frame not braced against joint translation (sideways) is not provided with any supporting structure, or provided with a supporting structure the rigidity of which against sideway translation is less than 5 times that of the frame itself (excluding the supporting structure).

3.4.6 Buckling stresses of compression members

3.4.6.1 Overall buckling

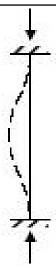
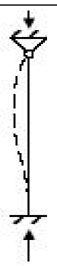
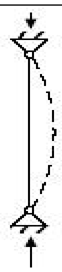
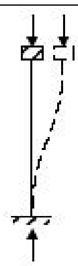
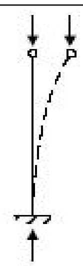
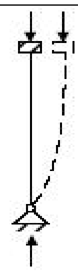
(1) For compression members, the critical overall buckling stress σ_{cr} is to be obtained from the following equation:

$$\sigma_{cr}=\begin{cases}\sigma_E & \sigma_E \le \dfrac{\sigma_s}{2}\\ \sigma_s(1-\dfrac{\sigma_s}{4\sigma_E}) & \sigma_E > \dfrac{\sigma_s}{2}\end{cases}$$

where: σ_E — Euler stress, in N/mm², $\sigma_E=\dfrac{\pi^2 E}{(Kl/r)^2}$;

Other symbols — see 3.4.5.1.

Effective Length Factor of Column Table 3.4.6.1 (1)

	No translation sideways			Translation sideways		
Shape of column under unstable condition (indicated by dotted line)						
Theoretical value	0.50	0.70	1.00	1.00	2.00	2.00
Recommended K value under ideal condition	0.65	0.80	1.00	1.20	2.10	2.00

End restraint condition	Liner displacement	Angular displacement
	Fixed	Fixed
	Fixed	Free
	Free	Fixed
	Free	Free

When the end conditions of the column is difficult to determine (as shown in Fig. 3.4.6.1), value K may be taken as follows. The value G (G_A, G_B) of column ends may be calculated by the following formula:

$$G = \sum \frac{I_g}{L_g} \Big/ \sum \frac{I_c}{L_c}$$

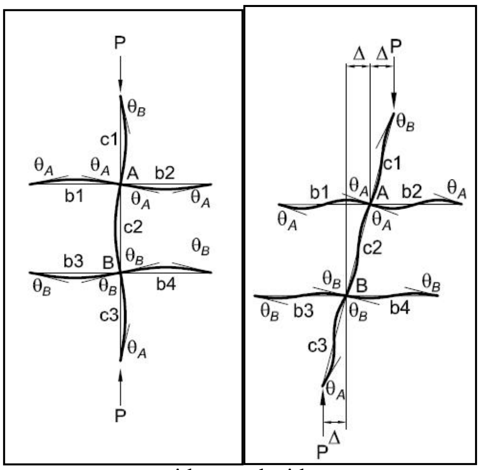
where: G — ratio of rigidity coefficient;

I_g — cross-sectional inertia moment of restraining beams, in cm^4;

L_g — unsupported length of restraining beams, in m;

I_c — inertia moment of cross-section of bearing column connecting ends (end A or end B), in cm^4;

L_c — unsupported length of bearing column connecting ends (end A or end B), in m.



a not sideways b sideways

Fig. 3.4.6.1 Diagram of Column Sideway Translation

When the column end is restrained but not fixed, the inertia moment of restraining beam I_g is 0 and the *G* at the compression member end is 0. But in practice, the minimum *G* is to be taken 0.1 unless the column end is restrained by frictionless hinged bearing; otherwise, the column end is fixed, the inertia moment I_g of the restraining beam is infinite and *G* is also infinite. But in practice, the column end generally cannot be completely fixed and *G* may be taken as 10.0. When the far end of the restraining beam is hinged or fixed, I_g/L_g is to be multiplied by the following factors:

Without sideway translation:

Far-end-hinged restraining beam 1.5

Far-end-fixed restraining beam 2.0

With sideway translation:

Far-end-hinged restraining beam 0.5

Far-end-fixed restraining beam 2/3

The effective length factor for columns without sideway translation may be obtained from the following formula or taken according to Table 3.4.6.1 (2):

$$\left[\left(\frac{\pi}{K}\right)^2 + 2\left(G_A+G_B\right) - 4G_AG_B\right]\frac{\pi}{K}\bullet\sin\frac{\pi}{K} - 2\left[\left(G_A+G_B\right)\left(\frac{\pi}{K}\right)^2 + 4G_AG_B\right]\cos\frac{\pi}{K}$$
$$+8G_AG_B = 0$$

The effective length factor for columns with sideway translation may be obtained from the following formula or taken according to Table 3.4.6.1 (3):

$$\left[36G_AG_B - \left(\frac{\pi}{K}\right)^2\right]\sin\frac{\pi}{K} + 6\left(G_A+G_B\right)\left(\frac{\pi}{K}\right)\cos\frac{\pi}{K} = 0$$

Effective Length Factor *K* for Columns Without Sideway Translation Table 3.4.6.1 (2)

G_A / G_B	0	0.05	0.1	0.2	0.3	0.4	0.5	1	2	3	4	5	≥10
0	1.000	0.990	0.981	0.964	0.949	0.935	0.922	0.875	0.820	0.791	0.773	0.760	0.732
0.05	0.990	0.981	0.971	0.955	0.940	0.926	0.914	0.867	0.814	0.784	0.766	0.754	0.726
0.1	0.981	0.971	0.962	0.946	0.931	0.918	0.906	0.860	0.807	0.778	0.760	0.748	0.720
0.2	0.964	0.955	0.946	0.930	0.916	0.903	0.891	0.846	0.795	0.767	0.749	0.737	0.711
0.3	0.949	0.940	0.931	0.916	0.902	0.889	0.878	0.834	0.784	0.756	0.739	0.728	0.701
0.4	0.935	0.926	0.918	0.903	0.889	0.877	0.866	0.823	0.774	0.747	0.730	0.719	0.693
0.5	0.922	0.914	0.906	0.891	0.878	0.866	0.855	0.813	0.765	0.738	0.721	0.710	0.685
1	0.875	0.867	0.860	0.846	0.834	0.823	0.813	0.774	0.729	0.704	0.688	0.677	0.654
2	0.820	0.814	0.807	0.795	0.784	0.774	0.765	0.729	0.686	0.663	0.648	0.638	0.615
3	0.791	0.784	0.778	0.767	0.756	0.747	0.738	0.704	0.663	0.640	0.625	0.616	0.593
4	0.773	0.766	0.760	0.749	0.739	0.730	0.721	0.688	0.648	0.625	0.611	0.601	0.580
5	0.760	0.754	0.748	0.737	0.728	0.719	0.710	0.677	0.638	0.616	0.601	0.592	0.570
≥10	0.732	0.726	0.720	0.711	0.701	0.693	0.685	0.654	0.615	0.593	0.580	0.570	0.549

Effective Length Factor *K* for Columns with Sideway Translation Table 3.4.6.1 (3)

G_A / G_B	0	0.05	0.1	0.2	0.3	0.4	0.5	1	2	3	4	5	≥10
0	∞	6.020	4.460	3.420	3.010	2.780	2.640	2.330	2.170	2.110	2.080	2.070	2.030
0.05	6.020	4.160	3.470	2.860	2.580	2.420	2.310	2.070	1.940	1.900	1.870	1.860	1.830
0.1	4.460	3.470	3.010	2.560	2.330	2.200	2.110	1.900	1.790	1.750	1.730	1.720	1.700
0.2	3.420	2.860	2.560	2.230	2.050	1.940	1.870	1.700	1.600	1.570	1.550	1.540	1.520
0.3	3.010	2.580	2.330	2.050	1.900	1.800	1.740	1.580	1.490	1.460	1.450	1.440	1.420
0.4	2.780	2.420	2.200	1.940	1.800	1.710	1.650	1.500	1.420	1.390	1.370	1.370	1.320
0.5	2.640	2.310	2.110	1.870	1.740	1.650	1.590	1.450	1.370	1.340	1.320	1.320	1.300
1	2.330	2.070	1.900	1.700	1.580	1.500	1.450	1.320	1.240	1.210	1.200	1.190	1.170
2	2.170	1.940	1.790	1.600	1.490	1.420	1.370	1.240	1.160	1.140	1.120	1.120	1.100
3	2.110	1.900	1.750	1.570	1.460	1.390	1.340	1.210	1.140	1.110	1.100	1.090	1.070
4	2.080	1.870	1.730	1.550	1.450	1.370	1.320	1.200	1.120	1.100	1.080	1.080	1.060
5	2.070	1.860	1.720	1.540	1.440	1.370	1.320	1.190	1.120	1.090	1.080	1.070	1.050

≥10	2.030	1.830	1.700	1.520	1.420	1.320	1.300	1.170	1.100	1.070	1.060	1.050	1.030

(2) For compression members, the safety factor S_u of the overall buckling is to be obtained from the following equation:

$$S_u = \begin{cases} 1.667 + 0.265\lambda_0 - 0.044\lambda_0^2 & \lambda_0 \le \sqrt{2} \\ 1.917\lambda_0^2 & \lambda_0 > \sqrt{2} \end{cases} \quad \text{for static loading condition;}$$

$$S_u = \begin{cases} 1.250 + 0.199\lambda_0 - 0.033\lambda_0^2 & \lambda_0 \le \sqrt{2} \\ 1.438\lambda_0^2 & \lambda_0 > \sqrt{2} \end{cases} \quad \text{for combined loading condition.}$$

where: λ_0 — relative slenderness ratio, $\lambda_0 = \sqrt{\dfrac{\sigma_s}{\sigma_E}}$;

Other symbols — see 3.4.5.1.

3.4.6.2 Local buckling

(1) Local buckling of cylindrical shell

Members of cylindrical shell which are subjected to possible local buckling are to be checked for local buckling strength, in addition to overall buckling as specified in 3.4.6.1. The following or a recognized method may be used for assessment of local stability of structural members.

① In the case of unstiffened or ring-stiffened cylindrical shells, the local buckling strength is not to be checked if the proportions of the shell conform to the following relationship:

$$\frac{D}{t} \le 60$$

where: D — nominal diameter of cylindrical shell;

t — thickness of cylindrical shell (expressed in the same unit as D).

② For cylindrical shells with $\dfrac{D}{t} < 300$ and $t \ge 6$ mm, the critical local buckling stress σ_{cx} is to be the lesser of the following: Elastic buckling: $\sigma_{cx} = \dfrac{0.6Et}{D}$ N/ mm^2

Non-Elastic buckling: $$\sigma_{cx} = \begin{cases} \sigma_s & D/t \le 60 \\ (1.64 - 0.23\sqrt[4]{D/t})\sigma_s & D/t > 60 \end{cases} \quad \text{N/mm}^2$$

where: D, t — the same as in 3.4.6.2 (1)/①;

Other symbols— see 3.4.5.1.

③ The safety factors for local buckling strength are as given in Table 3.4.3.2.

(2) Local buckling of sections

See 3.4.8.6 of this Chapter.

3.4.7 Plate panel buckling check

3.4.7.1 Plane plated structures which are subject to possible buckling failure are to be checked for panel buckling strength in accordance with the Rules or by a recognized method.

3.4.7.2 The term "panel" in the Rules means a plate not fitted with any framing member and stiffener, apart from boundary. Only rectangular panels are considered in panel buckling calculations. The buckling strength of stiffened plates may be assessed using a recognized method, subject to approval by CCS.

3.4.7.3 The panel buckling is to be checked as follows:

(1) To obtain critical buckling stress

① The ideal elastic buckling stress σ_{xcr_e} of the panel, of which the shorter side is subjected to compression, is defined as follows:

$$\sigma_{xcr\_e} = k_x C_1 \frac{\pi^2 E}{12\left(1-\nu^2\right)}\left(\frac{t}{s}\right)^2 \quad \text{N/ mm}^2$$

where: k_x — buckling coefficient for shorter side subjected to compression and bending, to be calculated according to Table 3.4.7.3 (1), generally taken as 4.0 if based on finite element method;

E — see 3.4.5.1;

ν — Poisson's ratio of material, $\nu = 0.3$;

C_1 — boundary constraint coefficient, see Table 3.4.7.3(2);

t — thickness of panel, in mm;

s — length of shorter side of panel, in mm, taken as spacing of longitudinals, reinforcing bars or stiffeners;

x — defined as axial direction of longer side of panel.

② The ideal elastic buckling stress σ_{ycr_e} of the panel, of which the longer side is subjected to compression and bending, is defined as follows:

$$\sigma_{ycr\_e} = k_y C_2 \frac{\pi^2 E}{12\left(1-\nu^2\right)}\left(\frac{t}{s}\right)^2 \quad \text{N/ mm}^2 \ {}_2$$

where: k_y — buckling coefficient for longer side subjected to compression and bending, to be calculated according to Table 3.4.7.3(1);

l — length of longer side of panel, in mm;

C_2 — boundary constraint coefficient, see Table 3.4.7.3(2);

y — defined as axial direction of shorter side of panel.

Other symbols — the same as ①.

③ The ideal elastic buckling stress τ_{cr_e} of the panel subjected to shearing is defined as follows:

$$\tau_{cr\_e} = k_t C_1 \frac{\pi^2 E}{12\left(1-\nu^2\right)}\left(\frac{t}{s}\right)^2 \quad \text{N/ mm}^2$$

where: k_t — shear buckling coefficient, to be calculated according to Table 3.4.7.3(1);
Other symbols — the same as ① and ②.

(2) Elastic correction of ideal elastic buckling stress of panel

$$\sigma_{xcr\,(ycr)} = \begin{cases} \sigma_{xcr\_e\,(ycr\_e)} & \text{for } \sigma_{xcr\_e\,(ycr\_e)} \le \dfrac{\sigma_S}{2} \\ \sigma_S\left(1 - \dfrac{\sigma_S}{4\sigma_{xcr\_e\,(ycr\_e)}}\right) & \text{for } \sigma_{xcr\_e\,(ycr\_e)} > \dfrac{\sigma_S}{2} \end{cases}$$

$$\tau_{cr} = \begin{cases} \tau_{cr\_e} & \text{for } \tau_{cr\_e} \le \dfrac{\tau_S}{2} \\ \tau_S\left(1 - \dfrac{\tau_S}{4\tau_{cr\_e}}\right) & \text{for } \tau_{cr\_e} > \dfrac{\tau_S}{2} \end{cases}$$

where: σ_{xcr}, σ_{ycr}, τ_{cr} — respectively as critical buckling compressive stress and critical buckling shear stress of panel along axes x and y under uniaxial stress;

σ_{xcr_e}, σ_{ycr_e}, τ_{cr_e} — respectively as ideal elastic buckling compressive stress and ideal elastic buckling shear stress of panel along axes x and y under uniaxial stress, see (1)/①, ② and ③;

σ_s — see 3.4.5.1;

τ_s — $\dfrac{\sigma_S}{\sqrt{3}}$.

(3) Criteria for panel buckling strength

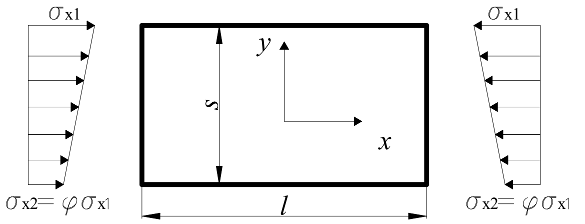
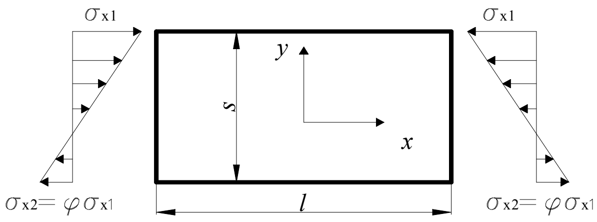
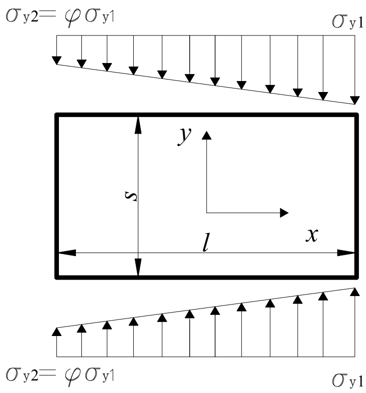
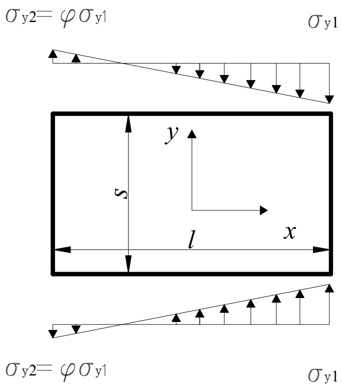
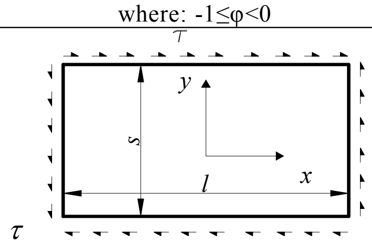
$$\left(\frac{\sigma_x}{\sigma_{xcr}/S_{bu}}\right)^2+\left(\frac{\sigma_y}{\sigma_{ycr}/S_{bu}}\right)^2+\left(\frac{\tau_{xy}}{\tau_{cr}/S_{bu}}\right)^2\leq 1$$

where: σ_x, σ_y, τ_{xy} — computed compressive and shear stresses on longer and shorter sides of panel under same condition. Mean median plane stress (membrane stress) at centroid of all plate elements is to be considered (compressed as negative). If computed σ_x, σ_y are greater than zero, they are to be taken as zero;

σ_{xcr}, σ_{ycr}, τ_{cr} — see (2);

S_{bu} — safety factor for buckling, taken from Table 3.4.3.2.

Panel Buckling Coefficient **Table 3.4.7.3(1)**

Mechanical model of panel subjected to compression, bending and shearing		Buckling coefficient
Shorter side compressed	 where: 0≤φ≤1	$k_x = \dfrac{8.4}{\varphi+1.1}$
	 where: -1≤φ<0	$k_x = 7.6 - 6.4\phi + 10\phi^2$
Longer side compressed	 where: 0≤φ≤1	$k_y = \left[1+(\frac{s}{l})^2\right]^2 \dfrac{2.1}{\phi+1.1}$
	 where: -1≤φ<0	$k_y = 1.909(1+\phi)\left[1+(\frac{s}{l})^2\right]^2 - k_p\phi$ $+10\phi(1+\phi)(\frac{s}{l})^2$ where: $k_p = \begin{cases} 24(\frac{s}{l})^2 & \frac{l}{s} \le \frac{3}{2} \\ 2+16(\frac{s}{l})^2+8(\frac{s}{l})^4 & \frac{l}{s} > \frac{3}{2} \end{cases}$
Sides subject to shearing		$k_t = 5.34 + 4(\frac{s}{l})^2$

Boundary Constraint Coefficients C_1 and C_2 of Panel Table 3.4.7.3(2)

Boundary	C_1	C_2	
		In double bottom or double hull or double deck	Other locations
Angel bar or T-stiffener	1.1	1.3*	1.2
Flat or bulb flat, plate, stiffener web	1.0	1.2*	1.1

Note: "*" applicable to panels the shorter side of which is supported by a rigid structure, e.g. bottom, inner bottom, side shell, inner shell, double bottom solid floor/girder, side girder, double deck.

3.4.8 Stiffener (stiffened framing member) buckling strength check

3.4.8.1 The bulking failure modes of the stiffeners on the stiffened panel include the column buckling mode and torsional buckling mode, and the local buckling mode of stiffener face plates and webs.

3.4.8.2 The failure criteria of each buckling mode is to be determined by the formulas in paragraph 3.4.3.2 and based on the safety factors s in Table 3.4.3.2 of this Chapter.

3.4.8.3 For the column buckling mode and torsional buckling mode of the stiffeners on the stiffened panel and the local buckling mode of stiffener face plates and webs, the critical buckling stress σ_{cr} under compression is to be calculated by the following formula:

$$\sigma_{cr} = \begin{cases} \sigma_E & \sigma_E \le 0.5\sigma_s \\ \sigma_s\left(1 - \dfrac{\sigma_s}{4\sigma_E}\right) & \sigma_E > 0.5\sigma_s \end{cases}$$

where: σ_E — ideal elastic buckling stress of stiffeners in various buckling failure modes, in N/mm^2, see 3.4.8.4, 3.4.8.5 and 3.4.8.6;

σ_s — see 3.4.5.1.

3.4.8.4 For the column buckling mode, the ideal elastic buckling stress is to be calculated by the following formula:

$$\sigma_E = 0.001E\frac{I_a}{Al^2} \quad \text{N/mm}^2$$

where: I_a — moment of inertia, in cm^4, of stiffener, where the effective width b_e of attached plate flange, calculated as follows, may be considered;

$b_e = C_x s$, mm;

$$C_x = \begin{cases} \dfrac{2}{\beta} - \dfrac{1}{\beta^2} & \beta > 1 \\ 1.0 & \beta \le 1 \end{cases}$$

β — coefficient for slenderness ratio, $\beta = \frac{s}{t}\sqrt{\frac{\sigma_s}{E}}$;

s — spacing of longitudinals, stiffening bars or stiffeners, in mm;

t — plate thickness, in mm;

E、σ_s — see 3.4.5.1;

A — cross-sectional area of stiffener, in cm^2, where the above effective width of attached plate flange may be considered;

l — span of stiffener, in m.

3.4.8.5 The ideal elastic buckling stress for the torsional mode is to be calculated by the following formula:

$$\sigma_E = \frac{\pi^2 E I_w}{I_p l^2 \times 10^4}(n^2 + \frac{K_B}{n^2}) + 0.385E\frac{I_t}{I_p} \qquad \text{N/ mm}^2$$

where: $K_B = \frac{Cl^4}{\pi^4 E I_w} \times 10^6$;

n — number of half waves, given by Table 3.4.8.5;

I_t — St Venant's moment of inertia, in cm^4, of profile (without attached plate flange) is given by:

$I_t = \frac{h_w t_w^3}{3} \times 10^{-4}$, for flat bars;

$I_t = \frac{1}{3}[h_w t_w^3 + b_f t_f^3 (1 - 0.63\frac{t_f}{b_f})] \times 10^{-4}$, for flanged profiles;

I_p — polar moment of inertia, in cm^4, of profile about connection of stiffener to plate;

$I_p = \frac{h_w^3 t_w}{3} \times 10^{-4}$, for flat bars;

$I_p = (\frac{h_w^3 t_w}{3} + h_w^2 b_f t_f) \times 10^{-4}$, for flanged profiles;

I_w — sectorial moment of inertia, in cm^6, of profile about connection of stiffener to plate;

$I_w = \frac{h_w^3 t_w^3}{36} \times 10^{-6}$, for flat bars;

$I_w = \frac{t_f b_f^3 h_w^2}{12} \times 10^{-6}$, for "Tee" profiles;

$I_w = \frac{b_f^3 h_w^2}{12(b_f + h_w)^2}[t_f (b_f^2 + 2b_f h_w^2 + 4h_w^2) + 3t_w b_f h_w] \times 10^{-6}$, for angles and bulb profiles;

E, l — same as 3.4.8.4;

h_w — stiffener web height, in mm;

t_w — stiffener web thickness, in mm;

b_f — stiffener face plate width, in mm;

t_f — stiffener face plate thickness, in mm. For bulb profiles, the mean thickness of the bulb may be used;

C — spring stiffness exerted by supporting panel, given by:

$$C = \frac{K_p E t_p^3}{3s(1 + \frac{1.33 K_p h_w t_p^3}{1000 s t_w^3})} \times 10^{-3}$$

s — spacing of stiffeners, in m;

t_p — panel thickness, in mm;

$K_p = 1 - \eta_p$, not to be taken less than zero and for flanged profiles, not less than 0.1;

$$\eta_p = \frac{\sigma}{\sigma_{EP}};$$

σ — calculated compressive stress, in N/mm^2;

σ_{EP} — elastic buckling stress of supporting plate as calculated in 3.4.7.3 (1).

Number n of Half Waves **Table 3.4.8.5**

	$0 < K_B \le 4$	$4 < K_B \le 36$	$36 < K_B \le 144$	$(n-1)^2 n^2 < K_B \le n^2 (n+1)^2$
n	1	2	3	n

3.4.8.6 Local buckling of stiffener webs and face plates

(1) Where stiffeners comply with the following, their local buckling need not be considered:

① Rolled sections; or

② Flat bars:

$$\frac{h_w}{t_w} \le 0.45\sqrt{\frac{E}{\sigma_s}}$$

③ Flanged stiffeners:

Flange of stiffeners: $\frac{b_f}{t_f} \le 0.45\sqrt{\frac{E}{\sigma_s}}$

Web of stiffeners: $\frac{h_w}{t_w} \le 1.4\sqrt{\frac{E}{\sigma_s}}$

where: h_w, t_w, t_f — same as 3.4.8.5;

b_f — flange width, in mm, for angles, half the flange width for T-sections;

E、σ_s — see 3.4.5.1.

(2) For stiffeners not complying with (1) above, the ideal elastic buckling stress σ_E of local buckling may be calculated by the following formula:

$$\sigma_E = \begin{cases} 3.8E\left(\frac{t_w}{h_w}\right)^2 & \text{N/mm}^2 \quad \text{for web} \\ 0.9\left[0.43 + \left(\frac{b_t}{l}\right)^2\right]E\left(\frac{t_f}{b_f}\right)^2 & \text{N/mm}^2 \quad \text{for panel} \end{cases}$$

where: symbols are same as (1).

Section 5 FATIGUE ANALYSIS

3.5.1 General requirements

3.5.1.1 The purpose of the fatigue analysis is to ensure that the fatigue life of the unit structure is sufficien for its operation. The calculation results of fatigue life may be the basis for development of survey specificationsfor units under construction and in service.

3.5.1.2 Unless specified otherwise by this Rules, fatigue stregth check of mobile units may be carried out with reference to CCS Guidelines for Fatigue Strength Assessment of Offshore Structures.

3.5.1.3 The type and extent of the fatigue analysis will be dependent on the intended mode andarea of operations to be considered in the unit's design. Unless specially required by CCS, fatigueanalysis is in general not necessary for units restricted to operation in shallow sea.

3.5.1.4 The design fatigue life of the structure is to be at least the design life of the unit, but not less than 20 years.

3.5.1.5 For cyclic loading, consideration is to be given to waves (including those which cause slamming and variable-buoyancy effects), wind (especially when vortex shedding is induced, e.g. on slender members), currents (where these influencethe forces generated by waves and/or induced vortex shedding) and mechanical vibration caused by operation of machinery.

3.5.1.6 Any weld which may cause potential fatigue cracks and any structural configuration which brings stress concentration are to be designed for fatigue strength. If necessary, fatigue analysis is to be conducted for slender portions of connections. At least, the following structural elements are to be checked:

(1) Column-stabilized units

① bracing structure;

② bracing connections to lower hulls, columns and decks;

③ column connections to lower hulls;

④ column connections to deck;

⑤ general structural discontinuities.

(2) Self-elevating units

① lattice legs;

② leg support structure;

③ connections of raw water tower to legs.

(3) Surface-type units

① connections of longitudinals to transverse ring frames and transverse bulkheads;

② connections of transverse ring frames to shell, bottom plates, inner bottom plating and bulkhead plating;

③ hopper plating connections to inner bottom plating and longitudinal bulkhead plating;

④ connections to longitudinal/transverse girder end brackets.

(4) Miscellaneous

① supporting structure under drilling derrick;

② flare boom structure;

③ other structures subjected to significant cycle loading.

3.5.1.7 The safety in respect to fatigue strength is to be appropriately increased for those areas not readily accessible to surveyors and underwater welded parts. Special consideration is to be given to fatigue damages which will possibly bring serious effects, e.g. loss of personnel, significant corrosion and major economic losses.

3.5.2 Methods of fatigue analysis

3.4.2.1 Recognized methods of fatigue analysis are to be used, e.g. the linear cumulative damage method based on S – N curve. Alternatively, an appropriate fracture mechanics assessment may also be used. All fatigue analysis reports are to be submitted to CCS for approval.

3.5.2.2 For fatigue analysis, a simplified method is to be used first to determine critical fatigue areas of which the fatigue life is relatively short, and then a more accurate method for calculation and analysis of structural details of such areas.

3.5.2.3 The ranges of all significant stresses contributing to fatigue damage is to be considered. The long-term distribution of stress ranges may be obtained by deterministic fatigue analysis or spectral fatigue analysis.

3.5.3 Simplified fatigue analysis method (also known as simplified method)

3.5.3.1 The simplified method may be used at the early stage of fatigue strength design. After the critical nodes are determined, random fatigue analysis is to be conducted.

3.5.3.2 Conservative design parameters are to be taken as appropriate in using the simplified method. Double-parameters Weibull distribution may be applied to describe the long-term distribution of stress ranges.

3.5.4 Random fatigue analysis method (also known as spectral analysis method)

3.5.4.1 For random fatigue analysis, recognized methods and criteria are to be used for calculations.

3.5.4.2 The loads applied in fatigue analysis are to be based on the environmental loading data of long-term distribution for the intended area of operations or North Atlantic Ocean.

3.5.4.3 At least 7 wave direction angles are to be considered in load response calculation, and at least 30 wave frequencies are to be considered for the load transfer function.

3.5.4.4 Where a simplified structural configuration (e.g. spacial rigid-frame model) representative of the unit model is used in overall structural analysis, a detailed model for fatigue analysis is to be established in respect to the part intended to be analyzed (e.g. key area of structural intersection).

3.5.5 Fatigue damage calculations

3.5.5.1 Fatigue damage calculations are to be based on a sufficient number of loading conditions.

3.5.5.2 Appropriate wave spectrums are to be used, and percentages are to be applied to represent all cumulative spectrums (including each direction under consideration). When using a limited number of directions, account is to be taken of symmetry within the structure.

3.5.5.3 Cumulative damage assessment is generally to be based on Palmgren-Miner linear cumulative damage theory, and the fatigue damage D is to be calculated as follows:

$$D = \sum_{i=1}^{r} \left(\frac{n_i}{N_i} \right)$$

where: r — number of stress range blocks in the histogram of stress ranges;

n_i — number of stress cycles for stress range block number i (i.e. expected number of cycles to which the member is subjected for stress range S_i);

N_i — corresponding number of stress cycles obtained from the relevant S-N curve for the details under consideration (i.e. allowable maximum number of cycles where no fracture of the member will occur for stress range S_i).

3.5.6 Fatigue failure criteria

3.5.6.1 The fatigue failure criteria may be based on the fatigue damage or fatigue life. When based on the fatigue damage, the fatigue strength of the considered point is to comply with:

$$D \le \frac{1.0}{S_{ftg}}$$

where: D — cumulative damage;

S_{ftg} — safety factor of fatigue strength, to be taken from Table 3.5.6.1;

When based on the fatigue life, the fatigue strength of the considered point is to comply with:

$$T_{ftg} \ge T_D \cdot S_{ftg}$$

where: T_{ftg} — calculated fatigue life;

T_D — design fatigue life.

Safety Factor Sftg of Fatigue **Table 3.5.6.1**

Safety factor of fatigue	Structural members
1	Internal structures, accessible for survey and without direct welded connections to underwater structures
1	External structures, accessible for survey and periodic servicing in dry and clean environment
2	Internal structures, accessible for survey and with direct welded connections to underwater structures
2	External structures, accessible for survey but not for periodic servicing in dry and clean environment
3	Areas inaccessible for survey and not intended to be accessible for survey and servicing during operation

Note:

① For shell envelope plating required to be subject to docking survey according to CCS Rules, 1 is to be taken.

② For shell envelope plating intended to be subject to survey under floating condition in sheltered waters, 1 is to be taken for areas over 1 m above the lowest inspection waterline, 2 for areas below.

③ 3 is to be taken for splash zones.

④ In case fractures may extend from areas accessible to those inaccessible for survey, the maximum value along the fracture extension is to be taken, e.g. for the welded connections to the inner side of the underwater shell plating (dry hold), the value of similar external connection is to be taken.

⑤ For the fatigue failure of connections likely to cause major dangerous accidents and serious consequences, the value is to be specially considered.

3.5.7 S-N curve

The S-N curve used for fatigue analysis may be selected with reference to CCS Guidelines for Fatigue Strength Assessment of Offshore Engineering Structures.

Section 6 ANALYSIS AND DETAILS OF STRUCTURAL CONNECTIONS

3.6.1 General requirements

3.6.1.1 Unless connections of structural members are specifically detailed as articulated joints, proper consideration is to be given in the structural analysis to the degree of restraint at such connections. Structural connections are to be detailed in such a manner as to ensure reasonable transmission of stresses between members joined and to minimize stress concentrations. The following details are to be considered, as may be appropriate:

(1) shear web plates, continuous through the joint, to transmit tension and compression loads between members by means of shear in the web plate;

(2) flaring and transition of the joint, to lower stress levels and/or to minimize stress concentrations;

(3) thicker joint material, high strength steel, or both, consistent with good weldability to reduce the effect of high stress levels;

(4) brackets or other supplemental transition members, with scallops and proper end attachment details to minimize high stress concentrations.

3.6.1.2 Critical connections that depend upon transmission of tensile stresses through the thickness of the plating of one of the members may result in lamellar tearing and are to be avoided wherever possible. Where unavoidable, plate material with suitable through-thickness (Z direction) properties complying with CCS Rules for Materials and Welding are to be used.

3.6.2 Chords, braces and tubular joints

3.6.2.1 The wall thickness of the brace is not to be greater than that of the chord, and the chord is normally to be subjected to greater internal forces. The chord is to be sufficiently strengthened at the joint.

3.6.2.2 The welded joints are to be arranged outside stress concentration areas so far as practicable and in compliance with the welding requirements in 1.5.5 of this part.

3.6.2.3 The requirements for tubular joints may be referred to CCS Rules for the Classification and Construction of Fixed Offshore Drilling Units.

Section 7 LOCAL STRENGTHENING

3.7.1 General requirements

3.7.1.1 The structural strength of the structures forming necessary component parts of the safety system as required by the Rules or bearing heavy loads, such as the raw water tower, burner boom, lifeboat platform, crane pedestal, supporting structures of helicopter deck, pipe racks and foundations of other important equipment as well as their supporting structures, are to comply with the requirements of the Rules under the environmental and operational loads of all operation modes. Unless otherwise specified in this Section, the allowable stresses of such structures are to be applied according to Section 4 of this Chapter.

3.7.2 Lifeboat platform

3.7.2.1 The lifeboat platform is to be designed in accordance with the following requirements:

(1) In the most adverse combination of list and trim conditions, the allowable stress of the lifeboat platform is to be 0.22 times the tensile strength when the fully loaded lifeboat is launched.

(2) In the transit condition where the unit is in the most dangerous motion, the allowable stress of the lifeboat platform is to be 0.8 times the yield strength. For self-elevating units, the most dangerous motion may refer to lateral roll or pitch to 15° at one side with a period of 10 s.

3.7.3 Crane pedestal and supporting structure

3.7.3.1 The crane pedestal is to comply with the relevant requirements of CCS Rules for Lifting Appliances of Ships and Offshore Installations.

3.7.3.2 The supporting structure of the crane pedestal is to comply with the relevant requirements of Section 4 of this Chapter.

3.7.4 Pipe racks

3.7.4.1 Pipe racks and corresponding supporting structures are to be designed to withstand the loads applied to them by drill pipes and risers under survival, normal operating and transit conditions, and the yield strength and critical buckling strength are to be checked in accordance with the provisions in Section 4 of this Chapter.

3.7.4.2 The loads due to the unit inclining under damage condition are to be considered, and the yield strength and critical buckling strength are to be checked in accordance with the provisions in Section 4 of this Chapter but the safety factor may be taken as 1.0.

Section 8 DRILLING DERRICK SUPPORTING STRUCTURE

3.8.1 General requirements

3.8.1.1 The foundations supporting drilling derricks, drill floors and relevant equipment as well as their supporting structures are subject to structural strength analysis and check as required in Sections 3 and 4 of this Chapter respectively.

3.8.1.2 The stiffness of the connection between each drill floor supporting leg and the unit hull structure is to be kept as consistent as possible in order to prevent stress concentration due to uneven distribution of derrick loads on the supporting legs.

3.8.2 Loadings

3.8.2.1 Operational loadings

The strength analysis of the supporting structures of drilling derricks is to apply the operational loadings specified by the owner or designer, generally including but not limited to the following loadings:

(1) dead loadings (weight of steel structures and fixed equipment);

(2) deck loadings (weight of persons, movable equipment and supplies);

(3) loadings of ice and snow (where applicable);

(4) loadings of hooks,pipe setback load, rotary tables, and riser tension load.

3.8.2.2 Combined loadings

The combined loadings refer to the combination of operational loadings and environmental loadings like wind, wave and current. All the loadings are to be combined based on the most unfavorable conditions that may occur during the service life of the unit. And additionally, the loadings due to motions of the unit in floating are to be considered.

3.8.3 Moveable drilling cantilever/skid beam

The moveable drilling cantilever/skid beam used to support the drilling derrick foundation and their supporting structures are subject to structural strength analysis and check as required in Sections 3 and 4 of this Chapter respectively. The loadings applied to the hull structure are to include the maximum support reaction of the drilling cantilevers/skid beams.

The moveable drilling cantilever refers to the structure capable of stretching outside the unit's hull structure during drilling operation. The moveable skid beam refers to the structure entirely supported on the hull structure during drilling operation.

CHAPTER 4 SELF-ELEVATING UNITS

Section 1 GENERAL PROVISIONS

4.1.1 General requirements

4.1.1.1 This Chapter applies to structural design and analysis of self-elevating units as defined in Chapter 2 of PART ONE.

4.1.2 Scantlings

4.1.2.1 Scantlings of the major structural elements of the unit are to be determined by direct calculations in accordance with load distribution under all intended loading conditions.

4.1.2.2 Scantlings of the structural elements of the unit not covered by this Chapter are to comply with Chapter 3 of this part and/or CCS Rules for Classification of Sea-Going Steel Ships as appropriate.

Section 2 DESIGN CONDITIONS AND DESIGN LOADINGS

4.2.1 Design conditions

4.2.1.1 The strength analysis of the unit is at least to take the following design conditions into account: the typical load conditions in normal operating mode, transit mode, jacking mode and survival mode . If necessary, a damaged condition is to be specially considered. In designing the unit, special attention is to be paid to the typical condition in transit, jacking and survival conditions.

4.2.2 Design loadings

4.2.2.1 For each design mode, static loading condition and combined condition of static loadings and environmental loadings are to be taken into account. The environmental loadings are to be calculated in accordance with Chapter 2 of this part, and the safety factor appropriate for each design condition is to be taken in accordance with Section 4, Chapter 3 of this part.

4.2.2.2 Normal operating mode:

(1) Static loadings include the weight of the unit, the weight of all permanent installations and supplies, ballast weight and operational loads.

(2) Environmental loadings consist of the maximum wind, wave and current elements or loadings as specified for normal operations in the operating manual and seabed supporting capabilities.

4.2.2.3 Transit mode:

(1) Static loadings include the weight of the unit, the weight of all permanent installations and supplies, ballast weight and buoyancy during transit.

(2) Environmental loadings:

① Field transit condition: wind velocity is not to be less than 36 m/s (70 kn), elements of wave loadings are to be determined according to environmental conditions for field transit and combined with current loadings under the most unfavorable condition.

② Ocean transit condition: wind velocity is not to be less than 51.5 m/s (100 kn), elements of wave loadings are to be determined according to extreme environmental conditions for field transit and combined with current loadings under the most unfavorable condition.

(3) The effects of the inclination and acceleration of the unit and towing forces are to be taken into account.

4.2.2.4 Jacking mode:

(1) Static loadings include the weight of the unit, the weight of all permanent installations and supplies, ballast weight during elevating or lowering the hull or legs.

(2) Environmental loadings consist of the maximum wind, wave and current elements or loadings as specified

for elevating or lowering the hull or legs in the operating manual.

(3) Units without bottom mats are also to be capable of withstanding pre-loads which are to be such that the vertical counterforce on each leg is not less than the maximum one under various conditions of the unit.

4.2.2.5 Survival mode:

(1) Static loadings include the weight of the unit, the weight of all permanent installations and supplies, ballast weight for achieving survival.

(2) Environmental loadings are to comply with the most severe storm conditions as specified for survival in the operating manual.

4.2.3 Seabed conditions

4.2.3.1 The owner/operator is to specify the seabed conditions for operations of the unit and assume appropriate responsibilities. All classification requirements of the Rules in this respect are to be based upon the seabed conditions specified by the owner/operator. The owner/operator is to ensure that actual seabed conditions do not impose more severe loadings on the unit than the design assumptions specified by him. These seabed conditions are to be recorded in the operating manual.

Section 3 WAVE CLEARANCE

4.3.1 Wave clearance

4.3.1.1 Wave clearance refers to the clearance between the lowest edge of hull bottom plating of the unit and the crest of maximum design wave (see Fig. 4.3.1.1) while the unit is standing. Wave clearance C is to be the lesser of C_1 and 1.2 m:

$$C_1 = 0.1(H_1 + H_2 + H_3) \qquad \text{M}$$

where: H_1 — elevation of astronomical tide, in m;

H_2 — elevation of storm tide, in m;

H_3 — elevation of crest of maximum design wave to cardinal water level, in m.

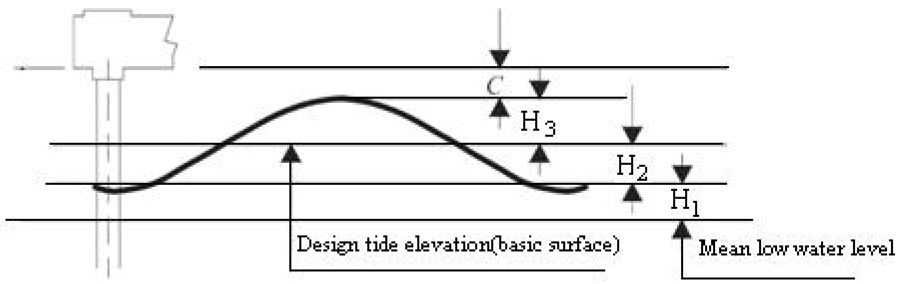


Fig. 4.3.1.1 Diagram of Wave Clearance C Values

Note: The mean low water level as shown in Fig. 4.3.1.1 may be defined as the low tide level of mean spring tide.

4.3.1.2 The wave clearance of the unit is to be recorded in the operating manual.

Section 4 OVERALL STRUCTURAL ANALYSIS

4.4.1 General requirements

4.4.1.1 A three-dimensional finite element model of structure including the hull and legs of the unit is to be established and the primary structural members are subject to strength assessment.

4.4.1.2 When considering the elastic connection of the hull to legs, the transfer of loads between them is to be properly simulated. The stiffness calculations together with their technical reasons are to be submitted for examination.

4.4.1.3 The rack-and-pinion system is also to be included into the structural analysis model so as to confirm that the gear withstands no more than its maximum allowable load.

4.4.1.4 If the rack is installed only at one side, the effects of eccentricity of the legs are to be appropriately considered.

4.4.1.5 Penetrating legs are to be considered articulated 3 m below the seabed for simulating boundary conditions of their finite element model.

4.4.1.6 The boundary conditions of legs with independent spudcans may be established with due consideration being given to penetration depth of legs/spudcans. Except as approved by CCS for detailed calculation regarding spudcan-seabed interactions, the following may be considered:

(1) When the spudcan is partially penetrated into the seabed, the hinged point is to be taken at half of the maximum penetration depth.

(2) When the spudcan is fully or more than fully penetrated into the seabed, the hinged point is to be taken at half of the height of the spudcan.

4.4.1.7 Under the standing condition wherein the dynamic amplification factor (DAF) obtained from the following formula is more than 1.1, consideration is to be given to the dynamic effects resulted from waves or the combined effects of wave and current:

$$DAF = \frac{1}{\sqrt{\left\{1-\left(\frac{T_n}{T}\right)^2\right\}^2 + \left(2\zeta\frac{T_n}{T}\right)^2}}$$

where: ζ =fraction of critical damping (generally not more than 7%);

T——wave period, expressed in unit s;

T_n——natural vibration period of the unit’s translational motion, expressed in unit s.

If feasible, the natural vibration period and modal of Tn can be obtained using the finite element model that reflects the unit’s mass and stiffness properties. If not feasible, they can be estimated as follows:

$$T_n = 2\pi\sqrt{M_e/K_e}$$

Where: M_e——Effective mass on each leg of the unit, the value of which may be taken as the total elevated weight devided by the total number of legs. In calculating the total elevated mass, for the mass above the effectve binding point between the leg and the unit’s hull, the total mass is to be taken and for that below the effectve binding point between the leg and the unit’s hull, half of the mass is to be taken (excluding the footage, but including the added water mass of the leg);

K_e——The following factors are to be taken into account when calculating the effective bending stiffness of each leg to resist the unit’s horizontal displacement at the corresponding elevated height of the unit: hinged support of the leg at the point at least 3m below the mud surface, stiffness of the connection between the unit’s hull and the leg, and the lateral displacement of the leg under the effect of the considered environmental loads and the maximum elevated weight of the unit.

Section 5 HULL STRUCTURE

4.5.1 Main girders

4.5.1.1 The hull structure may be divided into main girders and other structures. The main girders are the strength structures connecting the leg wells and generally composed of bottom plate, side plates, strength deck, internal side walls or watertight bulkheads along the length of the main girders as well as girders connecting and supporting such bulkheads.

4.5.1.2 The hull is to be designed as a complete structure having sufficient strength to resist all induced stresses while in the elevated position and supported by all legs. All fixed and variable loads of the unit are to be distributed by a recognized method and in accordance with the distribution and point of action of each load. The scantlings of the hull are then to be determined consistent with this load distribution.

4.5.2 Scantlings

4.5.2.1 The scantlings are to be determined in accordance with the requirements in Chapter 3 of this part for overall strength, local strength and allowable stresses.

4.5.3 Structural members of jack house

4.5.3.1 The scantlings of structural members of the jack house are to comply with the requirements for overall and local strength and are to be not less than those required for deckhouses. An appropriate transition is to be made for the connection of this area with other parts so as to achieve effective transferring of loads between the unit's hull and legs.

4.5.3.2 Any opening is generally to be avoided on the shell plating in this area and the adjacent area within 10% of the length of the main girder. When it is necessary to have an opening in this area, the appropriate compensation is to be made and approved by CCS.

4.5.3.3 During jacking of the unit, the loads applied to the jacking system is to be the total elevated weight plus appropriate friction which is not to be less than 5% of the elevated loads.

4.5.3.4 In any case, the loads applying to the elevating arrangements, locking apparatus or bolts are not to exceed the allowable values given by the manufacturer.

Section 6 BOTTOM MATS AND SPUDCANS

4.6.1 General requirements

4.6.1.1 The scantlings of the primary structure are generally to be calculated in accordance with the relevant requirements in Chapter 3 of this part.

4.6.1.2 The Rule scantlings are to be designed in accordance with the requirements in Section 2 of Chapter 3 of this part, but the plate thickness of the boundary is to be 1 mm more than the required value. And the design head h is to be taken as follows:

(1) For a bottom mat/spudcan that is freely vented to the sea: for plate, the vertical distance from the lower edge of the plate to the free flooding point or 15 m, whichever is greater; for stiffener or girder, the vertical distance from the mid-point of the span l of the stiffener or girder to the free flooding point or 15 m, whichever is greater.

(2) For a bottom mat/spudcan that is not freely vented to the sea: for plate, the vertical distance from the lower edge of the plate to the maximum operational waterline, including the height of astronomical and storm tides; for stiffener or girder, the vertical distance from the mid-point of the span l of the stiffener or girder to the maximum operational waterline, including the height of astronomical and storm tides.

(3) The substructure of the spudcans is to be designed to withstand pressure head which is corresponding to the maximum preload concentrically distributed over a range of potential contact areas between spudcans and the seabed. For flat bottom spudcans, a maximum preload is to be assumed to be evenly distributed over 50% of the bottom area.

4.6.1.3 In the direct calculation and analysis of the strength of the pile shoe and its adjacent legs, all circumstances shall be taken into account to determine the most dangerous action. The checking range shall reflect the local strength of the joint between the pile leg and the pile shoe and the strength of the nearby pile leg under the bending moment of the pile shoe, and the length of the pile leg model can be selected with reference to 1 time the diameter of the pile shoe. For loads and combinations, at least the following action conditions shall be considered and checked according to the combined operating conditions::

(1) In preload conditions, the spudcans and the their connections to the legs are to be designed to have the capability of withstanding the maximum preload which is provided to be concentrically distributed over the range of potential bearing areas, from the initial contact area of spudcans up to and including full embedment;

(2) In normal operating and survival conditions, the spudcans and their connections to the legs are to be designed to have the capability of withstanding the maximum vertical reaction and the associated horizontal

reaction in conjunction with 50% of maximum bending moment at the lower guide calculated in the global analysis with the hinged boundary condition, acting along the most unfavorable direction.

(3) Additionally, in view of the possible uncertainty of the bottom of spudcans, they and their connections to legs are to be capable of withstanding the force and moment induced by the maximum vertical counterforce acting on 50% of the area on the same side of the bottom area.

(4) Where it is intended to move the unit without the spudcans being fully retracted, particular attention is needed. If necessary, a special detailed analysis of the leg-to-spudcan connections is to be required.

(5) Where spudcans are not freely vented to the sea, hydrostatic pressure load shall be superimposed when checking the strength of the pile shoe under the conditions described in (1)-(3).

4.6.1.4 Particular attention is to be given to connection between bottom mat/spudcans and legs and to the attachment, framing and bracing of the internal structure of bottom mat/spudcans for making sure that loads are properly transmitted between bottom mat/spudcans and legs.

4.6.1.5 The effects of scouring on the bottom bearing surface are to be considered. The mat is to be further investigated while resting on the seabed with 20% of the bottom bearing area washed away due to scouring. The effects of skirt plates, where provided, will be specially considered by CCS.

4.6.1.6 Mats and spudcans are to be designed to withstand the shock of touching bottom while the unit is afloat and subject to wave motions, with sufficient strength margin.

Section 7 LEGS

4.7.1 General requirements

4.7.1.1 A self-elevating unit is usually provided with three or four legs. The legs may be either shell type or truss type. Shell type legs may be designed as either stiffened or unstiffened shells. Individual spudcans may be fitted or legs may be permanently attached to a bottom mat for preventing excessive leg penetration into the seabed.

4.7.1.2 The scantlings of legs are to be determined by calculation, analysis and strength check of their structure under conditions stated in this Section.

4.7.1.3 Attention is to be paid to the possibility that critical loading cases of spudcans, jack-house structure and main parts of legs occur under the normal operating condition and survival condition, and that critical loading cases of jack-house structure and lower parts of legs occur under the transit condition. In addition, particular attention is to be given to shear forces acting on legs in way of supporting points of the main structure.

4.7.1.4 The structural adequacy of the legs is to be investigated for any anticipated vertical position with respect to the hull during transit moves, and the approved positions are to be specified in the operating manual.

4.7.1.5 For truss type legs, the slenderness ratio of the main chord members between joints is not to exceed 40, or two thirds of the slenderness ratio of the leg column as a whole, whichever is the lesser, otherwise the buckling strength of the bending-compression failure mode of the members is to be verified taking into account joint rigidity and joint eccentricity. In addition, the tubular joint is to be checked on punching shear strength in accordance with the international accepted standards (e.g. API RP 2A).

4.7.1.6 The force and moment induced by axial compression force and lateral displacement of the whole leg are to be considered, and the $P-\Delta$ effect is to be taken into account as follow:

$$\Delta = \frac{\delta}{1-\dfrac{P}{P_E}} \quad \text{m}$$

where: δ — the linear-elastic first order hull displacement, in m;

P — the average axial load in the leg at the hull (i.e. the total leg load at the hull divided by the number of legs);

P_E — the critical elastic force of the whole leg (Euler force), in same unit as P, refer to σ_E in 3.4.6.1 of Chapter 3 of this part.

4.7.1.7 For truss-type legs, the effects of the rack phase differential on the strength of the legs are to be considered.

4.7.1.8 Unless otherwise supported by calculation, the distance from the upper guide plate to the end of the pile leg shall meet the following requirements:

(1) No less than 1.5m;

(2) For bolt pile legs, the distance shall not be less than a vertical stroke height between bolt holes;

(3) Truss-type pile legs shall have a strut not lower than the upper guide plate.

4.7.1.9 For cylindrical pile legs not connected with seawater, the circumferential stress caused by internal and external pressure difference shall be considered in buckling check. The check method refers to Chapter 4 of CCS Guidelines for Buckling Strength Evaluation of Offshore Engineering Structures.

4.7.2 Normal operating condition and survival condition

4.7.2.1 The loadings are to be calculated for the most unfavorable combination of maximum static gravity load, wind, wave and current as well as the additional bending moment due to displacement of legs.

4.7.2.2 The wave and current loads on legs are generally to be calculated in accordance with Section 3 of Chapter 2. Values of drag coefficient C_D and inertia coefficient C_M for cylindrical chord members with protruding racks, triangular chord members or other shapes of non-tubular members are to be determined based on tests or relevant published data.

4.7.2.3 When self-elevating units normally operating in deep waters are to operate in shallow waters, the vibration analysis of the protruding portions of legs above the unit's hull deck is to be performed.

4.7.3 Transit condition

4.7.3.1 In the field transit condition, the design bending moment M of the legs is to be determined according to the following formula:

$$M = M_1 + 1.2M_2 \qquad \text{kN·m}$$

where: M_1 — dynamic bending moment of legs caused by rolling or pitching of the unit at self-vibration period to 6°single amplitude, in kN · m;

M_2 — static bending moment caused by leg weight at 6°inclination of the unit, in kN · m.

The legs are to be investigated for any proposed leg arrangement with respect to vertical position during field transit moves, covering structural and stability aspects. The approved vertical positions of legs corresponding to the hull are to be specified in the operating manual.

4.7.3.2 In the ocean transit condition, the design bending moment M of the legs is to be determined according to the following formula:

(1) $M = M_3 + M_4 + M_5$ kN·m

where: M_3 — bending moment of legs caused by acceleration of the unit in the most severe anticipated environmental transit conditions, in kN · m;

M_4 — gravity bending moment caused by motions of the unit in the same conditions as those of M_3, in kN · m;

M_5 — corresponding wind moment, (the wind velocity is not to be less than 51.5m/s), in kN·m.

(2) Alternatively, legs may be designed for a bending moment M caused by minimum design criteria of a 15° single amplitude of roll or of a 15° single amplitude of pitch at a 10 second period, plus 120% of the gravity moment at that angle of the legs.

(3) M may also be obtained through an approved method or model test.

4.7.3.3 Attention is to be paid in case of the primary wave period approaching the natural period of the legs under the transit condition. Appropriate measures are to be taken to prevent probable resonance or excessive vibratory amplitude.

4.7.3.4 For the ocean transit condition, it is necessary to reinforce or support the legs, or to remove sections of them.

4.7.3.5 The approved environmental ocean transit conditions are to be included in the operating manual of the unit.

4.7.4 Jacking condition

4.7.4.1 Legs are to be designed to withstand the dynamic loads which may be encountered by their unsupported length just prior to touching bottom, and also to withstand the shock of touching bottom while the unit is afloat and subject to wave motions.

4.7.4.2 The unit's maximum design motions, bottom conditions and sea state while lowering legs are to be clearly indicated in the operating manual. Legs are not to be permitted to touch bottom when the site conditions exceed the allowable limits.

4.7.4.3 Units without the bottom mat is to be capable of withstanding the preload which is to be such that the vertical counterforce on each leg is not less than the maximum one under various conditions of the unit. The approved preload is to be included in the operating manual.

4.7.5 Local strength of pile legs

If necessary, it is necessary to check the local strength of the contact position between the pile leg and the guide device.

Section 8 STRUCTURE IN WAY OF JACKING OR OTHER ELEVATING ARRANGEMENTS

4.8.1 General requirements

4.8.1.1 Jack-house structures or frames are to have adequate strength to resist and properly transmit the loads between the legs and the hull. Load-carrying members in way of elevating arrangements are to be checked for maximum design loads.

4.8.1.2 For special analysis of jack-house structures or frames, a local 3-dimensional finite element method is in general to be used to analyze and check strength. The model is to be representative of the stress distribution of all primary members.

CHAPTER 5 COLUMN-STABILIZED UNITS

Section 1 GENERAL PROVISIONS

5.1.1 General requirements

5.1.1.1 This Chapter applies to structural design and analysis of column-stabilized units as defined in Chapter 2 of PART ONE. Those not covered by this Chapter are to be considered in accordance with Chapter 3 of this part and/or CCS Rules for Classification of Sea-Going Steel Ships, as appropriate.

5.1.1.2 Scantlings of the major structural elements of the unit are to be determined by direct calculations in accordance with load distribution under all intended loading conditions.

5.1.1.3 Local structure in way of fairleads, mooring windlass/winches, etc., forming part of the position mooring system, is to be designed to withstand forces equivalent to the breaking strength of the mooring line. The allowable stress is to comply with the provisions for combined conditions specified in Chapter 3 of this part.

Section 2 DESIGN CONDITIONS AND DESIGN LOADINGS

5.2.1 Design conditions

5.2.1.1 The strength analysis of the unit is at least to take the following design conditions into account: normal operating mode, transit mode and survival mode. If necessary, a accident condition is to be specially considered.

5.2.2 Design loadings

5.2.2.1 For each design mode, the static loading condition and combined conditions of static loadings and environmental loadings are to be taken into account. The environmental loadings are to be calculated in accordance with Chapter 2 of this part, and the safety factor appropriate for each design condition is to be taken in accordance with Section 3, Chapter 3 of this part. The strength assessment and service limitations related to classification of the unit are to be based on all environmental conditions specified by the owner/operator.

5.2.2.2 For column-stabilized units, the highest stresses of local structure may be associated with less severe environmental conditions than the maxima specifiedby the owner/operator. Where considered necessary, such high stress and the increased probability of their occurrence are to be taken into account by either or both of the following:

(1) Suitable reduction of the allowable stress levels considered in combined loading conditions specifid in Section 3, Chapter 3 of this PART.

(2) Detailed investigation of the fatigue properties.

5.2.2.3 Transit mode:

(1) Static loadings include the weight of the unit, the weight of all permanent installations and supplies, ballast weight and buoyancy during transit.

(2) Environmental loadings consist of the allowable wind, wave and current elements as specified for transit in the operating manual.

5.2.2.4 Normal operating mode:

(1) Static loadings include the weight of the unit, the weight of all permanent installations and supplies, ballast weight, operational loads and buoyancy.

(2) Environmental loadings consist of the maximum wind, wave and current elements or loadings as specified for normal operations in the operating manual and the position mooring loading.

5.2.2.5 Survival mode:

(1) Static loadings include the weight of the unit, the weight of all permanent installations and supplies, ballast

weight and buoyancy for achieving survival.

(2) Environmental loadings are to be calculated for the maximum wind, wave and current elements as specified for survival in the operating manual. The additional loadings due to the inclination and motions of the unit and the position mooring loading are also to be taken into account.

Section 3 WAVE CLEARANCE

5.3.1 General requirements

5.3.1.1 Unless the underside structures and side shell of the upper hull are designed for wave impact and approved by CCS, reasonable clearance between the underside of the upper hull and the wave crest is to be ensured for all afloat modes of operation, taking into account the predicted motion of the unit relative to the surface of the sea. This clearance may be based on calculations, model test results, or prototype experiences and is to be submitted to CCS for examination and approval.

5.3.1.2 For on-bottom modes of operation, clearances are to be in accordance with those specified for self-elevating units.

Section 4 UPPER HULL

5.4.1 General requirements

5.4.1.1 The upper hull refers to the structure constructed on the column for the purpose of supporting the drilling operating zone and accommodation module. The upper hull together with the column, bracing member and lower hull forms the primary structure of the unit. The upper hull may be multi-tier “box” type or of a single tier deck.

5.4.1.2 The scantlings of the upper hull structure are to comply with the requirements for deck loadings. The deck loadings to be applied are not to be less than the minimum ones required in Section 5 of Chapter 2 of this part.

5.4.1.3 When the upper hull is considered to be an effective member of the overall structural frame of the unit, the scantlings are to be based on the total stress synthesized by global stress and local stresses and determined in accordance with the requirements in Chapter 3 of this part for global strength, local strength and allowable stresses.

5.4.1.4 Where the upper hull is designed to be waterborne in any mode of operation, its minimum scantlings are to comply with the corresponding requirements for ship structures.

5.4.2 Construction

5.4.2.1 Bulkhead openings in tweendecks are generally not to be fitted in the same vertical line.

5.4.2.2 Columns are to be aligned and integrated with the bulkheads in the upper hull structure. Particular attention is to be given to the design of details at the intersection of columns with the upper hull structure to minimize stress concentrations.

5.4.2.3 Deckhouses fitted to the upper hull structure are to be designed in accordance with relevant requirements, with due consideration given to their location and to the environmental conditions in which the unit will operate.

Section 5 COLUMNS, FOOTINGS AND LOWER HULLS

5.5.1 General requirements

5.5.1.1 Columns, lower hulls or footings may be designed as either framed or unframed shells. In either case, framing, ring stiffeners, bulkheads or other suitable diaphragms which are used are to be sufficient to maintain shape and stiffness under all the anticipated loadings.

5.5.1.2 Portlights or windows including those of the non-opening type, or other similar openings, are not to be fitted in columns.

5.5.1.3 Columns are to be, as far as practicable, continuous through the plating of the lower hull deck structure and be aligned and integrated with the internal bulkheads and/or side shell.

5.5.1.4 Particular attention is to be given to the design of the local structure at the intersection of columns with lower hulls and due consideration is to be given to weld penetrations and stress concentrations.

5.5.1.5 Scantlings of columns, lower hulls or footings as determined according to 5.5.2 and 5.5.3 are minimum requirements for hydrostatic pressure loads. Where wave and current forces are superimposed, the local structure of the shell is to be increased in scantlings as necessary, to meet the strength requirements of Chapter 3 of this part.

5.5.2 Framed shells

5.5.2.1 Where the components of columns, lower hulls or footings incorporate stiffened plating, the minimum scantlings of plating, framing, girders, etc. are to be determined in accordance with Section 2 of Chapter 3 of this part.

5.5.2.2 Internal column structure supporting main bracings is not to be of a lesser strength than the bracing itself.

5.5.3 Unframed shells

5.5.3.1 Where columns, lower hulls or footings are designed to be located in way of shells either unstiffened or ring stiffened, the minimum scantlings of shell plating and ring stiffeners are to be analyzed by recognized shell mechanics method and determined on the basis of the design pressure heads as given in Section 2 of Chapter 3.

5.5.4 Non-watertight internal structural flats

5.5.4.1 The plate thickness t of non-watertight structural flats within columns, footings and lower hull is to be taken as $t = 10\ s$ (mm), but not less than 6 mm, where s is the spacing of framing members, in m.

5.5.5 Additional requirements for direct calculations

5.5.5.1 Scantlings of columns, lower hulls or footings, as determined according to 5.5.2 and 5.5.3 above, are minimum requirements for hydrostatic loads. When the columns, footings or lower hull is an effective member of the overall structural frame of the unit, the actual scantlings are to be increased by a proper corrosion margin to obtain the final scantlings, in accordance with the stress and corresponding strength requirements in Chapter 3 of this part, based on direct calculation and analysis in respect to static loadings and superimposed overall environmental loadings (e.g. wind, wave, current) and effects of local loadings.

5.5.5.2 In checking the scantlings of compartments, the two loading conditions of assumed empty compartment and fully loaded compartment are to be taken into account, regardless of actual compartment arrangement.

5.5.5.3 Particular consideration is to be given to structural details, reinforcement, etc., in areas subject to high local loadings, or to such loadings that may cause shell distortion, for example:

(1) bottom bearing area, where applicable;

(2) partially filled tanks;

(3) local structure against external damage;

(4) continuity member through joints;

(5) wave impacts area, such as deck bottom close to column, vicinity of column waterline, cross-brace, anchor rack and lower hull bow, etc.

Section 6 BRACING MEMBERS

5.6.1 General requirements

5.6.1.1 The bracing members refer to the braces with tubular sections or other shapes connecting various parts of the column-stabilized unit to form a space framing. The loadings, which are mainly dependent on the arrangement and position of the bracing members and the number of columns, are usually to be determined by direct calculation.

5.6.1.2 Stresses in bracing members due to all anticipated loadings are to be determined in accordance with the relevant requirements in this Section and Chapter 3 of this part.

5.6.2 Structural strength

5.6.2.1 Bracing members are to be designed to transmit loadings and to make the overall structure effective against all anticipated loadings (environmental forces and, when the unit is supported by the seabed, against the possibility of uneven bearing loads). Therefore, the strength of bracing members is to be sufficient to withstand the total of local stresses due to wave, current and buoyancy forces superimposed on global stress transmitted from the primary structure, and if applicable, to be effective against uneven bearing loads when the unit is supported by the seabed.

5.6.2.2 Where applicable, special consideration is to be given to local stresses due to wave impact.

5.6.2.3 Where bracing members are of tubular section, ring frames may be required to maintain stiffness and roundness of their shape.

5.6.2.4 Bracing members are usually to be made watertight and provided with adequate means of access to enable internal inspection to be carried out when the unit is afloat. They are to be suitably designed to prevent collapse from external hydrostatic pressure (including hydrodynamic head).. The bracing members underwater are to be made watertight and provided with a leakage detection system

5.6.2.5 Special attention is to be given to openings and joints on bracing members. The welding specification is to be such as to minimize the risk of cracks, lack of penetration and lamellar tearing of the parent steel.

Section 7 DECKHOUSE STRUCTURE

5.7.1 General requirements

5.7.1.1 Deckhouses are to have sufficientstrength for their size, function and location, taking into account the environmental loadings that the deckhouses have to withstand. And special consideration is to be given to the deckhouses acting as the foundations of important equipment.

5.7.1.2 The loadings on deckhouses generally include wind loadings, motion-induced inertia forces, various live loadings, deadweight and forces generated by unit inclination. Therefore, the deckhouses are to be designed to withstand the combined effects of these loadings and checked for strength in accordance with the requirements in 3.4 of Chapter 3 of this PART.

5.7.1.3 In strength calculations for deckhouse with a longer span, consideration is to be given to the effects of the global deformation of the unit and attention paid to the type of connection nodes between deckhouse corners and the main deck, in order to avoid excessive stress concentration.

5.7.1.4 Where the deckhouses are likely to withstand wave loadings, the loading effects as mentioned in 5.7.1.1 and 5.7.1.2 as well as the effects of wave slamming are to be considered in their design.

5.7.1.5 Where the contribution of a deckhouse to the stability is considered in stability calculation, the boundary of the deckhouse is to be watertight and in compliance with the requirements for watertight bulkheads specified in 3.2.4 of Chapter 3 of this ART.

Section 8 STRUCTURAL REDUNDANCY

5.8.1 General requirements

5.8.1.1 The structural redundancy for column-stabilized units is to be determined according to the following assumed damage conditions:

(1) The unit’s structure is to be designed to be capable of withstanding the loss of any slender bracing member and not to cause overall collapse of the unit’s structure;

(2) Structural redundancy will be based on the applicable requirements of Chapter 3 of this part, except:

① Maximum calculated stresses in the structure remaining after the loss of a slender bracing member are to be checked in association with a safety factor not less than 1.0. This criterion may be exceeded for local areas, provided redistribution of forces due to yielding or buckling is taken into consideration;

② ② When environmental factors are taken into account, a return period of one year and the corresponding most unfavorable loading conditions can be assumed for the predetermined operation area. If other standards are adopted to take into account environmental loads, it must be agreed by CCS.

5.8.1.2 For column-stabilized units in the form of single deck, the structural arrangement of the upper hull is to be considered with regard to the structural integrity of the unit after the failure of any primary girder. The loading conditions and strength check of the remaining structures for calculation are to be the same as in 5.8.1.1 (2).

Section 9 REQUIREMENTS FOR ON-BOTTOM MODE OF OPERATION

5.9.1 General requirements

5.9.1.1 For a column-stabilized unit intended for the class notation of On Bottom Strengthened, the strength of the bottom and its supporting structure is to be effective against uneven bearing loads when the unit is supported by the seabed.

5.9.2 Scouring

5.9.2.1 For units designed to rest on the seabed, the effect of scouring action on the area of the lower hull or footings resting on the seabed is to be considered:

(1) For units equipped with lower hull, 20% of the bottom-bearing area may be considered washed away due to scouring as the most adverse condition.

(2) The units of other structural types are to be specially considered.

Where skirt plates are provided, their effectiveness in preventing the scouring may be taken into account.

CHAPTER 6 SUBMERSIBLE UNITS

Section 1 GENERAL PROVISIONS

6.1.1 General requirements

6.1.1.1 This Chapter applies to structural design and analysis of submersible units as defined in Chapter 2 of PART ONE. Those not covered by this Chapter are to be considered in accordance with Chapter 3 of this part and/or CCS Rules for Classification of Sea-Going Steel Ships as well as Chapter 4 of this part, as appropriate.

6.1.1.2 The relevant requirements of Chapters and Sections in this part may be complied with, if applicable.

6.1.1.3 Scantlings of the major structural elements of the unit are to be determined by direct calculation in accordance with load distribution under all intended loading conditions.

6.1.1.4 The requirements for deckhouse structures of the unit are given in Section 7 of Chapter 5 of this part.

Section 2 DESIGN CONDITIONS AND DESIGN LOADINGS

6.2.1 Design conditions

6.2.1.1 The strength analysis of the unit is to take the following design conditions into account: transit condition, normal operating condition, survival condition, and descending and ascending condition.

6.2.2 Design loadings

6.2.2.1 For each design condition, static loading conditions and conditions of combined static loadings and environmental loadings are to be taken into account. The environmental loadings are to be calculated in accordance with Chapter 2 of this part, and the safety factor appropriate for each design condition is to be taken in accordance with Section 4 of Chapter 3 of this part. The strength assessment and service limitations related to classification of the unit are to be based on all environmental conditions specified by the owner/operator.

6.2.2.2 Transit condition:

(1) Static loadings include the weight of the unit, the weight of all permanent installations and supplies, ballast weight and buoyancy during transit.

(2) Environmental loadings consist of the allowable wind, wave and current as specified for transit.

6.2.2.3 Normal operating condition:

(1) Static loadings include the weight of the unit, the weight of all permanent installations and supplies, ballast weight, operational loads and buoyancy.

(2) Environmental loadings consist of the maximum wind, wave and current loadings as specified for normal operations in the operating manual and seabed supporting capabilities.

6.2.2.4 Survival condition:

(1) Static loadings include the weight of the unit, the weight of all permanent installations and supplies, ballast weight and buoyancy for achieving survival.

(2) Environmental loadings are to be calculated for the wind, wave and current loadings as specified in Chapter 2 of this part. The seabed supporting capabilities are also to be taken into account.

6.2.2.5 Descending and ascending condition

(1) Static loadings include the weight of the unit, the weight of all permanent installations and supplies, ballast weight and buoyancy during transition between floating and resting on the seabed.

(2) Environmental loadings are not to be taken into consideration.

6.2.2.6 Seabed conditions

The owner/operator is to specify the seabed conditions for operations of the unit and assume appropriate responsibilities. All classification requirements of the Rules in this respect will be based upon the seabed conditions specified by the owner/operator. The owner/operator is to ensure that actual seabed conditions do not impose more severe loadings on the unit than the design assumptions specified by him. These seabed conditions are to be recorded in the operating manual.

6.2.2.7 Operating conditions:

Procedures and limitations for ballasting and re-floating the unit are to be such as to avoid overstressing the structure by static or dynamic loads.

Section 3 WAVE CLEARANCE

6.3.1 General requirements

6.3.1.1 The wave clearance of the unit is to avoid wave impact on the bottom structure of upper hull when the unit is resting on the seabed. The wave clearance is to be determined as specified in 4.3.1.1.

6.3.1.2 The wave clearance of the unit is to be included into the operating manual.

Section 4 UPPER HULL

6.4.1 External loadings on the upper hull

6.4.1.1 The external loadings on the upper hull comprise:

(1) weight of the upper hull including weight of heavy objects on the deck;

(2) deck loadings;

(3) loadings transmitted by columns and bracing members, varying with conditions of the unit.

6.4.2 Scantlings

6.4.2.1 The scantlings are to be determined in accordance with the requirements in Chapter 3 of this part for global strength, local strength and allowable stresses.

Section 5 COLUMNS AND BRACING MEMBERS

6.5.1 General requirements

6.5.1.1 The columns and bracing members are to be designed to connect the upper and lower hulls to form a integral space framing structure and transmit the loadings of the upper hull to the lower hull or vice versa.

6.5.2 Strength analysis

6.5.2.1 The columns and bracing members are to be designed generally in tubular or shell shape and structured in compliance with the relevant requirements of Sections 6 and 8 of Chapter 5 of this part.

6.5.2.2 In the analysis, the external loadings are to be determined in accordance with the conditions stated in 6.2.1.1.

Section 6 LOWER HULL

6.6.1 General requirements

6.6.1.1 Lower hulls are generally to be designed in barge shape or as framed shells of other shapes, the scantlings of which are to comply with applicable requirements of Section 5, Chapter 5 and Section 6, Chapter 4 of this part. The local strengthening and wearing of shell plating in way of the on-bottom part of the lower hull are also to be taken into consideration.

6.6.1.2 In general, shell stiffeners supported as primary bottom members are to be spaced not more than 1.85 m apart and side girders or equivalent are to be spaced not more than 2.2 m apart.

6.6.1.3 The effects of scouring on the bottom bearing surface are to be considered. The mat is to be further investigated while resting on the sea bed with 20% of the bottom bearing area washed away due to scouring. Where skirt plates are provided, their effectiveness in preventing the scouring will be specially considered by CCS.

CHAPTER 7 SURFACE-TYPE UNITS

Section 1 GENERAL PROVISIONS

7.1.1 General requirements

7.1.1.1 This Chapter applies to structural design and analysis of surface-type units as defined in Chapter 2 of PART ONE.

7.1.1.2 The scantlings of surface-type units, including ship type ones and barge type ones, are in general to comply with CCS Rules for Classification of Sea-Going Steel Ships as appropriate. In addition, special consideration is to be given to other requirements in this Section below.

7.1.1.3 All surface-type units are to comply with Section 12, Chapter 2 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships and be fitted with a collision bulkhead. Sluice valves, cocks, manholes, watertight doors, etc., are not to be fitted in the collision bulkhead. Elsewhere, watertight bulkheads are to be fitted as necessary to provide transverse strength and subdivision.

7.1.2 Other requirements

7.1.2.1 The required longitudinal strength of the unit is to be maintained in way of the drilling well, and the transition of fore and aft members is to be developed so as to maintain continuity of the longitudinal material. In addition, the plating of the well is to be suitably stiffened to prevent damage due to foreign objects which may become trapped in the well while the unit is underway.

7.1.2.2 The deck area in way of large hatches is to be suitably compensated where necessary to maintain the strength of the unit.

7.1.2.3 The structure in way of heavy concentrated loads resulting from derricks, storage yards, pipe setbacks, mud pools, etc., is to be suitably reinforced.

7.1.2.4 The local structure in way of fairleads, winches, etc., forming part of the position mooring system, is to be designed to withstand forces equivalent to the breaking strength of the mooring line. The allowable stress is to comply with the requirements for combined loading conditions as specified in Chapter 3 of this part.

CHAPTER 8 BOTTOM-SITTING BOX UNITS

Section 1 General Provisions

8.1.1 General requirements

8.1.1.1 Dimensions of the main structure of the bottom-sitting box unit shall be determined by direct calculation based on the load distribution under typical operating conditions under all expected operation modes.

8.1.1.2 Component dimensions not covered in this chapter shall comply with the corresponding requirements of Chapter 3 of this Part and/or CCS Rules for Classification of Steel Seagoing Vessels.

Section 2 Design Conditions and Design Loads

8.2.1 Design conditions

8.2.1.1 Typical operating conditions under migration mode, normal operation mode, self-storage mode and ups and downs mode shall be considered in the design operating conditions of bottom-sitting box unit according to its own characteristics. When necessary, special consideration shall be given to accident conditions.

8.2.1.2 Under normal operation mode, the influence of hoisting or piling operations in different directions shall be considered.

8.2.1.3 The unit is in a state of ups and downs, so it is unnecessary to calculate the strength due to utilization of the natural rising and falling mode when the tide rises and falls.

8.2.2 Design load

8.2.2.1 For each design condition, the static load condition and the combination of static load and environmental load shall be considered. The environmental load shall be calculated according to the requirements of Chapter 2 of this Part, and the corresponding safety factor of each design working condition shall be taken according to the provisions of Section 4 of Chapter 3. Strength assessment and classification use restrictions related to unit classification are determined according to all environmental conditions provided by the owner/operator.

8.2.2.2 Migration mode:

(1) Static loads include weight of unit during migration, weight and buoyancy of all fixed devices, supplies, ballasts, etc.;

(2) The environmental load is calculated according to the maximum wind, wave and current when the migration is allowed.

8.2.2.3 Normal operation mode:

(1) Static loads include weight of unit, weight of all fixed devices, supplies and ballasts, operation load, buoyancy, etc.;

(2) Environmental load shall be the maximum wind, wave and current load allowed for normal operation in the operation manual and the supporting force of seabed to the unit.

8.2.2.4 Self-save mode:

(1) Static loads are weight of unit, fixed devices, supplies, ballast weight and buoyancy adapted to the self-storage mode;

(2) The wind, wave and current loads in the environmental loads shall be calculated according to the corresponding provisions in Chapter 2 of this Part, and the supporting force of seabed to the unit shall also be considered.

8.2.2.5 Ups and downs mode:

(1) Static loads include weight of unit, weight and buoyancy of fixed devices, supplies and ballasts when the unit is in floating and bottom-sitting transition state;

(2) The environmental load is not considered.

Section 3 Main Structure

8.3.1 General requirements

8.3.1.1 The strength analysis and verification of the main structure shall be carried out through the three-dimensional finite element method. The model shall be able to characterize the stress distribution of all main components.

8.3.1.2 The main structure shall be designed as a hull with skeleton support. Timbers, annular stiffeners, bulkheads or other suitable diaphragms shall be used to maintain the shape and stiffness of the main structure under all expected load combinations.

8.3.1.3 In general, there shall be no portholes or windows or other similar openings in the main structure.

8.3.1.4 Special attention shall be paid to the local structure at the joint between the main structure and the crane, and sufficient consideration shall be given to its weldability and stress concentration.

8.3.1.5 The component dimensions of the main structure shall meet the minimum requirements for bearing hydrodynamic pressure. For areas directly subjected to wave and current loads, the dimensions of local hull structures shall be further increased as necessary to meet the strength requirements specified in Chapter 3 of this Part.

8.3.1.6 The impact of scouring on the bottom area shall be taken into account. The loss rate of bottom-sitting area can be calculated by 20%. If the unit is equipped with anti-scouring device, CCS will give special consideration to its effect.

CHAPTER 9 EQUIPMENT AND OUTFITS

Section 1 GENERAL PROVISIONS

9.1.1 Application

9.1.1.1 This Chapter applies to equipment and outfits of the unit, including rudder, temporary anchoring and towing equipment.

9.1.2 Anchoring equipment

9.1.2.1 The anchoring equipment for the units comprise:

(1) Temporary anchoring equipment – including anchors, cables, winches, etc. intended to be used while not in a working condition but during transit and location move and for anchoring in harbors or in sheltered areas.

(2) Position mooring equipment – a system for the purpose of positioning the unit, which is to keep the movement of the unit within the prescribed limits and prevent the unit from drifting under all anticipated sea and weather conditions.

The requirements for position mooring equipment are given in Chapter 8 , PART EIGHT of this RULES.

9.1.2.2 All self-propelled units are to be provided with temporary anchoring equipment. However, where the dynamic positioning system of a unit with the class notation DP-2 or DP-3 is fully capable of positioning under the environmental conditions of 2.5 m/s current speed and 25 m/s wind velocity, the temporary anchoring equipment may not be required for classification.

9.1.2.3 For non-self-propelled units, the owner/designer is to decide whether temporary anchoring equipment is necessary.

9.1.2.4 Where there are two sets of position mooring equipment complying with the requirements for temporary anchoring, they may substitute for the temporary anchoring equipment required by the Rules.

9.1.3 Rudder

9.1.3.1 All self-propelled units are to be provided with rudder equipment or other equipment that can achieve similar functions. The rudder is to comply with Chapter 3 of PART TWO of CCS Rules for Classification of Sea-Going Steel Ships as appropriate.

Section 2 TEMPORARY ANCHORING EQUIPMENT

9.2.1 Equipment number

9.2.1.1 The number, weight and specifications of the anchoring equipment are to be determined in accordance with Table 9.2.1.1 based on the equipment number N obtained according to the following formula. The requirements for towing and mooring lines listed in table 9.2.1.1 are only guiding requirements. The technical requirements of towing lines and mooring lines shall comply with the relevant provisions of Section 2 of Chapter 3 of Part Two of the Rules for Classification of Steel Seagoing Vessels.

$$N = \Delta^{2/3} + 2A_1 + 0.1A_2$$

where: Δ — moulded displacement in transit condition, in tonnes;

A_1 — projected area perpendicular to wind direction when at anchor, in m^2;

A_2 — projected area parallel to wind direction when at anchor, in m^2.

In calculating A_1 and A_2, the masking effect between structures is generally not to be taken into account. However, the projected area of members at lee side may be properly reduced on a case-by-case basis. The cylindrical surface may be taken as 50 % of its projected area.

9.2.2 Anchors

9.2.2.1 The material and tests of anchors are to be in compliance with the relevant requirements of Chapter 10 of PART ONE of the CCS Rules for Materials and Welding.

9.2.2.2 The mass of head including pins and fittings of an ordinary stockless anchor is not to be less than 60% of the total mass of the anchor.

9.2.2.3 Where stock anchors are accepted, the mass excluding the stock is not to be less than 80% of the mass of the ordinary stockless anchors given in Table 9.2.2.1.

9.2.2.4 The total mass of anchors is not to be less than the sum of the masses of individual anchors listed in Table 9.2.2.1. However, the real mass of individual anchors may vary from -3% to 7% of the mass given in the Table.

9.2.2.5 When high holding power anchors are used as bower anchors, the mass of each anchor may be 75% of the mass required for ordinary stockless bower anchors in Table 9.2.2.1, and when large grip anchors are used as the first anchors, the mass of each anchor may be 50% of the mass of the ordinary rodless first anchors specified in Table 9.2.1.1 of this section. For specific requirements, please refer to Chapter 10 of Part One of CCS Rules for Materials and Welding.

Temporary Anchoring Equipment **Table 9.2.1.1**

Serial No.	Equipment No. *N*		Bower anchors		Stud link chain cable for bower				towline		系船索		
	Exceeding	Not exceeding	No.	Mass per anchor Kg	Total length m	Diameter (mm) CCS1	CCS2	CCS3	Length（m）	Breaking load(kN)	Number	Length（m）	Breaking load(kN)
1	50	70	2	180	220	14	12.5		180	98	3	80	37
2	70	90	2	240	220	16	14		180	98	3	100	40
3	90	110	2	300	247.5	17.5	16		180	98	3	110	42
4	110	130	2	360	247.5	19	17.5		180	98	3	110	48
5	130	150	2	420	275	20.5	17.5		180	98	3	120	53
6	150	175	2	480	275	22	19		180	98	3	120	59
7	175	205	2	570	302.5	24	20.5		180	112	3	120	64
8	205	240	2	660	302.5	26	22	20.5	180	129	4	120	69
9	240	280	2	780	330	28	24	22	180	150	4	120	75
10	280	320	2	900	357.5	30	26	24	180	174	4	140	80
11	320	360	2	1020	357.5	32	28	24	180	207	4	140	85
12	360	400	2	1140	385	34	30	26	180	224	4	140	96
13	400	450	2	1290	385	36	32	28	180	250	4	140	107
14	450	500	2	1440	412.5	38	34	30	180	277	4	140	117
15	500	550	2	1590	412.5	40	34	30	190	306	4	160	134
16	550	600	2	1740	440	42	36	32	190	338	4	160	143
17	600	660	2	1920	440	44	38	34	190	370	4	160	160
18	660	720	2	2100	440	46	40	36	190	406	4	160	171
19	720	780	2	2280	467.5	48	42	36	190	440	4	170	187
20	780	840	2	2460	467.5	50	44	38	190	479	4	170	202
21	840	910	2	2640	467.5	52	46	40	190	518	4	170	218
22	910	980	2	2850	495	54	48	42	190	559	4	170	235
23	980	1060	2	3060	495	56	50	44	200	603	4	180	250
24	1060	1140	2	3300	495	58	50	46	200	647	4	180	272
25	1140	1220	2	3540	522.5	60	52	46	200	691	4	180	293
26	1220	1300	2	3780	522.5	62	54	48	200	738	4	180	309
27	1300	1390	2	4050	522.5	64	56	50	200	786	4	180	336
28	1390	1480	2	4320	550	66	58	50	200	836	4	180	352
29	1480	1570	2	4590	550	68	60	52	220	888	5	190	352
30	1570	1670	2	4890	550	70	62	54	220	941	5	190	362

31	1670	1790	2	5250	577.5	73	64	56	220	1024	5	190	384
32	1790	1930	2	5610	577.5	76	66	58	220	1109	5	190	411
33	1930	2080	2	6000	577.5	78	68	60	220	1168	5	190	437
34	2080	2230	2	6450	605	81	70	62	240	1259			
35	2230	2380	2	6900	605	84	73	64	240	1356			
36	2380	2530	2	7350	605	87	76	66	240	1453			
37	2530	2700	2	7800	632.5	90	78	68	260	1471			
38	2700	2870	2	8300	632.5	92	81	70	260	1471			
39	2870	3040	2	8700	632.5	95	84	73	260	1471			
40	3040	3210	2	9300	660	97	84	76	280	1471			
41	3210	3400	2	9900	660	100	87	78	280	1471			
42	3400	3600	2	10500	660	102	90	78	280	1471			
43	3600	3800	2	11100	687.5	105	92	81	300				
44	3800	4000	2	11700	687.5	107	95	84	300				
45	4000	4200	2	12300	687.5	111	97	87	300				
46	4200	4400	2	1290O	715	114	100	87	300				
47	4400	4600	2	13500	715	117	102	90	300				
48	4600	4800	2	14100	715	120	105	92	300				
49	4800	5000	2	14700	742.5	122	107	95	300				
50	5000	5200	2	15400	742.5	124	111	97	300				
51	5200	5500	2	16100	742.5	130	111	97	300				
52	5500	5800	2	16900	742.5	130	114	100	300				
53	5800	6100	2	17800	742.5	132	117	102	300				
54	6100	6500	2	18800	742.5		120	107					

Note: One of the third anchors given in the Table is spare anchor.

9.2.3 Chain cables

9.2.3.1 The material and tests of chain cables given in Table 9.2.1.1 are to be in compliance with the relevant requirements of Chapter 10 of PART ONE of CCS Rules for Materials and Welding.

9.2.3.2 A swivel is to be provided to the chain cables at the outboard end to which the anchor is connected. The inboard end of the chain cables is to be secured to the hull structure, and is to be so arranged as will be capable of being immediately released from a position easily accessible outside the chain lockers.

9.2.3.3 At least one anchor shackle and 4 connecting shackles or links are to be provided on board for spares.

9.2.3.4 Grade AM1 material having a tensile stress of less than 400 N/mm^2 is not to be used in association with high holding power anchors.

9.2.3.5 Grade AM3 material is to be used only for chains 20.5 mm or more in diameter.

9.2.3.6 Where steel wires are to be used in lieu of chain cables for temporary anchoring, this is to be agreed by CCS and the following requirements are to be complied with:

(1) The breaking strength of steel wires is to be not less than that of chain cables.

(2) The length of steel wires is to be at least 1.5 times that required for chain cables.

(3) A chain cable not less than 12.5 m in length or as long as the distance from anchor pocket to the windlass, whichever is lesser, is to be provided between the anchor and the steel wire. Swivels are to be provided at the connection of steel rope to chain cable.

(4) The material, design, manufacture and tests of steel wires are to be in compliance with the relevant requirements of Chapter 10 of PART ONE of the CCS Rules for Materials and Welding.

9.2.4 Chain lockers

9.2.4.1 Chain pipes and chain lockers are to be made watertight up to weather deck.

9.2.4.2 Where an opening is provided for letting chain cables in or out, it is to be closed and secured by a solid steel cover with closely spaced bolts.

9.2.4.3 Chain pipes that lead chain cables out are to be provided with a permanently installed closing appliance for dewatering, e.g. a notched plate that matches the chain or a tarpaulin cover secured by lashings.

Section 3 TOWING EQUIPMENT

9.3.1 General requirements

9.3.1.1 All non-self-propelled units are to be provided with adequate towing equipment.

9.3.1.2 Towing systems and emergency towing systems as well as towing equipment are to be designed, manufactured, provided and arranged in accordance with the relevant requirements of CCS Guidelines for Ocean Towing.

9.3.1.3 The safe working load of the towing equipment and the breaking load of the cable are to be indicated on plans submitted for approval.

9.3.1.4 Particulars of the towing system, its design load and the operational instructions are to be incorporated into the operating manual.

9.3.1.5 Means are to be provided to retrieve the unit's towing pendants or bridle in the event that the towing vessel's towline or the towline (weak link) breaks.

9.3.1.6 Attention is to be given to compliance of towing systems and equipment with relevant regulations of the Administration for towing of units.