Section 4 BASIC INFORMATION

1. Definitions

1.1 Principal Particulars

1.1.1 *L*, rule length

1.1.1.1 L, the rule length, is the distance on the waterline at the scantling draught, from the forward side of the stem to the centreline of the rudder stock, in metres. L is not to be less than 96%, and need not be greater than 97%, of the extreme length on the summer load waterline. In ships with an unusual stern and bow arrangement the length, L, will be specially considered.

1.1.2 L_L, load line length

1.1.2.1 L_L, the load line length is defined in the *International Convention on Load Lines*.

1.1.3 Moulded breadth

1.1.3.1 B, the moulded breadth, is the maximum breadth of the ship, measured amidships to the moulded line of the frame, in metres.

1.1.4 Moulded depth

1.1.4.1 D, the moulded depth, is the vertical distance, in metres, amidships, from the moulded baseline to the moulded deck line of the uppermost continuous deck measured at deck at side. On vessels with a rounded gunwale, D is to be measured to the continuation of the moulded deck line.

1.1.5 Draughts

1.1.5.1 T, the draught in metres, is the summer load line draught for the ship in operation, measured from the moulded base line at amidships. Note this may be less than the maximum permissible summer load waterline draught.
1.1.5.2 T_{bal}, is the minimum design ballast draught, in metres, at which the strength requirements for the scantlings of the ship are met. The minimum design ballast draught is not to be greater than the minimum ballast draught, measured from the moulded base line at amidships, for any ballast loading condition in the loading manual including both departure and arrival conditions.
1.1.5.3 T_{bal-n}, the normal ballast draught in metres, is the draught at departure given for the normal ballast condition in the loading manual, measured from the moulded base line at amidships. The normal ballast condition is the ballast condition in compliance with condition specified in **Section 8/1.1.2.2(a)**.
1.1.5.4 T_{full}, the full load draught in metres, is the draught at departure given for the homogeneous full load condition in the loading manual, measured from the moulded base line at amidships. This draught is also known as the full load design draught.
1.1.5.5 T_{sc}, is the maximum design draught, in metres, at which the strength requirements for the scantlings of the ship are met.

1.1.6 Amidships

1.1.6.1 Amidships is to be taken as the middle of the rule length, L.

1.1.7 Moulded displacement

1.1.7.1 Δ, the moulded displacement, in tonnes, corresponding to the underwater volume of the ship, at draught T_{sc}, in sea water with a density of $1.025 t/m^3$.

1.1.8 Maximum service speed

1.1.8.1 V, the maximum service speed, in knots, which the ship is designed to maintain at the summer load line draught and at the propeller RPM corresponding to MCR (Maximum Continuous Rating).

1.1.9 Block coefficient

1.1.9.1 C_b, the block coefficient, is defined as:

$$C_b = \frac{\nabla}{L B_{WL} T_{sc}}$$

Where:

∇	: moulded displacement volume at the scantling draught, in m^3
L	: rule length, as defined in **1.1.1.1**
B_{WL}	: moulded breadth, in m, at the scantling draught waterline
T_{sc}	: scantling draught, as defined in **1.1.5.5**

1.1.10 Length between perpendiculars

1.1.10.1 L_{pp}, the length between perpendiculars, is the distance, in metres, on the scantling draught waterline from the fore side of the stem to the after side of the rudder post, or to the centre of the rudder stock if there is no rudder post.

1.1.11 The forward perpendicular

1.1.11.1 *F.P.*, the forward perpendicular, is the perpendicular at the intersection of the scantling draught waterline with the fore side of the stem. The *F.P.* is the forward end of the rule length, L.

1.1.12 The aft perpendicular

1.1.12.1 *A.P.*, the aft perpendicular, is the perpendicular at the aft end of the rule length, L, measured from the *F.P.*

1.1.13 Load line block coefficient

1.1.13.1 C_{bL}, the load line block coefficient, is defined in the *International Convention on Load Lines* as follows:

$$C_{bL} = \frac{\nabla_L}{L_L B T_L}$$

Where:

∇_L	: moulded displacement volume at the moulded draught, T_L, in m^3
L_L	: load line length, as defined in **1.1.2.1**
B	: moulded breadth, in m, as defined in **1.1.3.1**
T_L	: the moulded draught measured to the waterline at 85% of the least moulded depth, in m

1.1.14 Deadweight

1.1.14.1 *DWT*, is the deadweight of the ship, in tonnes, floating in water with a specific gravity of 1.025, at the summer load line draught.

1.2 Position 1 and Position 2

1.2.1 Position 1

1.2.1.1 Position 1 is defined as any location upon exposed freeboard and raised quarterdecks, and exposed superstructure decks within the forward $0.25L_L$.

1.2.2 Position 2

1.2.2.1 Position 2 is defined as any location upon exposed superstructure decks abaft the forward $0.25L_L$.

1.3 Type 'A' and Type 'B' Freeboard Ships

1.3.1 ICLL definition

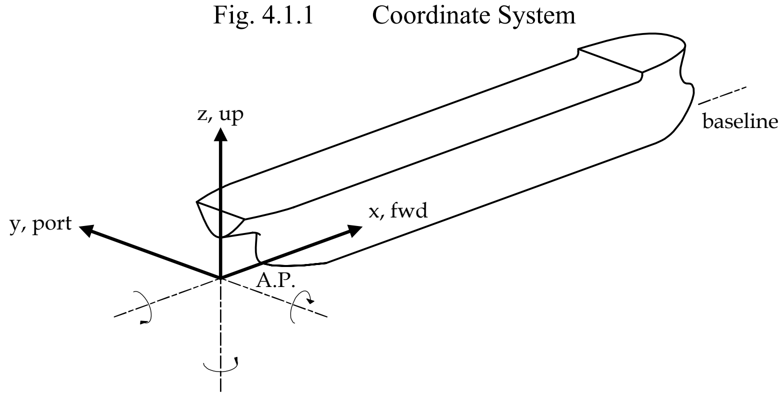
1.3.1.1 A Type 'A' or Type 'B' freeboard ship is as defined in the *International Convention on Load Lines*.

1.4 Coordinate System

1.4.1 Origin and orientation

1.4.1.1 The coordinate system used within this Part is shown in **Fig. 4.1.1**. Motions and displacements are considered positive in the forward, up and to port direction. Angular motions are considered positive in the clockwise direction about the x, y or z axis.

Fig. 4.1.1 Coordinate System



1.5 Naming Convention

1.5.1 Bulkhead nomenclature

1.5.1.1 **Fig. 4.1.2**, **4.1.3** and **4.1.4** show the common structural nomenclature used within this Part.

Fig. 4.1.2 Corrugated Transverse Bulkhead Nomenclature

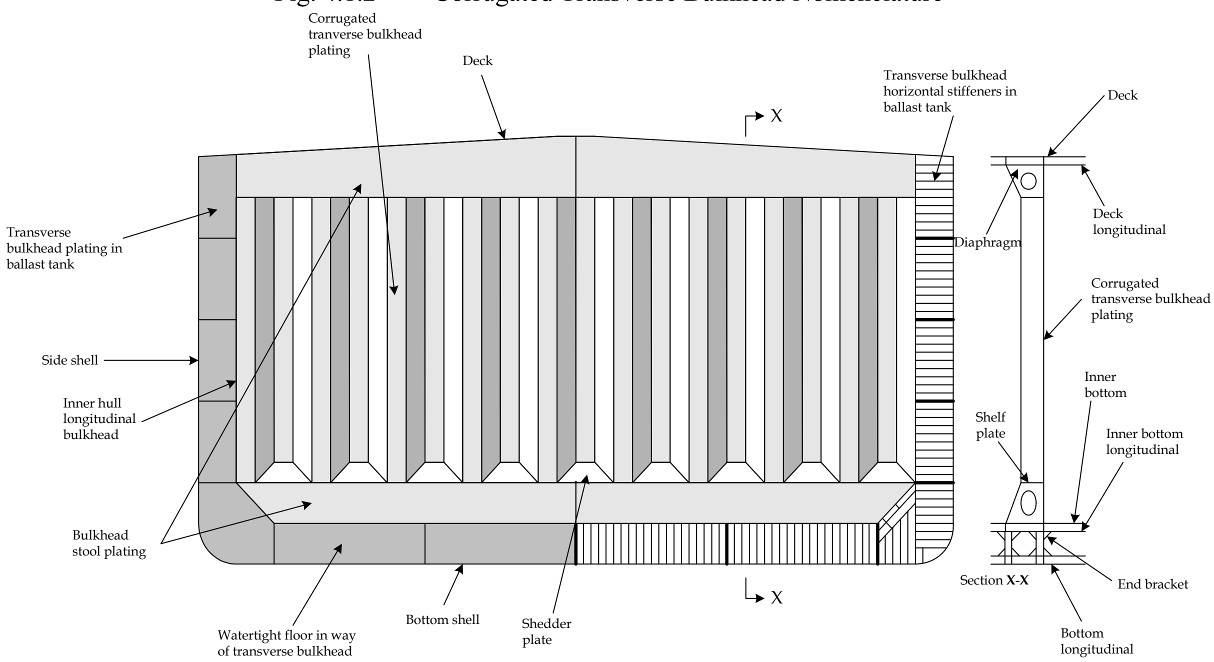


Fig. 4.1.3 Flat Transverse Bulkhead Nomenclature

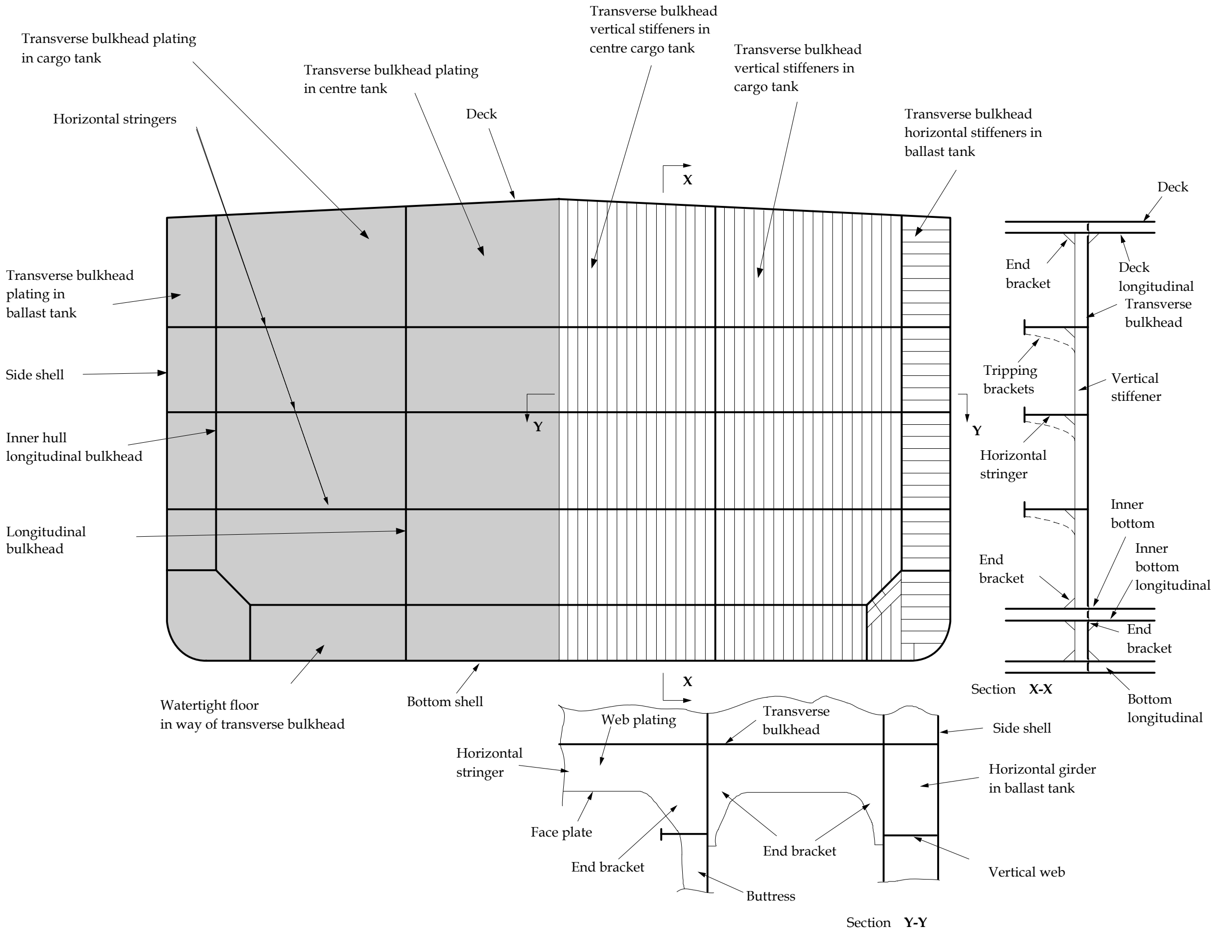
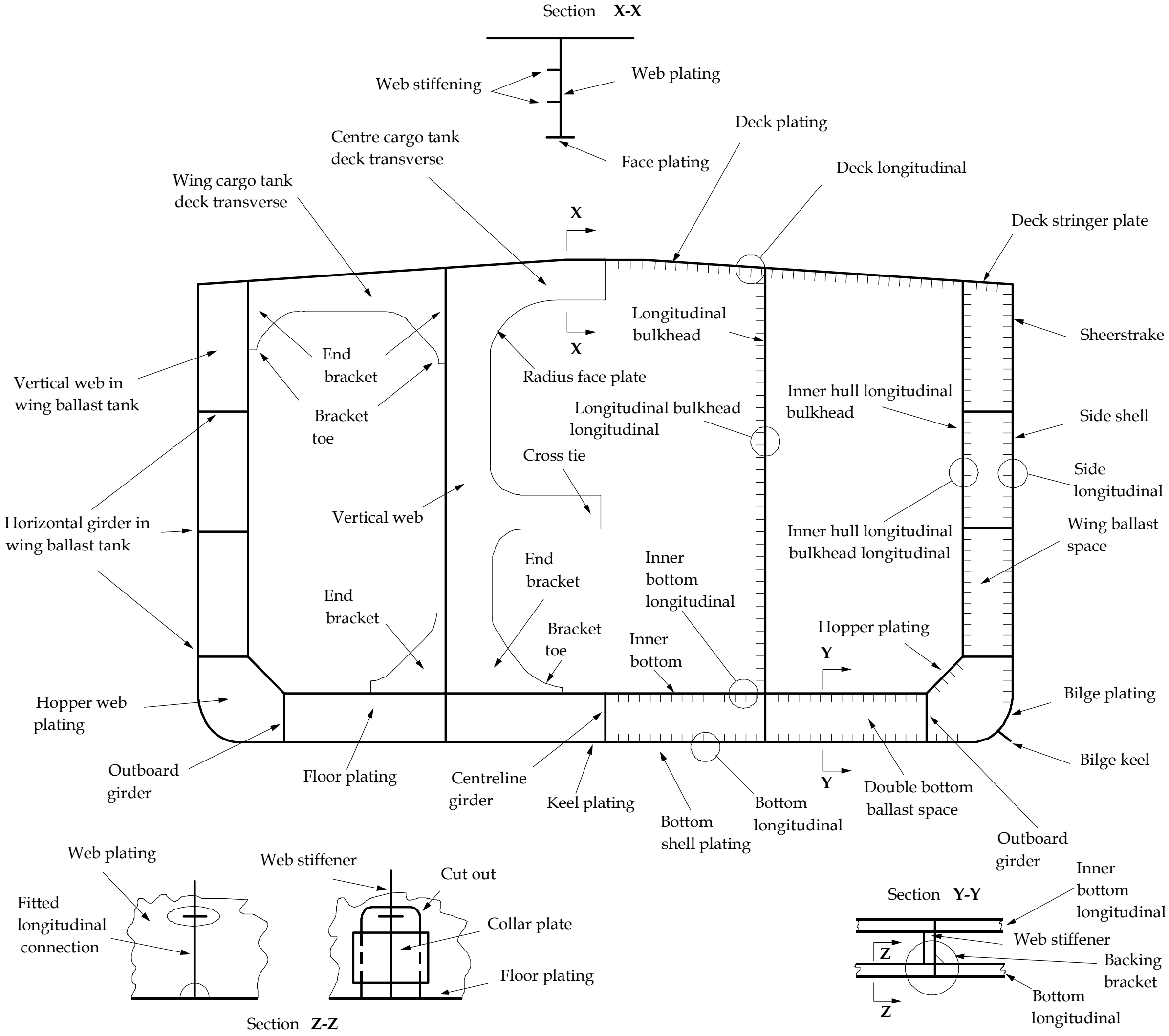


Fig. 4.1.4 Mid Cargo Hold Transverse Section



1.6 Symbols

1.6.1 General

1.6.1.1 The symbols and subscripts used within this Part are defined locally. The principal particulars, as defined in **1.1**, may be referred to within text without reference.

1.7 Units

1.7.1 General

1.7.1.1 The following units are used within this Part. The units to be used within equations are given locally.

(a) General:

• dimensions/distances	*m*
• primary spacings	*m*
• secondary spacings	*mm*
• area	m^2
• volume	m^3
• mass	*t*
• velocity	*m/s*
• acceleration	m/s^2

(b) Hull girder properties:

• dimensions	*m*

- area m^2
- section modulus m^3
- moment of inertia m^4
- moment of area m^3

(c) Stiffener properties:

- dimensions *mm*
- area cm^2
- section modulus cm^3
- inertia cm^4
- length/effective length *m*
- span *m*

(d) Plating dimensions:

- breadth *mm*
- length *m*
- thickness *mm*

(e) Loads:

- pressures kN/m^2
- loads *kN*
- bending moment *kNm*
- shear force *kN*

(f) Miscellaneous:

- yield strength N/mm^2
- stress N/mm^2
- deflections *mm*
- modulus of elasticity N/mm^2
- density t/m^3
- displacement *t*
- angle *deg*
- calculated angle *rad*
- period *s*
- frequency *Hz*
- ship speed *knots*

1.8 Glossary

1.8.1 Definitions of terms

1.8.1.1 The terms in **Table 4.1.1** are used within this Part to describe the items which their respective definitions describe.

Table 4.1.1 Definitions of Terms

Terms	Definition
Accommodation deck	A deck used primarily for the accommodation of the crew
Accommodation ladder	A portable set of steps on a ship's side for people boarding from small boats or from a pier
Aft peak	The area aft of the aft peak bulkhead
Aft peak bulkhead	The first main transverse watertight bulkhead forward of the stern
Aft peak tank	The compartment in the narrow part of the stern aft of the aft peak bulkhead
Anchor	a device which is attached to anchor chain at one end and lowered into the sea bed to hold a ship in position; it is designed to grip the bottom when it is dragged by the ship trying to float away under the influence of wind and current; usually made of heavy casting or casting
Ballast tank	A compartment used for the storage of water ballast
Bay	The area between adjacent transverse frames or transverse bulkheads
Bilge keel	A piece of plate set perpendicular to a ship's shell along the bilges to reduce the rolling motion
Bilge plating	The area of curved plating between the bottom shell and side shell. To be taken as follows: From the start of the curvature at the lower turn of bilge on the bottom to the lesser of, the end of curvature at the upper turn of the bilge on the side shell or $0.2D$ above the baseline/local centreline elevation
Bilge strake	The lower strake of bilge plating
Boss	The boss of propeller is the central part to which propeller blades are attached and through which the shaft end passes
Bottom shell	The shell envelope plating forming the predominantly flat bottom portion of the shell envelope including the keel plate
Bow	The structural arrangement and form of the forward end of the ship
Bower Anchor	An anchor carried at the bow of the ship
Bracket	An extra structural component used to increase the strength of a joint between two structural members
Bracket toe	The narrow end of a tapered bracket
Breakwater	Inclined and stiffened plate structure on a weather deck to break and deflect the flow of water coming over the bow
Breast hook	A triangular plate bracket joining port and starboard side structural members at the stem
Bridge	An elevated superstructure having a clear view forward and at each side, and from which a ship is steered
Bulb profile	A stiffener utilising an increase in steel mass on the outer end of the web instead of a separate flange
Bulkhead	A structural partition wall sub-dividing the interior of the ship into compartments
Bulkhead deck	The uppermost continuous deck to which transverse watertight bulkheads and shell are carried
Bulkhead stool	The lower or upper base of a corrugated bulkhead

Table 4.1.1 (Continued) Definitions of Terms

Terms	Definition
Bulkhead structure	The transverse or longitudinal bulkhead plating with stiffeners and girders
Bulwark	The vertical plating immediately above the upper edge of the ship's side surrounding the exposed deck(s)
Bunker	A compartment for the storage of fuel oil used by the ship's machinery
Cable	A rope or chain attached to the anchor
Camber	The upward rise of the weather deck from both sides towards the centreline of the ship
Cargo tank bulkhead	A boundary bulkhead separating cargo tanks
Cargo area	The part of the ship that contains cargo tanks and cargo/slop tanks and adjacent areas including ballast tanks, fuel tanks, cofferdams, void spaces and also including deck areas throughout the entire length and breadth of the part of the ship over the mentioned spaces. It includes the collision bulkhead and the transverse bulkhead at the aft end of the cargo block.
Carlings	A stiffening member used to supplement the regular stiffening arrangement
Casing	The covering or bulkhead around or about any space for protection
Cellular construction	A structural arrangement where there are two closely spaced boundaries and internal diaphragm plates arranged in such a manner to create small compartments
Centreline girder	A longitudinal member located on the centreline of the ship
Chain	Connected metal rings or links used for holding anchor, fastening timber cargoes, etc.
Chain locker	A compartment usually at the forward end of a ship which is used to store the anchor chain
Chain pipe	A section of pipe through which the anchor chain enters or leaves the chain locker
Chain stopper	A device for securing the chain cable when riding at anchor as well as securing the anchor in the housed position in the hawse pipe, thereby relieving the strain on the windlass
Coaming	The vertical boundary structure of a hatch or skylight
Cofferdams	The spaces between two bulkheads or decks primarily designed as a safeguard against leakage of oil from one compartment to another
Collar plate	A patch used to, partly or completely, close a hole cut for a longitudinal stiffener passing through a transverse web
Collision bulkhead	The foremost main transverse watertight bulkhead
Companionway	A weathertight entrance leading from a ship's deck to spaces below
Compartment	An internal space bounded by bulkheads or plating
Confined space	A space identified by one of the following characteristics: limited openings for entry and exit, unfavourable natural ventilation or not designed for continuous worker occupancy
Corrugated bulkhead	A bulkhead comprised of plating arranged in a corrugated fashion
Cross ties	Large transverse structural members joining longitudinal bulkheads and used to support them against hydrostatic and hydrodynamic loads
Deck	A horizontal structure element that defines the upper or lower boundary of a compartment
Deck house	A structure on the freeboard or superstructure deck not extending from side to side of the ship
Deck structure	The deck plating with stiffeners, girders and supporting pillars

Table 4.1.1 (Continued) Definitions of Terms

Terms	Definition
Deep tank	any tank which extends between two decks or the shell/inner bottom and the deck above or higher
Discharges	Any piping leading through the ship's sides for conveying bilge water, circulating water, drains etc.
Docking bracket	A bracket located in the double bottom to locally strengthen the bottom structure for the purposes of docking
Double bottom structure	The shell plating with stiffeners below the top of the inner bottom and other elements below and including the inner bottom plating
Doubler	Small piece of plate which is attached to a larger area of plate that requires strengthening in that location. Usually at the attachment point of a stiffener
Double skin member	Double skin member is defined as a structural member where the idealized beam comprises webs, with top and bottom flanges formed by attached plating
Duct keel	A keel built of plates in box form extending the length of the cargo tank. It is used to house ballast and other piping leading forward which otherwise would have to run through the cargo tanks
Enclosed superstructure	The superstructure with bulkheads forward and/or aft fitted with weather tight doors and closing appliances
Engine room bulkhead	A transverse bulkhead either directly forward or aft of the engine room
Face plate	The section of a stiffening member attached to the plate via a web and is usually parallel to the plated surface
Flange	The section of a stiffening member, typically attached to the web, but is sometimes formed by bending the web over. It is usually parallel to the plated surface
Flat bar	A stiffener comprising only of a web
Floor	A bottom transverse member
Forecastle	A short superstructure situated at the bow
Fore peak	The area of the ship forward of the collision bulkhead
Fore peak deck	A short raised deck extending aft from the bow of the ship
Freeboard deck	Generally the uppermost complete deck exposed to weather and sea, which has permanent means of closing all exposed openings
Freeing port	An opening in the bulwarks to allow water shipped on deck to run freely overboard
Gangway	The raised walkway between superstructure, such as between the forecastle and bridge, or between the bridge and poop
Girder	A collective term for primary supporting structural members
Gudgeon	A block with a hole in the centre to receive the pintle of a rudder; located on the stern post, it supports and allows the rudder to swing
Gunwale	The upper edge of the ship's sides
Gusset	A triangular plate, usually fitted to distribute forces at a strength connection between two structural members
Hatch ways	Openings, generally rectangular, in a ship's deck affording access into the compartment below
Hawse pipe	Steel pipe through which the hawser or cable of anchor passes, located in the ship's bow on either side of the stem, also known as spurling pipe
Hawser	Large steel wire or fibre rope used for towing or mooring
Hopper plating	Plating running the length of a compartment sloping between the tank top and inner side shell
HP	Holland Profile

Table 4.1.1 (Continued) Definitions of Terms

Terms	Definition
Independent tank	A self supporting tank
Inner hull	The innermost plating forming a second layer to the hull of the ship
Intercostal	Longitudinal member between the floors or frames of a ship; it is non-continuous
JIS	Japanese industrial standard profile
Keel	The main structural member or backbone of a ship running longitudinal along centreline of bottom. Usually a flat plate stiffened by a vertical plate on its centreline inside the shell
Knuckle	A discontinuity in a structural member
Lightening hole	A hole cut in a structural member to reduce its weight
Limber hole	A small drain hole cut in a frame or plate to prevent water or oil from collecting
Local support members	Local support members are defined as local stiffening members which only influence the structural integrity of a single panel, e.g. deck beams
Longitudinal centreline bulkhead	A longitudinal bulkhead located on the centreline of the ship
Longitudinal hull girder structural members	Structural members that contribute to the longitudinal strength of the hull girder, including: deck, side, bottom, inner bottom, inner hull longitudinal bulkheads including upper sloped plating where fitted, hopper, bilge plate, longitudinal bulkheads, double bottom girders and horizontal girders in wing ballast tanks
Longitudinal hull girder shear structural members	Structural members that contribute to strength against hull girder vertical shear loads, including: side, inner hull longitudinal bulkheads, hopper, longitudinal bulkheads and double bottom girders
Manhole	A round or oval hole cut in decks, tanks, etc., for the purpose of providing access
Margin plate	The outboard strake of the inner bottom and when turned down at the bilge the margin plate (or girder) forms the outer boundary of the double bottom
Notch	A discontinuity in a structural member caused by welding
Oil fuel tank	A tank used for the storage of fuel oil
Pillar	A vertical support placed between decks where the deck is unsupported by the shell or bulkhead
Pintle	Vertical pin on a rudder's forward edge that enables the rudder to hang onto the stern post and swing when it fits into the gudgeon
Pipe tunnel	The void space running in the midships fore and aft lines between the inner bottom and shell plating forming a protective space for bilge, ballast and other lines extending from the engine room to the tanks
Poop	The space below an enclosed superstructure at the extreme aft end of a ship
Poop deck	The first deck above the shelter deck at the aft end of a ship
Primary support members	Members of the beam, girder or stringer type which ensure the overall structural integrity of the hull envelope and tank boundaries, e.g. double bottom floors and girders, transverse side structure, deck transverses, bulkhead stringers and vertical webs on longitudinal bulkheads
Rudder	A device, usually of an aerofoil or flat section, that is used to steer a ship. A common type has a vertical fin at the stern and is able to move from 35 *degrees* port to 35 *degrees* starboard; rudders are characterised by their area, aspect ratio, and shape

Table 4.1.1 (Continued) Definitions of Terms

Terms	Definition
Scallop	A hole cut into a stiffening member to allow continuous welding of a plate seam
Scarfing bracket	A bracket used between two offset structural items
Scantlings	The physical dimensions of a structural item
Scupper	Any opening for carrying off water from a deck, either directly or through piping
Scuttle	A small opening in a deck or elsewhere, usually fitted with a cover or lid or a door for access to a compartment
Shedder plates	Slanted plates that are fitted to minimise pocketing of residual cargo in way of corrugated bulkheads
Sheer strake	The top strake of a ship's side shell plating
Shelf plate	A horizontal plate located on the top of a bulkhead stool
Shell envelope plating	The shell plating forming the effective hull girder
Side shell	The shell envelope plating forming the side portion of the shell envelope above the bilge plating
Single skin member	Single skin member is defined as a structural member where the idealized beam comprises a web, with a top flange formed by attached plating and a bottom flange formed by a face plate
Skylight	A deck opening fitted with or without a glass port light and serving as a ventilator for engine room, quarters, etc.
Slop tank	A tank in an oil tanker which is used to collect the oil and water mixtures from cargo tanks after tank washing
Spaces	Separate compartments including tanks
Stay	Bulwark and hatch coaming brackets
Stem	The piece of bar or plating at which a ship's outside plating terminates at forward end
Stern frame	The heavy strength member in single or triple screw ships, combining the rudder post
Stern tube	A tube through which the shaft passes to the propeller; and acts as an after bearings for the shafting and may be water or oil lubricated
Stiffener	A collective term for secondary supporting structural members
Stool	A structure supporting tank bulkheads
Strake	A course, or row, of shell, deck, bulkhead, or other plating
Strength deck	The uppermost continuous deck
Stringer	Horizontal girders linking vertical web frames
Stringer plate	The outside strake of deck plating
Superstructure	A decked structure on the freeboard deck extending for at least 92% of the breadth of the ship
Tank top	The horizontal plating forming the bottom of a cargo tank
Towing pennant	A long rope which is used to effect the tow of a ship
Transom	The structural arrangement and form of the aft end of the ship
Transverse ring	All transverse material appearing in a cross-section of the ship's hull, in way of a double bottom floor, vertical web and deck transverse girder
Transverse web frame	The primary transverse girders which join the ships longitudinal structure
Tripping bracket	A bracket used to strengthen a structural member under compression, against torsional forces
'Tween deck	An abbreviation of between decks, placed between the upper deck and the tank top in the cargo tanks

Table 4.1.1 (Continued) Definitions of Terms

Terms	Definition
Ullage	The quantity represented by the unoccupied space in a tank
Void	An enclosed empty space in a ship
Wash bulkhead	A perforated or partial bulkhead in a tank
Watertight	Watertight means capable of preventing the passage of water through the structure under a head of water for which the surrounding structure is designed
Weather deck	A deck or section of deck exposed to the elements which has means of closing weathertight, all hatches and openings
Weathertight	Weathertight means that in any sea conditions water will not penetrate into the ship
Web	The section of a stiffening member attached perpendicular to the plated surface
Wind and water strakes	The strakes of a ship's side shell plating between the ballast and the deepest load waterline
Windlass	A machine for lifting and lowering the anchor chain
Wing tank	The space bounded by the inner hull longitudinal bulkhead and side shell

2. Structural Idealisation

2.1 Definition of Span

2.1.1 Effective bending span of local support members

2.1.1.1 The effective bending span, l_{bdg}, of a stiffener is defined for typical arrangements in **2.1.1.3** to **2.1.1.7**. Where arrangements differ from those shown in **Fig. 4.2.1** through **Fig. 4.2.8**, span definition may be specially considered.

2.1.1.2 The effective bending span may be reduced due to the presence of brackets, provided the brackets are effectively supported by the adjacent structure, otherwise the effective bending span is to be taken as the full length of the stiffener between primary member supports.

2.1.1.3 If the web stiffener is sniped at the end or not attached to the stiffener under consideration, the effective bending span is to be taken as the full length between primary member supports unless a backing bracket is fitted, see **Fig. 4.2.2**.

2.1.1.4 The effective bending span may only be reduced where brackets are fitted to the flange or free edge of the stiffener. Brackets fitted to the attached plating on the side opposite to that of the stiffener are not to be considered as effective in reducing the effective bending span.

2.1.1.5 The effective bending span, l_{bdg}, for stiffeners forming part of a double skin arrangement is to be taken as shown in **Fig. 4.2.1**.

2.1.1.6 The effective bending span, l_{bdg}, for stiffeners forming part of a single skin arrangement is to be taken as shown in **Fig. 4.2.2**.

2.1.1.7 For stiffeners supported by a bracket on one side of primary support members, the effective bending span is to be taken as the full distance between primary support members as shown in **Fig. 4.2.2(a)**. If brackets are fitted on both sides of the primary support member, the effective bending span is to be taken as in **Fig. 4.2.2(b)**, **(c)** and **(d)**.

Fig. 4.2.1 Effective Bending Span of Stiffeners Supported by Web Stiffeners (Double Skin Construction)

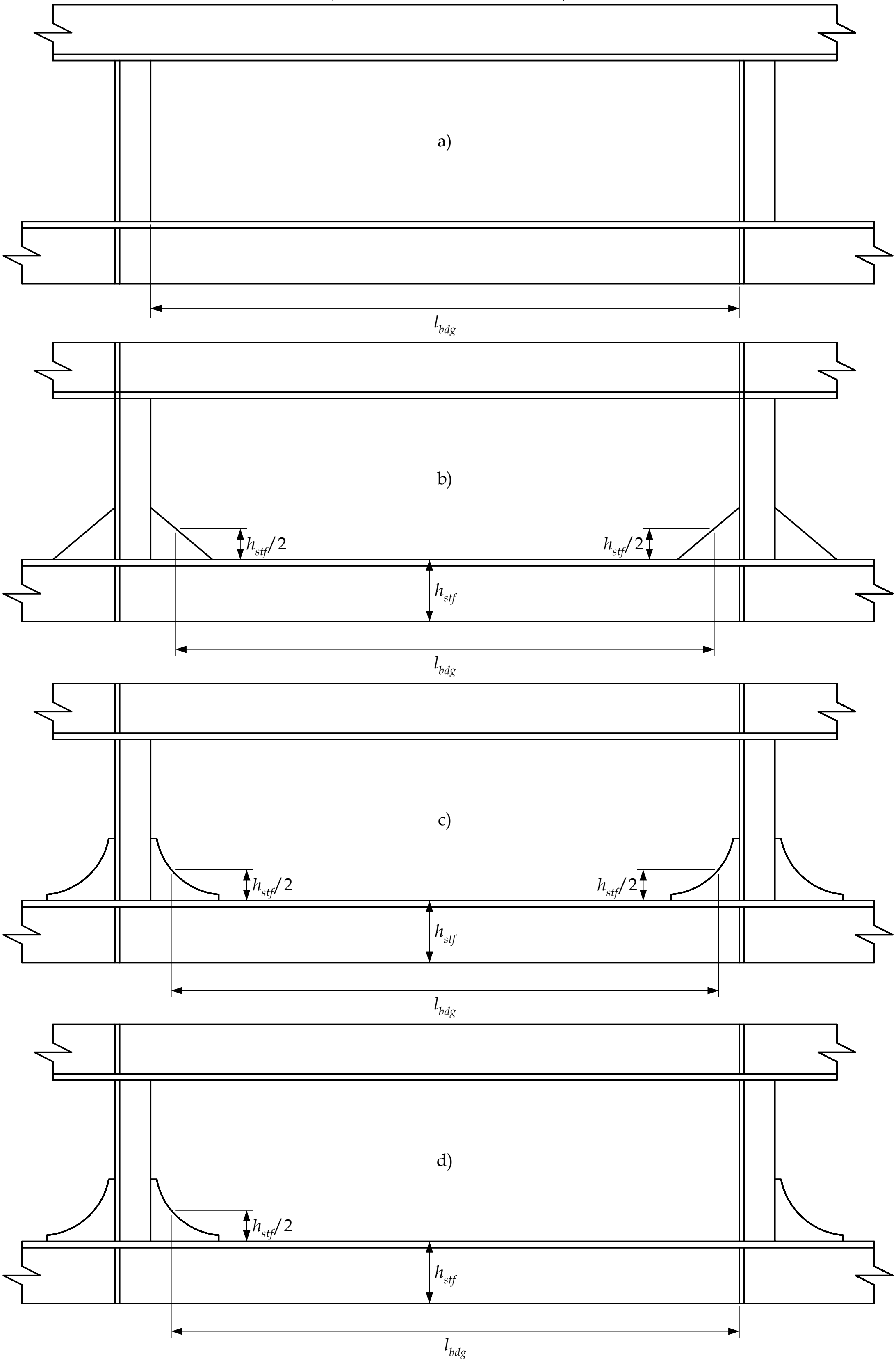
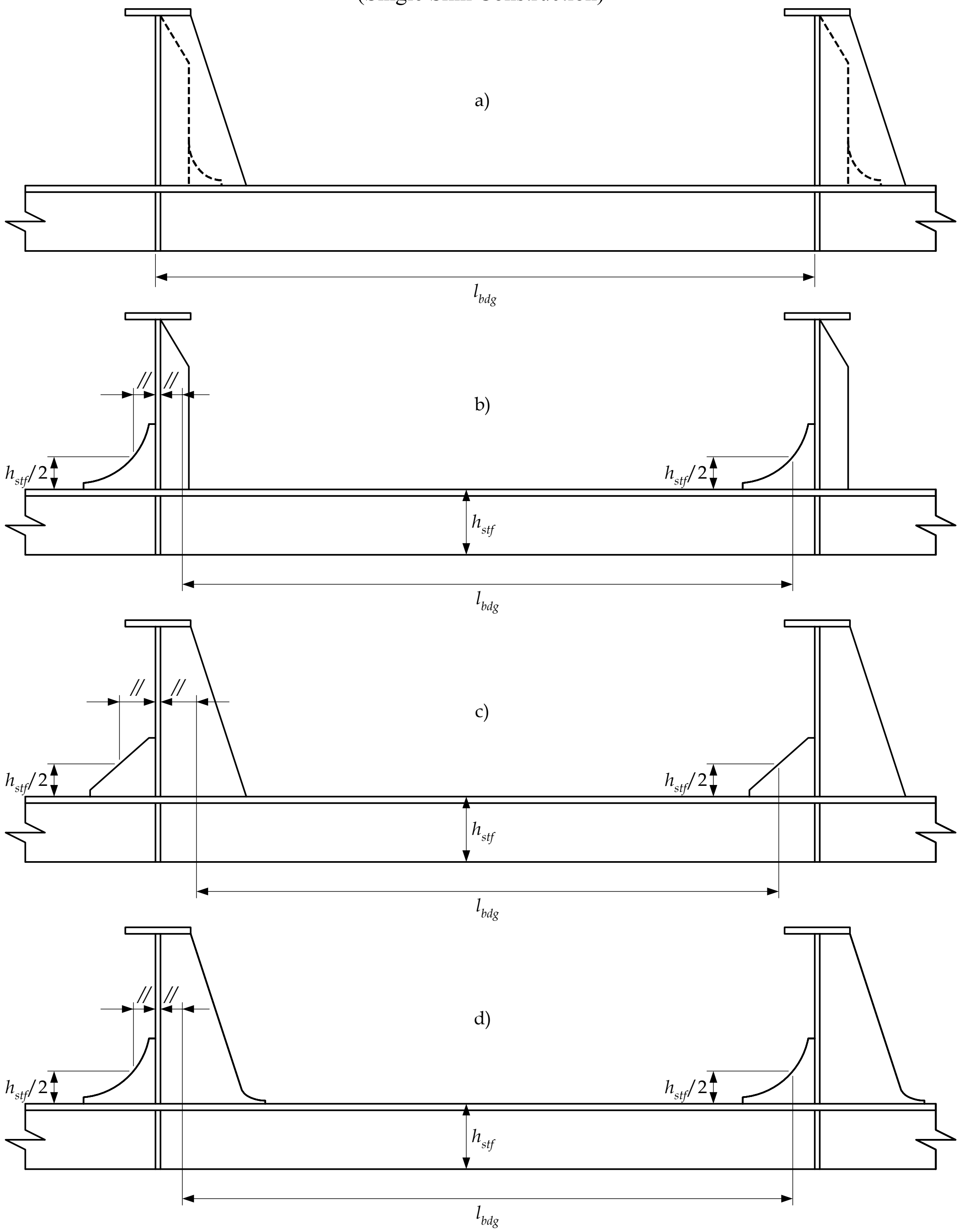
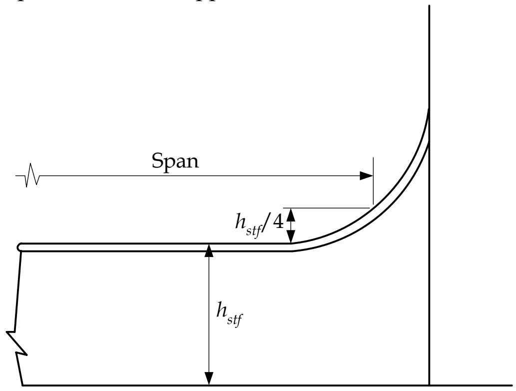


Fig. 4.2.2 Effective Bending Span of Stiffeners Supported by Web Stiffeners (Single Skin Construction)



2.1.1.8 Where the face plate of the stiffener is continuous along the edge of the bracket, the effective bending span is to be taken to the position where the depth of the bracket is equal to one quarter of the depth of the stiffener, see **Fig. 4.2.3**.

Fig. 4.2.3 Effective Bending Span for Local Support Members with Continuous Face Plate along Bracket Edge



2.1.1.9 For the calculation of the span point, the bracket length is not to be taken greater than 1.5 times the length of the arm on the bulkhead or base.

2.1.2 Effective shear span of local support members

2.1.2.1 The effective shear span, l_{shr}, of a stiffener is defined for typical arrangements in **2.1.2.5** to **2.1.2.7**. Effective bending span for other arrangements will be specially considered.

2.1.2.2 The effective shear span may be reduced due to the presence of brackets provided the brackets are effectively supported by the adjacent structure, otherwise the effective shear span is to be as the full length as given in **2.1.2.4**.

2.1.2.3 The effective shear span may be reduced for brackets fitted on either the flange or the free edge of the stiffener, or for brackets fitted to the attached plating on the side opposite to that of the stiffener. If brackets are fitted at both the flange or free edge of the stiffener, and to the attached plating on the side opposite to that of the stiffener the effective shear span may be calculated using the longer effective bracket arm.

2.1.2.4 The effective shear span may be reduced by a minimum of s/4000 m at each end of the member, regardless of support detail, hence the effective shear span, l_{shr}, is not to be taken greater than:

$$l_{shr} \le l - \frac{s}{2000} \quad m$$

Where:

l : full length of the stiffener between primary support members, in m

s : stiffener spacing, in mm, as defined in **2.2.1**

2.1.2.5 The effective shear span, l_{shr}, for stiffeners forming part of a double skin arrangement is to be taken as shown in **Fig. 4.2.4**.

2.1.2.6 The effective shear span, l_{shr}, for stiffeners forming part of a single skin arrangement is to be taken as shown in **Fig. 4.2.5**.

Fig. 4.2.4 Effective Shear Span of Stiffeners Supported by Web Stiffeners (Double Skin Construction)

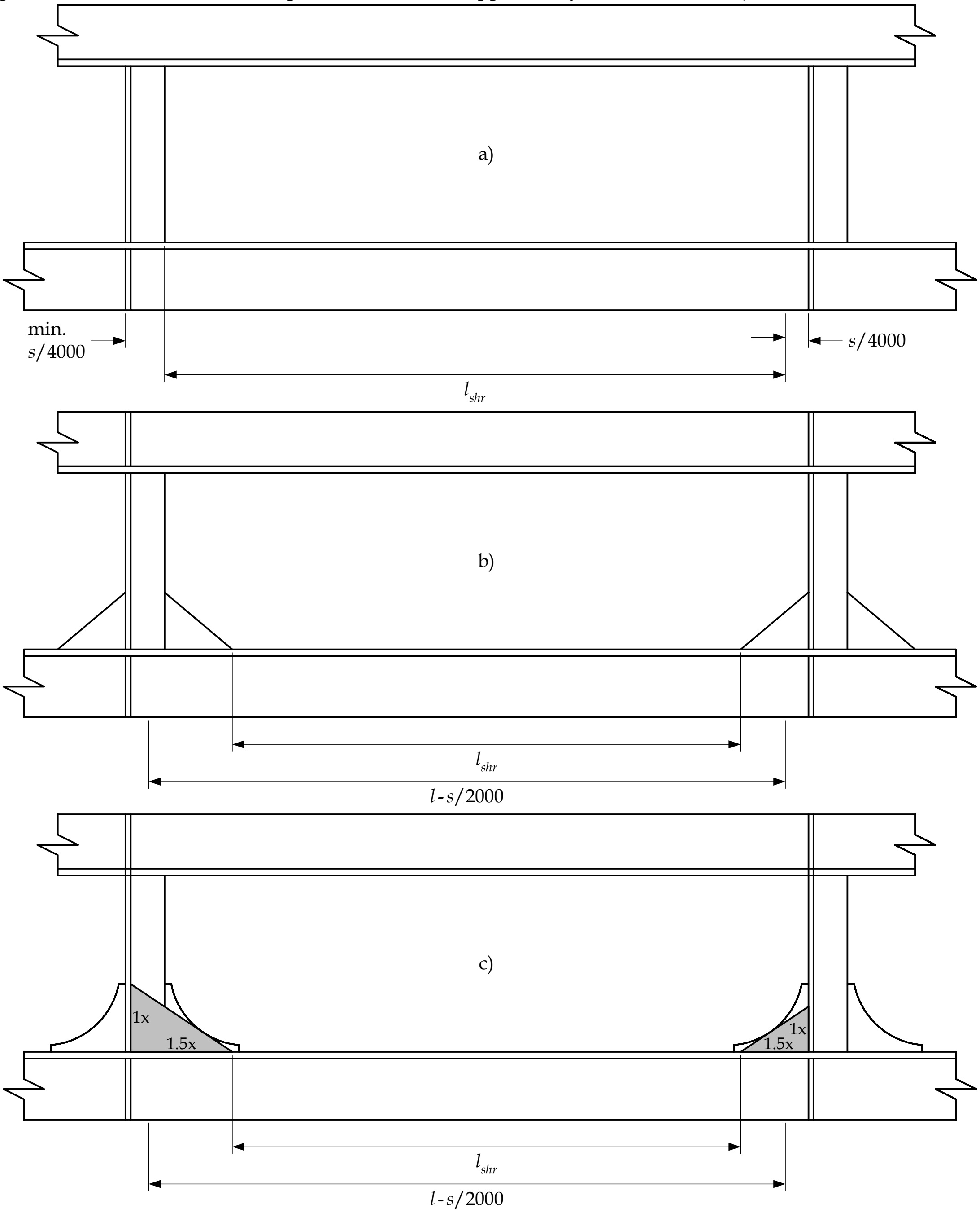


Fig. 4.2.5 Effective Shear Span of Stiffeners Supported by Web Stiffeners (Single Skin Construction)

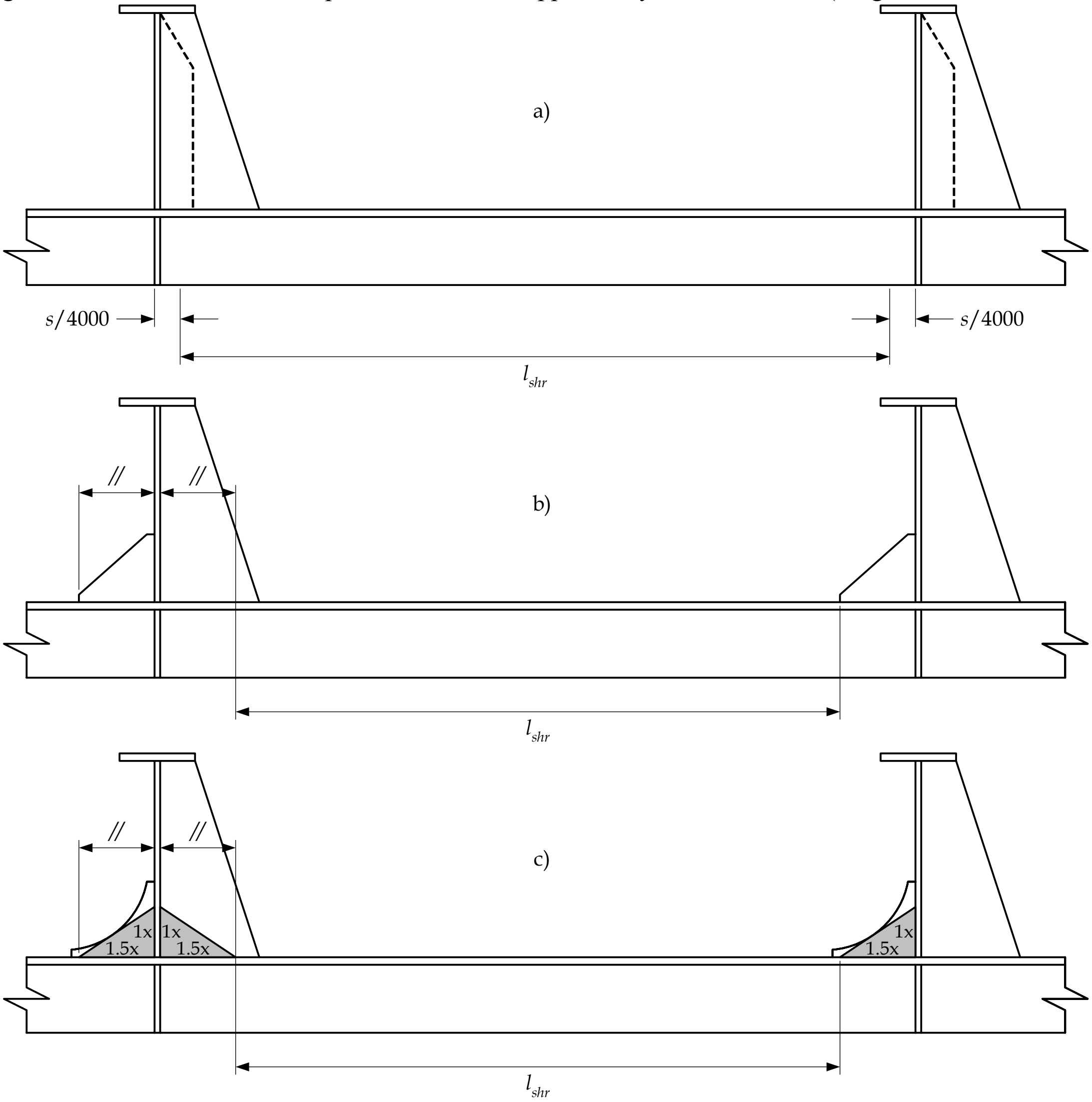
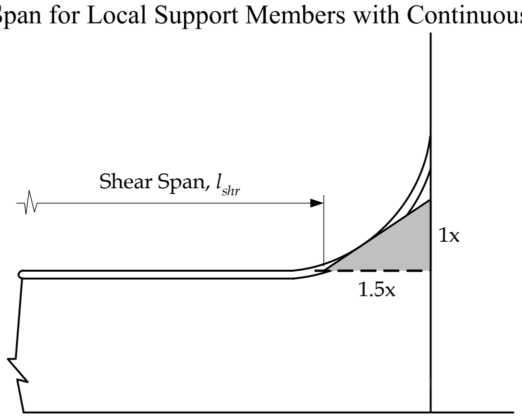


Fig. 4.2.6 Effective Shear Span for Local Support Members with Continuous Face Plate along Bracket Edge



2.1.2.7 Where the face plate of the stiffener is continuous along the curved edge of the bracket, the effective shear span is to be taken as shown in **Fig. 4.2.6**.

2.1.2.8 For curved and/or long brackets (high length/height ratio) the effective bracket length is to be taken as the maximum inscribed 1:1.5 bracket as shown in **Fig. 4.2.4(c)** and **Fig. 4.2.5(c)**.

2.1.3 Effect of hull form shape on span of local support members

2.1.3.1 The full length of the stiffener between primary support members, l, is to be measured along the flange for stiffeners with a flange, and along the free edge for flat bar stiffeners. For curved stiffeners the span is defined as the chord length between span points. The calculation of the effective span is to be in accordance with requirements given in **2.1.1**.

2.1.4 Effective bending span of primary support members

2.1.4.1 The effective bending span, l_{bdg}, of a primary support member may be taken as less than the full length of the member between supports provided that suitable end brackets are fitted.

2.1.4.2 For arrangements where the primary support member face plate is not carried continuously around the edge of the bracket, i.e. the bracket is welded to the primary support member, the span point at each end of the member, between which the effective bending span is measured, is to be taken at the point where the depth of end bracket measured from the face of the member is equal to one half the depth of the member, as shown in **Fig. 4.2.7(b)**. The effective bracket used to define the span point is to be taken as given in **2.1.4.4**.

2.1.4.3 For brackets where the face plate of the primary support member is continuous along the face of the bracket, i.e. the bracket is integral part of the primary support member, the span point is to be taken at the position where the depth of the bracket is equal to one quarter the depth of the member, see **Fig. 4.2.7(a)**, **(c)** and **(d)**. The effective bracket used to define the span point is to be taken as given in **2.1.4.4**.

2.1.4.4 The effective bracket is defined as the maximum size of triangular bracket with a length to height ratio of 1.5 that just fits inside the as fitted bracket, for curved brackets the tangent point is to be used to define the fit, see **Fig. 4.2.7** for examples.

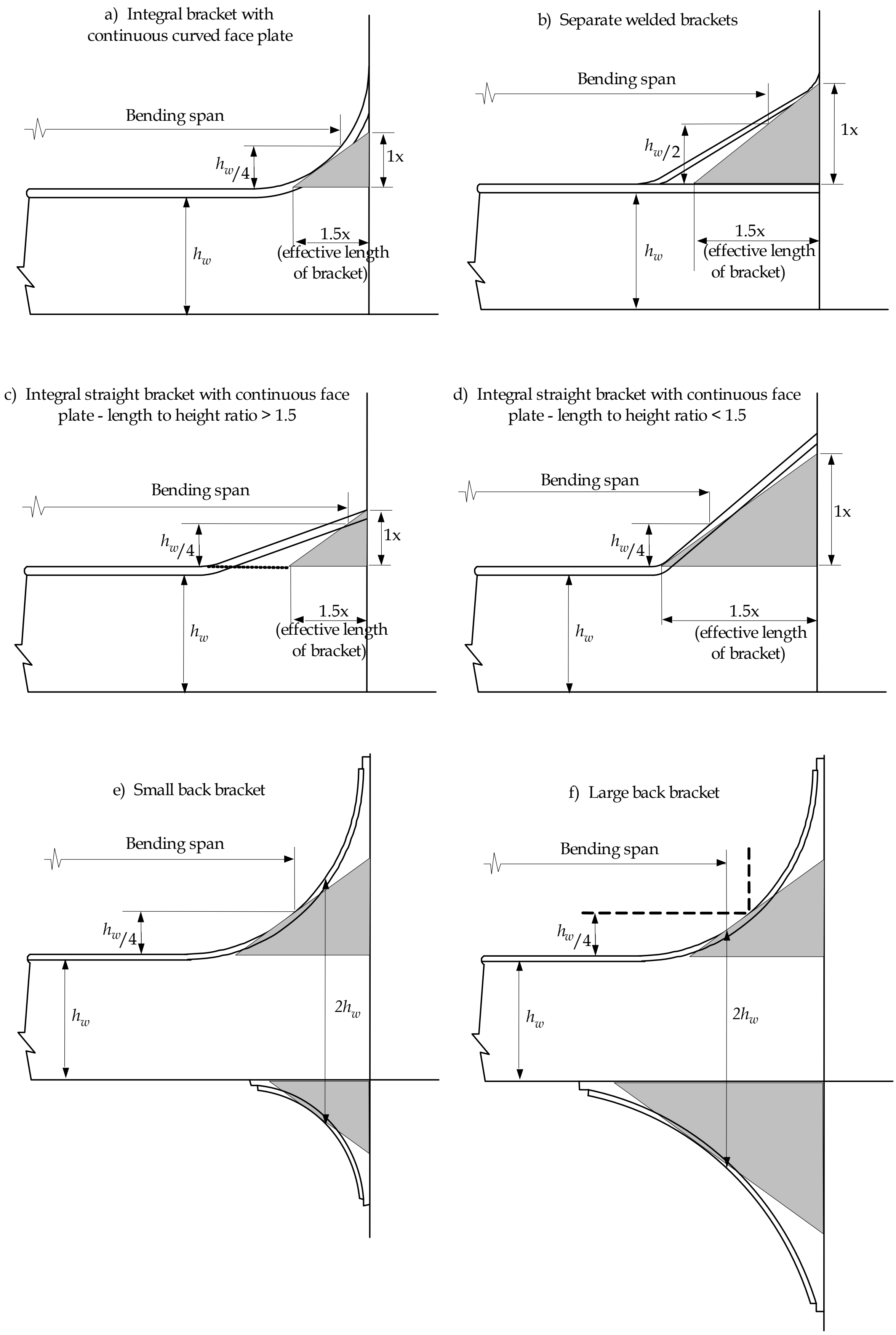
2.1.4.5 For straight brackets with a length to height ratio greater than 1.5, the span point is to be taken to the effective bracket; for steeper brackets the span point is to be taken to the as fitted bracket.

2.1.4.6 For curved brackets the span point is to be measured taken to the fitted bracket at span positions above the tangent point between fitted bracket and effective bracket. For span positions below the tangent point the span point is to be measured to the effective bracket.

2.1.4.7 For arrangements where the primary support member face plate is carried on to the bracket and backing brackets are fitted the span point need not be taken greater than to the position where the total depth reaches twice the depth of the primary support member. Arrangements with small and large backing brackets are shown in **Fig. 4.2.7(e)** and **(f)**.

2.1.4.8 For arrangements where the height of the primary support member is maintained and the face plate width is increased towards the support the effective bending span may be taken to a position where the face plate breadth reaches twice the nominal breadth.

Fig. 4.2.7 Effective Span of Primary Support Member for Bending Assessment

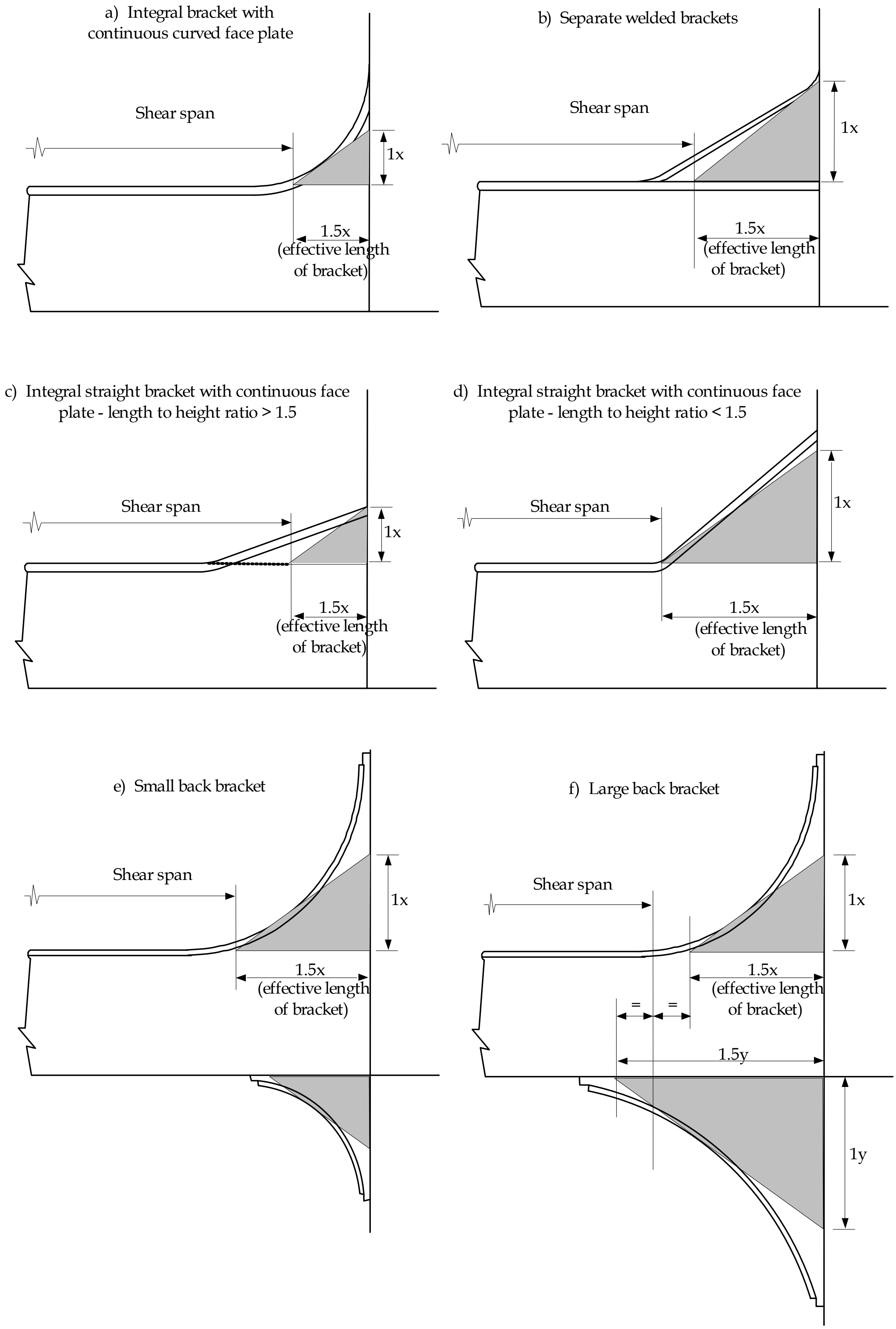


2.1.5 Effective shear span of primary support members

2.1.5.1 The span point at each end of the primary support member, between which the shear span is measured, is to be taken at the toe of the effective brackets supporting the member, where the toes of effective brackets are as shown in **Fig. 4.2.8**. The effective bracket used to define the toe point is given in **2.1.4.4**.

2.1.5.2 For arrangements where the effective backing bracket is larger than the effective bracket in way of face plate, the shear span is to be taken as the mean distance between toes of the effective brackets as shown in **Fig. 4.2.8 (f)**.

Fig. 4.2.8 Effective Span of Primary Support Member for Shear Assessment



2.2 Definition of Spacing and Supported Breadth

2.2.1 Supported load breadth of local support members

2.2.1.1 The mean of the stiffener spacings on each side is to be used for the calculation of the effective plate flange of stiffeners and the load breadth supported by a stiffener, *s*, see **Fig. 4.2.9**.

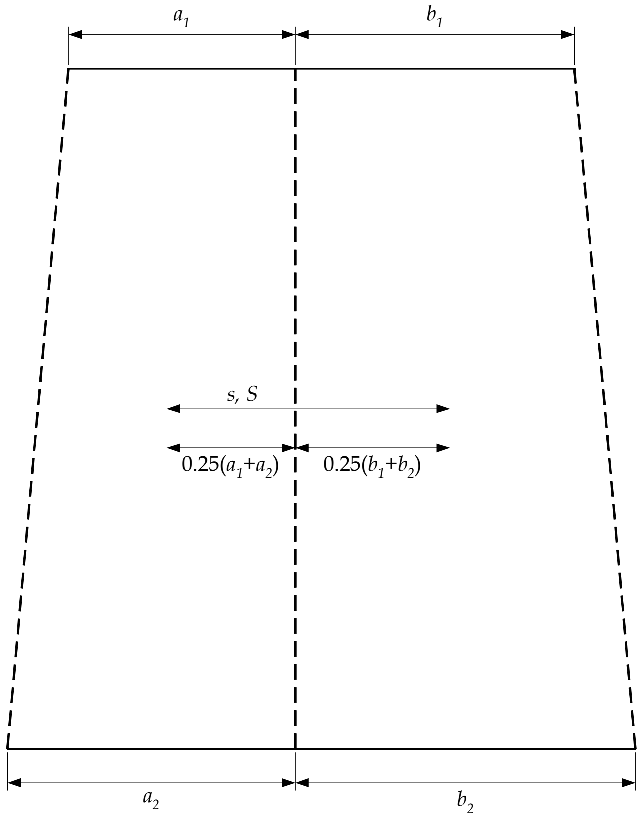
2.2.2 Spacing and supporting load breadth of primary support members

2.2.2.1 Primary support member spacing, *S*, for the calculation of the effective plate flange of primary support members is to be taken as the mean spacing between adjacent primary support members, as shown in **Fig. 4.2.9**.
2.2.2.2 Unless specifically defined elsewhere in the Rules, the loading breadth supported by a girder is defined as half the sum of the primary member spacing on each side, see **Fig. 4.2.9**.

2.2.3 Effective spacing of curved plating

2.2.3.1 For curved plating the stiffener spacing, *s* or *S*, is to be measured on the mean chord between members.

Fig. 4.2.9 Supported Load Breadth and Breadth of Attached Plating for Local and Primary Support Members



Note

1. The mean breadth is to be taken as 0.25 ($a_1 + a_2 + b_1 + b_2$), where a_1, a_2, b_1, b_2 are the spacings between local and primary support members at ends as appropriate.

2.3 Effective Breadth of Plating

2.3.1 Effective breadth of attached plate of local support members for strength evaluation

2.3.1.1 The effective breadth as defined in **2.3.1.2** is applicable to the scantling requirements of stiffeners as given in **Section 8**.
2.3.1.2 The effective breadth of the attached plate, b_{eff}, to be used for calculating the combined section modulus of the stiffener and attached plate is to be taken as the mean stiffener spacing, *s*, as given in **2.2.1**. However, where the attached plate net thickness, $t_{p\text{-}net}$, is less than 8*mm*, the effective breadth is not to be taken greater than 600*mm*.

2.3.2 Effective breadth of attached plate and flanges of primary support members for strength evaluation

2.3.2.1 The effective breadths as defined in **2.3.2.2** to **2.3.2.4** are applicable to the scantling requirements of primary support members as given in **Section 8**.

2.3.2.2 At the end of the span where no effective end bracket is fitted, the effective breadth of attached plate, b_{eff}, for calculating the section modulus of a primary support member is to be taken as:

$$b_{eff} = 0.67\,S\sin\left[\frac{\pi}{6}\left(\frac{l_{bdg}(1-\frac{1}{\sqrt{3}})}{2S}\right)\right] \quad (m) \qquad \text{for } \left(\frac{l_{bdg}(1-\frac{1}{\sqrt{3}})}{2S}\right)\leq 3$$

$$b_{eff} = 0.67S \quad (m) \qquad \text{for } \left(\frac{l_{bdg}(1-\frac{1}{\sqrt{3}})}{2S}\right)>3$$

Where:

S : mean spacing of primary support member as defined in **2.2.2** at position considered, in *m*

l_{bdg} : effective bending span, as defined in **2.1.4***,* in *m*

Note : sin() is to be calculated in *radians*

2.3.2.3 At mid span, the effective breadth of attached plate, b_{eff}, for calculating the section modulus of a primary support member is to be taken as:

$$b_{eff} = S\,\sin\left[\frac{\pi}{6}\left(\frac{l_{bdg}}{S\sqrt{3}}\right)\right] \quad (m) \qquad \text{for } \left(\frac{l_{bdg}}{S\sqrt{3}}\right)\leq 9$$

$$b_{eff} = 1.0S \quad (m) \qquad \text{for } \left(\frac{l_{bdg}}{S\sqrt{3}}\right)>9$$

Where:

S : mean spacing of primary support member as defined in **2.2.2** at position considered, in *m*

l_{bdg} : effective bending span, as defined in **2.1.4***,* in *m*

Note : sin() is to be calculated in *radians*

2.3.2.4 At the end of the span where an effective end bracket is fitted, the effective breadth of attached plate, b_{eff}, for calculating the section modulus of a primary support member is to be taken as the mean values of those given by **2.3.2.2** and **2.3.2.3**. A bracket is considered effective when the length as defined in **Fig. 4.2.7** is equal or greater than $0.1l_{bdg}$.

2.3.2.5 The free flange of primary support members of single skin construction may generally be considered fully effective provided tripping bracket arrangements are fitted as required in **Section 10/2.3.3**. For curved face plates see **2.3.4**.

2.3.3 Effective breadth of attached plate of local support members for fatigue strength evaluation

2.3.3.1 The effective breadths as defined in **2.3.3.2** and **2.3.3.3** are applicable to the fatigue strength evaluation of local support members as given in **Section 9/3** and **Appendix C**.

2.3.3.2 At the ends of the span and in way of end brackets and supports, the effective breadth of attached plating, $b_{eff,}$ to be used for calculating the combined section modulus of the stiffener and attached plate is to be taken as:

$$b_{eff} = 0.67\ s\ \sin\left[\frac{\pi}{6}\left(\frac{1000l_{bdg}(1-\frac{1}{\sqrt{3}})}{2s}\right)\right] \quad (mm) \qquad \text{for } \left(\frac{1000l_{bdg}(1-\frac{1}{\sqrt{3}})}{2s}\right)\leq 3$$

$$b_{eff} = 0.67s \quad (mm) \qquad \text{for } \left(\frac{1000l_{bdg}(1-\frac{1}{\sqrt{3}})}{2s}\right)>3$$

Where:

s : stiffener spacing, in *mm*, as defined in **2.2.1**

l_{bdg} : effective bending span, as defined in **2.1.1**, in *m*

Note : sin() is to be calculated in *radians*

2.3.3.3 At mid span, the effective breadth of attached plate, b_{eff}, to be used for calculating the combined section modulus of the stiffener and attached plate is to be taken as:

$$b_{eff} = s \sin\left[\frac{\pi}{6}\left(\frac{1000 l_{bdg}}{s\sqrt{3}}\right)\right] \quad (mm) \qquad \text{for } \left(\frac{1000 l_{bdg}}{s\sqrt{3}}\right) \le 9$$

$$b_{eff} = 1.0\, s \quad (mm) \qquad \text{for } \left(\frac{1000 l_{bdg}}{s\sqrt{3}}\right) > 9$$

Where:

s : stiffener spacing, in *mm*, as defined in **2.2.1**

l_{bdg} : effective bending span, as defined in **2.1.1**, in *m*

Note : sin() is to be calculated in *radians*

2.3.4 Effective area of curved face plates or attached plating of primary support members

2.3.4.1 The effective area as defined in **2.3.4.2** and **2.3.4.3** is applicable to primary support members as follows:

(a) deriving the effective net area of curved face plates and curved attached plating for calculating the section modulus of primary support members for the scantling requirements in **Section 8**

(b) deriving the effective net area of curved face plates, modelled by beam elements, for the strength assessment (FEM) in **Section 9/2** and **Appendix B**

2.3.4.2 The effective net area of curved face plates or attached plating of primary support members, $A_{eff\text{-}net50}$, is to be taken as:

$$A_{eff\text{-}net50} = C_f\, t_{f\text{-}net50}\, b_f \quad (mm^2)$$

Where:

C_f : flange efficiency coefficient as shown in **Fig. 4.2.10**

$= C_{f1} \dfrac{\sqrt{r_f\, t_{f-net50}}}{b_1}$ but not to be taken greater than 1.0

C_{f1} $= \dfrac{0.643\,(\sinh\beta \cosh\beta + \sin\beta\, \cos\beta)}{\sinh^2\beta + \sin^2\beta}$ for symmetrical and unsymmetrical face plates, see *Curve 1* in **Fig. 4.2.10**

$= \dfrac{0.78\,(\sinh\beta + \sin\beta)(\cosh\beta - \cos\beta)}{\sinh^2\beta + \sin^2\beta}$ for attached plating of box girders with two webs, see *Curve 2* in **Fig. 4.2.10**

$= \dfrac{1.56\,(\cosh\beta - \cos\beta)}{\sinh\beta + \sin\beta}$ for attached plating of box girders with multiple webs, see *Curve 3* in **Fig. 4.2.10**

β $\dfrac{1.285\, b_1}{\sqrt{r_f\, t_{f-net50}}}$ (*rad*)

b_1 $= 0.5\,(b_f - t_{w\text{-}net50})$ for symmetrical face plates

$= b_f$ for unsymmetrical face plates

$= s_w - t_{w\text{-}net50}$ for attached plating of box girders

s_w : spacing of supporting webs for box girders, in *mm*

$t_{f\text{-}net50}$: net flange thickness

$= t_{f\text{-}grs} - 0.5 t_{corr}$ *mm*

for calculation of C_f and β for unsymmetrical face plates $t_{f\text{-}net50}$ is not to be taken greater than $t_{w\text{-}net50}$

$t_{f\text{-}grs}$: gross flange thickness, in *mm*

$t_{w\text{-}net50}$: net web plate thickness

$= t_{w\text{-}grs} - 0.5 t_{corr}$ (mm)

$t_{w\text{-}grs}$: gross web thickness, in *mm*

t_{corr} : corrosion addition, as given in **Section 6/3.2**

r_f : radius of curved face plate or attached plating, in *mm*

b_f : breadth of face plate or attached plating, in *mm*

2.3.4.3 The effective net area of curved face plates supported by radial brackets, or attached plating supported by cylindrical stiffeners, $A_{eff\text{-}net50}$, is given by:

$$A_{eff-net50} = \left(\frac{3r_f\, t_{f-net50} + C_f\, s_r^2}{3r_f\, t_{f-net50} + s_r^2} \right) t_{f-net50}\; b_f \qquad (mm^2)$$

Where:

C_f : as defined in **2.3.4.2**

$t_{f\text{-}net50}$: net flange thickness, as defined in **2.3.4.2**

s_r : spacing of tripping brackets or web stiffeners or stiffeners normal to the web plating, in *mm*, see **Fig. 4.2.11**

b_f : breadth of face plate or attached plating, in *mm*, see **Fig. 4.2.11**

r_f : radius of curved face plate or attached plating, in *mm*, see **Fig. 4.2.11**

Fig. 4.2.10 Effective Width of Curved Face Plates for Alternative Structural Configurations

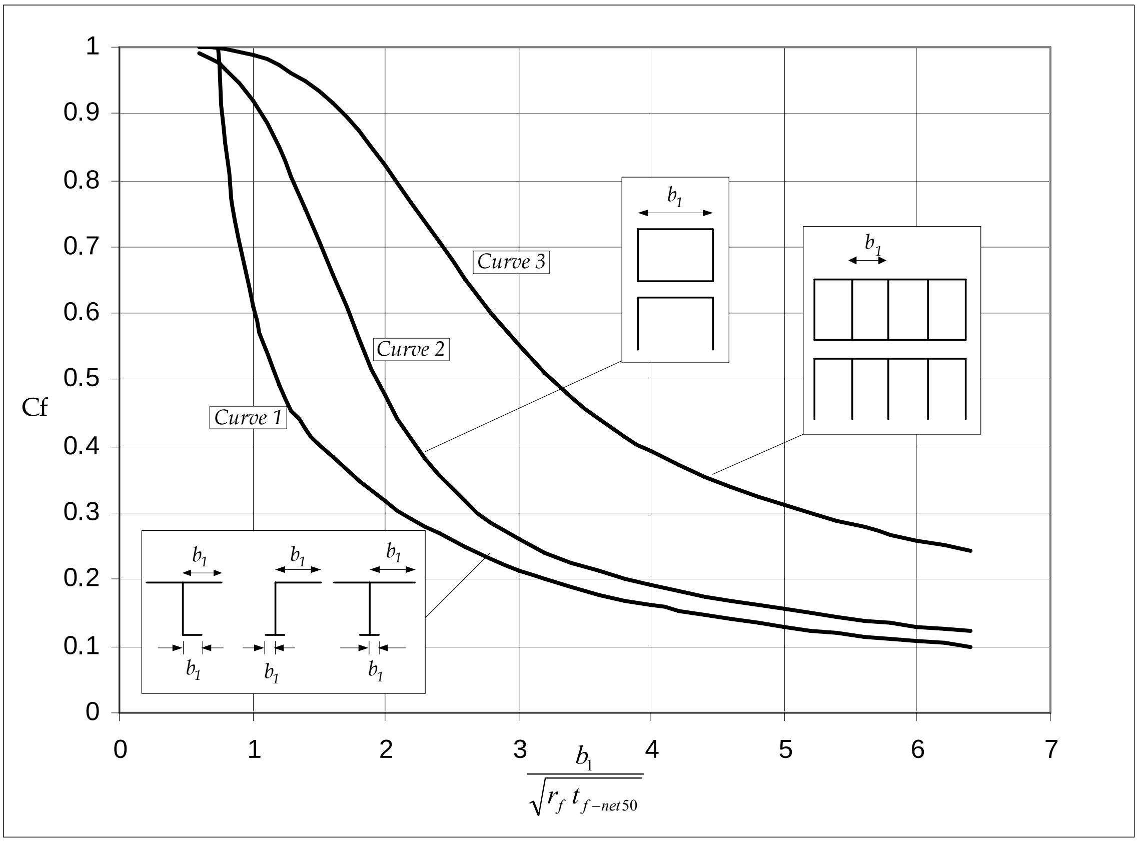
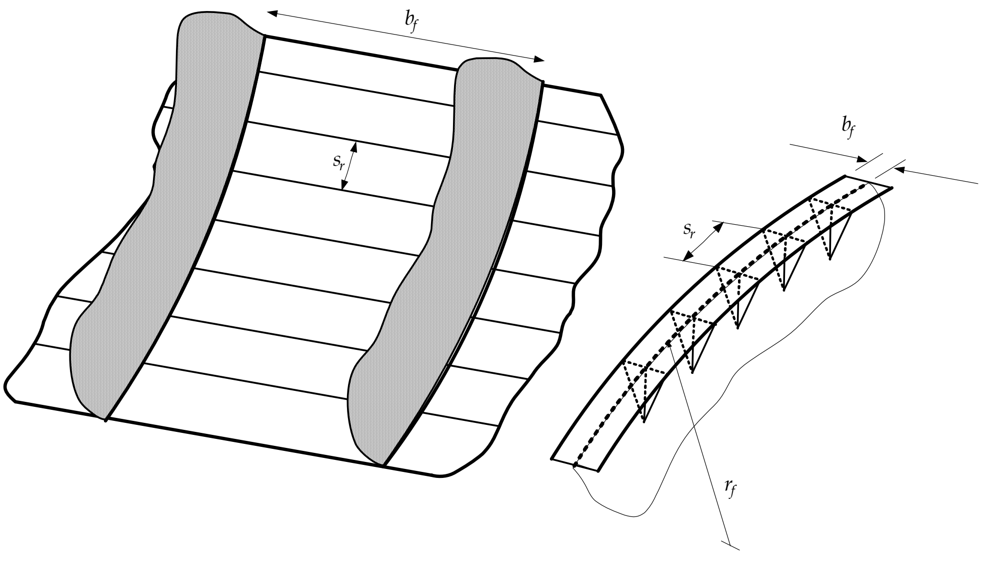


Fig. 4.2.11 Curved Shell Panel and Face Plate



2.3.4.4 The effective area given in **2.3.4.2** and **2.3.4.3** is only applicable to faceplates and attached plating of primary support members. This is not to be applied for the area of web stiffeners parallel to the face plate.

2.4 Geometrical Properties of Local Support Members

2.4.1 Calculation of net section properties for local support members

2.4.1.1 The net section modulus and shear area properties of local support members are to be calculated using the net thicknesses of the plate, web and flange.

2.4.1.2 The description of the net dimensions for typical profiles is given in **Fig. 4.2.12**.

Fig. 4.2.12 Net Sectional Properties of Local Support Members

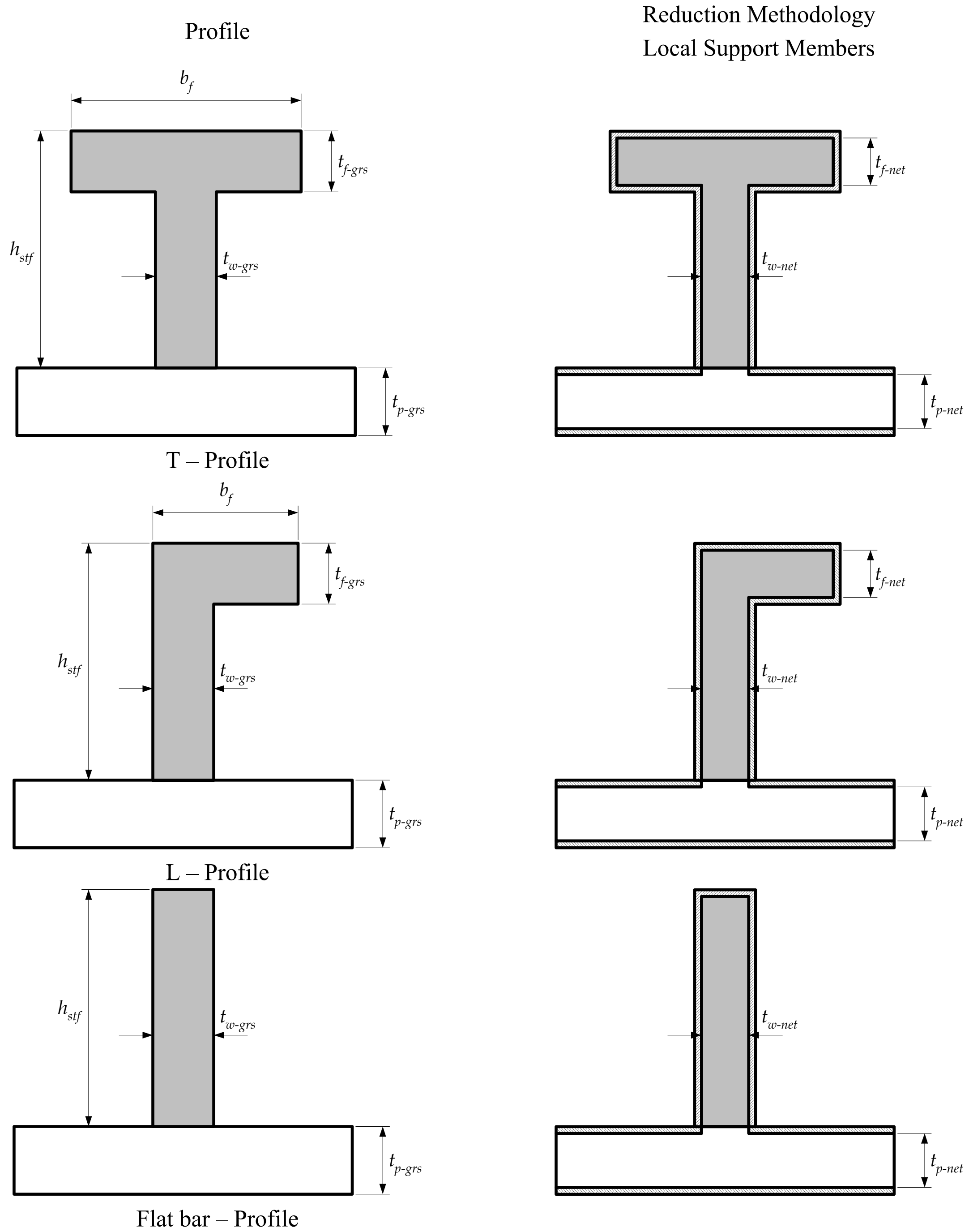
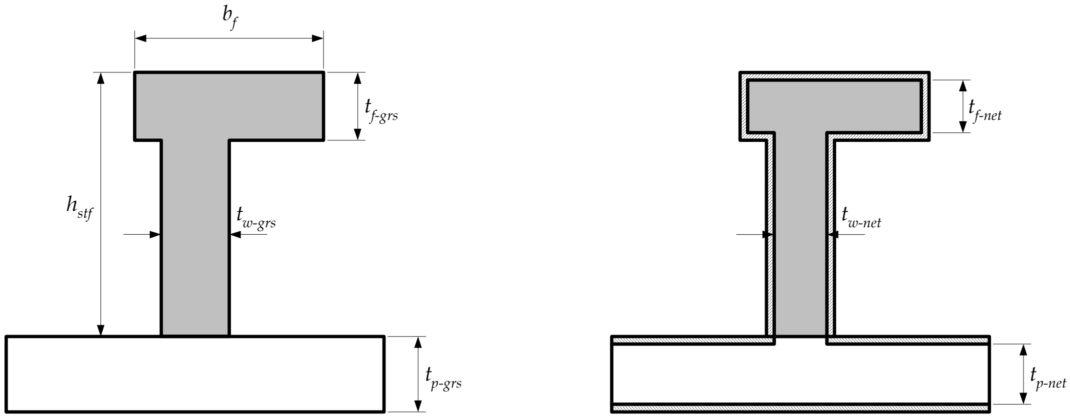
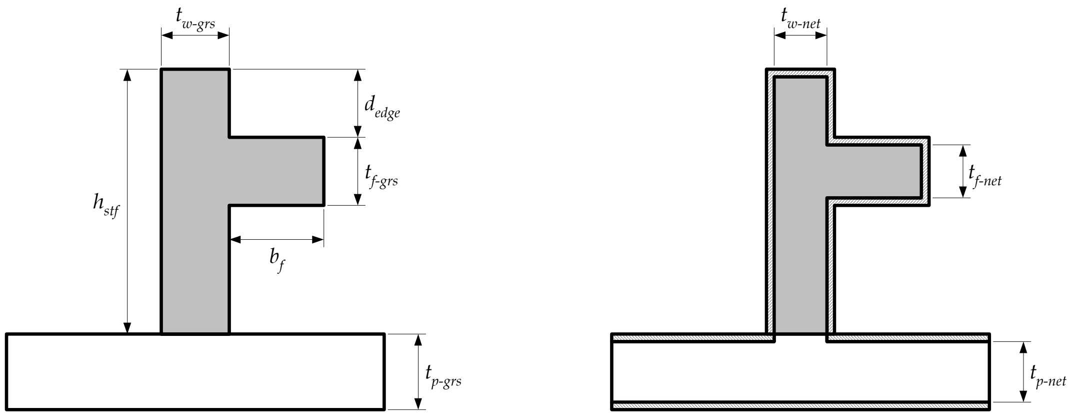


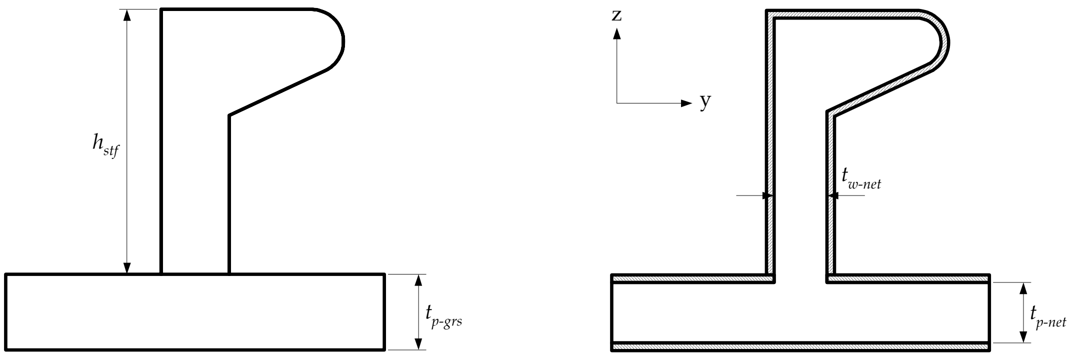
Fig. 4.2.12 (Continued) Net Sectional Properties of Local Support Members



L2 – Profile



L3 – Profile



Bulb Profile and Similar Profiles

The net cross-sectional area, the moment of inertia about the y-axis and the associated neutral axis position of the profile is to be determined assuming the corrosion magnitude $0.5t_{corr}$ deducted from the surface of the profile cross-section, see **2.4.1.3**

2.4.1.3 The combined net properties of *HP* and the *JIS* bulb profiles with attached plate flange are to be determined based on the net sectional properties of the profile, see **2.4.1.4**, which are then added to the attached plate flange.

2.4.1.4 The net sectional properties of the bulb profile without the attached plating are to be taken as:

(a) the net cross-sectional area of the bulb profile, $A_{bulb-net}$, is to be taken as:

$$A_{bulb-net} = A_{bulb-grs} - \Delta A_{bulb-grs}\ t_{corr} \qquad (mm^2)$$

(b) the neutral axis position of the net bulb profile, $NA_{bulb-net}$, is to be taken as:

$$NA_{bulb-net} \cong NA_{bulb-grs} \qquad (mm)$$

(c) the net moment of inertia of the bulb profile, $I_{bulb-net}$, is to be taken as:

$$I_{bulb-net} = I_{bulb-grs} - \Delta I_{bulb-grs}\ t_{corr} \qquad (cm^4)$$

Where:

$\Delta A_{bulb\text{-}grs}$	: as given in **Table 4.2.1** and **Table 4.2.2** for the profile height under consideration, in mm^2
$\Delta I_{bulb\text{-}grs}$	: as given in **Table 4.2.1** and **Table 4.2.2** for the profile height under consideration, in cm^4
$A_{bulb\text{-}grs}$	: cross-sectional area for the bulb profile under consideration with the nominal height and nominal gross web thickness, in mm^2
$I_{bulb\text{-}grs}$	: moment of inertia for the bulb profile under consideration with the nominal height and nominal gross web thickness, in cm^4
$NA_{bulb\text{-}grs}$	: neutral axis position above the lower edge of the web for the bulb profile under consideration with the nominal height and nominal gross web thickness, in *mm*
t_{corr}	: corrosion addition, as given in **Section 6/3.2**, in *mm*, for the local support member under consideration

2.4.1.5 The net profile properties of the bulb profiles including attached plating, as shown in **Fig. 4.2.13**, are to be taken as:

(a) the net cross-sectional area of the bulb profile including attached plating, $A_{tot\text{-}net}$, is to be taken as:

$$A_{tot-net} = A_{bulb-net} + A_{p-net} \qquad (mm^2)$$

(b) the neutral axis position of the net bulb profile including attached plating, $NA_{tot\text{-}net}$, is to be taken as:

$$NA_{tot-net} = \frac{A_{bulb-net}\left(NA_{bulb-net} + t_{p-net}\right) + 0.5A_{p-net}t_{p-net}}{A_{tot-net}} \qquad (mm)$$

(c) the net moment of inertia of the bulb profile including attached plating, $I_{tot\text{-}net}$, is to be taken as:

$$I_{tot-net} = I_{bulb-net} + I_{p-net} + A_{bulb-net}\left(NA_{bulb-net} + t_{p-net} - NA_{tot-net}\right)^2 \cdot 10^{-4} + A_{p-net}\left(NA_{tot-net} - 0.5t_{p-net}\right)^2 \cdot 10^{-4} \qquad (cm^4)$$

Where:

$A_{bulb\text{-}net}$	: net cross-sectional area of the bulb profile, in mm^2 ,as given in **2.4.1.4**,
$A_{p\text{-}net}$	: net area of attached plating $= t_{p\text{-}net}\ b_p \qquad (mm^2)$
$t_{p\text{-}net}$	: net thickness of attached plate $= t_{p\text{-}grs} - t_{corr} \qquad (mm)$
$t_{p\text{-}grs}$	: gross thickness of attached plate, in *mm*
t_{corr}	: corrosion addition, as given in **Section 6/3.2**, in *mm*
b_p	: breadth of attached plating, in *mm*
$NA_{bulb\text{-}net}$	: neutral axis of the net bulb profile, in *mm*, as given in **2.4.1.4**
$I_{bulb\text{-}net}$	: net moment of inertia of the bulb profile, as given in **2.4.1.4**, in cm^4
$I_{p\text{-}net}$	: net moment of inertia of attached plating: $= \frac{1}{12} b_p t_{p-net}^{\ 3} \cdot 10^{-4} \qquad (cm^4)$

Fig. 4.2.13 Definition of Neutral Axis for Bulb Profiles with Attached Plating

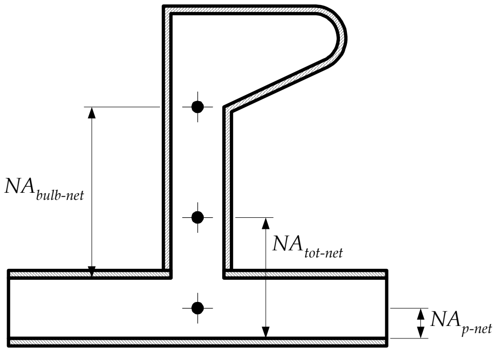


Table 4.2.1 Correction Factors for Net *HP* Bulb Profile Data

Profile height h_{stf} (mm)	$\Delta A_{bulb\text{-}grs}$ (mm^2 per *mm* corrosion)	$\Delta I_{bulb\text{-}grs}$ (cm^4 per *mm* corrosion)
200	253	100
220	279	133
240	305	173
260	330	220
280	357	276
300	383	339
320	409	413
340	435	496
370	474	640
400	513	810
430	552	1007

Table 4.2.2 Correction Factors for Net *JIS* Bulb Profile Data

Profile height h_{stf} (mm)	$\Delta A_{bulb\text{-}grs}$ (mm^2 per *mm* corrosion)	$\Delta I_{bulb\text{-}grs}$ (cm^4 per *mm* corrosion)
180	202	72
200	225	100
230	258	152
250	281	197

2.4.2 Effective elastic sectional properties of local support members

2.4.2.1 The net elastic shear area, $A_{shr\text{-}el\text{-}net}$, of local support members is to be taken as:

$$A_{shr-el-net} = \frac{(h_{stf} + t_{p-net})t_{w-net}\sin\varphi_w}{100} \qquad (cm^2)$$

Where:

h_{stf} : stiffener height, including face plate, in *mm*. See also **2.4.1.2**

$t_{p\text{-}net}$: net thickness of attached plate, in *mm*

$t_{w\text{-}net}$: net web thickness, in *mm*

φ_w : angle between the stiffener web and attached plating, see **Fig. 4.2.14**, in *degrees*. φ_w is to be taken as 90 *degrees* if the angle is greater than or equal to 75 *degrees*

2.4.2.2 The effective web depth of stiffeners, d_{shr}, is to be taken as:

$$d_{shr} = (h_{stf} + t_{p-net})\sin\varphi_w \qquad (mm)$$

Where:

h_{stf}	: stiffener height, including face plate, in *mm*. See also **2.4.1.2**
$t_{p\text{-}net}$	: net thickness of attached plate, in *mm*
φ_w	: angle between the stiffener web and attached plating, see **Fig. 4.2.14**, in *degrees*. φ_w is to be taken as 90 *degrees* if the angle is greater than or equal to 75 *degrees*

2.4.2.3 The elastic net section modulus, $Z_{el\text{-}\varphi\text{-}net}$ of local support members is to be taken as:

$$Z_{el\text{-}\varphi\text{-}net} = Z_{stf\text{-}net} \sin\varphi_w \qquad (cm^3)$$

Where:

$Z_{stf\text{-}net}$	: net section modulus of corresponding upright stiffener, i.e. when φ_w is equal to 90 *degrees*, in cm^3. See also **2.4.1.2**
φ_w	: angle between the stiffener web and attached plating, see **Fig. 4.2.14**, in *degrees*. φ_w is to be taken as 90 *degrees* if the angle is greater than or equal to 75 *degrees*

2.4.3 Effective plastic section modulus and shear area of stiffeners

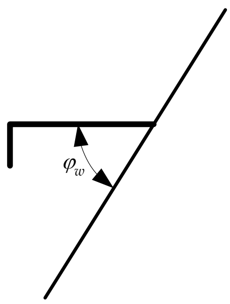
2.4.3.1 The net plastic shear area, $A_{shr\text{-}pl\text{-}net}$, of local support members is to be taken as:

$$A_{shr-pl-net} = \frac{\left(h_{stf} + t_{p-net}\right) t_{w-net} \sin\varphi_w}{100} \qquad (cm^2)$$

Where:

h_{stf}	: stiffener height, including face plate, in *mm*. See also **2.4.1.2**
$t_{p\text{-}net}$	: net thickness of attached plate, in *mm*
$t_{w\text{-}net}$	: net web thickness, in *mm*
φ_w	: angle between the stiffener web and the plate flange, see **Fig. 4.2.14**, in *degrees*. φ_w is to be taken as 90 *degrees* if the angle is greater than or equal to 75 *degrees*

Fig. 4.2.14 Angle between Stiffener Web and Plate Flange



2.4.3.2 The effective net plastic section modulus, $Z_{pl\text{-}net}$, of local support members is to be taken as:

$$Z_{pl-net} = \frac{f_w\, d_w^{\,2}\, t_{w-net} \sin{}_{w}}{2000} + \frac{(2\gamma - 1) A_{f-net}\left(h_{f-ctr} \sin{}_{w} - b_{f-ctr} \cos{}_{w}\right)}{1000} \qquad (cm^3)$$

Where:

f_w	: web shear stress factor	
	= 0.75	for flanged profile cross-sections with n = 1 or 2
	= 1.0	for flanged profile cross-sections with n = 0 and for flat bar stiffeners
n	: number of moment effective end supports	

Each member may have 0, 1 or 2 moment effective end supports. A moment effective end support may be considered where:

the stiffener is continuous at the support

the stiffener passes through the support plate while it is connected at it's

termination point by a carling (or equivalent) to adjacent beams
the stiffener is attached to a abutting beam effective in bending (not a buckling stiffener) or bracket. The bracket is assumed to be bending effective when it is attached to another beam (not a buckling stiffener).

d_w : depth of stiffener web, in *mm*
$= h_{stf} - t_{f\text{-}grs}$ for T, L (rolled and built up) and L2 profiles
$= h_{stf}$ for flat bar and L3 profiles
to be taken as given in **Table 4.2.3** and **Table 4.2.4** for bulb profiles

h_{stf} : stiffener height, in *mm*, see **Fig. 4.2.12**

γ $= 0.25\left(1+\sqrt{3+12\beta}\right)$

β = 0.5 for all cases, except L profiles without a mid span tripping bracket

$$= \frac{10^6 t^2{}_{w-net}\, f_b\, l_f^2}{80\, b_f^2\, t_{f-net}\, h_{f-ctr}} + \frac{t_{w-net}}{2 b_f}$$

but not to be taken greater than 0.5 for L (rolled and built-up) profiles without a mid span tripping bracket

$A_{f\text{-}net}$: net cross-sectional area of flange, in mm^2
$= b_f\, t_{f\text{-}net}$ in general
= 0 for flat bar stiffeners

b_f : breadth of flange, in *mm*, see **Fig. 4.2.12**. For bulb profiles, see **Table 4.2.3** and **Table 4.2.4**

$b_{f\text{-}ctr}$: distance from mid thickness of stiffener web to the centre of the flange area
$= 0.5\left(b_f - t_{w-grs}\right)$ for rolled angle profiles
= 0 for T profiles
as given in **Table 4.2.3** and **Table 4.2.4** for bulb profiles

$h_{f\text{-}ctr}$: height of stiffener measured to the mid thickness of the flange
$= h_{stf} - 0.5\, t_{f\text{-}grs}$ for profiles with flange of rectangular shape except for L3 profiles
$= h_{stf} - d_{edge} - 0.5\, t_{f\text{-}grs}$ for L3 profiles
as given in **Table 4.2.3** and **4.2.4** for bulb profiles

d_{edge} : distance from upper edge of web to the top of the flange, in *mm*. For L3 profiles, see **Fig. 4.2.12**

f_b 1.0 in general
0.8 for continuous flanges with end bracket(s). A continuous flange is defined as a flange that is not sniped and continuous through the primary support member
0.7 for non-continuous flanges with end bracket(s). A non-continuous flange is defined as a flange that is sniped at the primary support member or terminated at the support without aligned structure on the other side of the support

l_f : length of stiffener flange between supporting webs, in *m*, but reduced by the arm length of end bracket(s) for stiffeners with end bracket(s) fitted

$t_{f\text{-}net}$: net flange thickness, in *mm*
= 0 for flat bar stiffeners
as given in **Table 4.2.3** and **Table 4.2.4** for bulb profiles

$t_{w\text{-}net}$: net web thickness, in *mm*

φ_w : angle between the stiffener web and the plate flange, see **Fig. 4.2.14**, in *degrees*. φ_w is to be taken as 90 *degrees* if the angle is greater than or equal to 75 *degrees*

Table 4.2.3 Characteristic Flange Data for *HP* Bulb Profiles (see **Fig. 4.2.15**)

h_{stf} (mm)	d_w (mm)	$b_{f\text{-}grs}^*$ (mm)	$t_{f\text{-}grs}^*$ (mm)	$b_{f\text{-}ctr}$ (mm)	$h_{f\text{-}ctr}$ (mm)
200	171	40	14.4	10.9	188
220	188	44	16.2	12.1	206
240	205	49	17.7	13.3	225
260	221	53	19.5	14.5	244
280	238	57	21.3	15.8	263
300	255	62	22.8	16.9	281
320	271	65	25.0	18.1	300
340	288	70	26.4	19.3	318
370	313	77	28.8	21.1	346
400	338	83	31.5	22.9	374
430	363	90	33.9	24.7	402

Note

1. Characteristic flange data converted to net scantlings are given as:

$b_f \cong b_{f\text{-}grs}^* + 2\, t_{w\text{-}net}$

$t_{f\text{-}net} = t_{f\text{-}grs}^* - t_{corr}$

$t_{w\text{-}net} = t_{w\text{-}grs} - t_{corr}$

Table 4.2.4 Characteristic Flange Data for *JIS* Bulb Profiles (see **Fig. 4.2.15**)

h_{stf} (mm)	d_w (mm)	$b_{f\text{-}grs}^*$ (mm)	$t_{f\text{-}grs}^*$ (mm)	$b_{f\text{-}ctr}$ (mm)	$h_{f\text{-}ctr}$ (mm)
180	156	34	11.9	9.0	170
200	172	39	13.7	10.4	188
230	198	45	15.2	11.7	217
250	215	49	17.1	12.9	235

Note

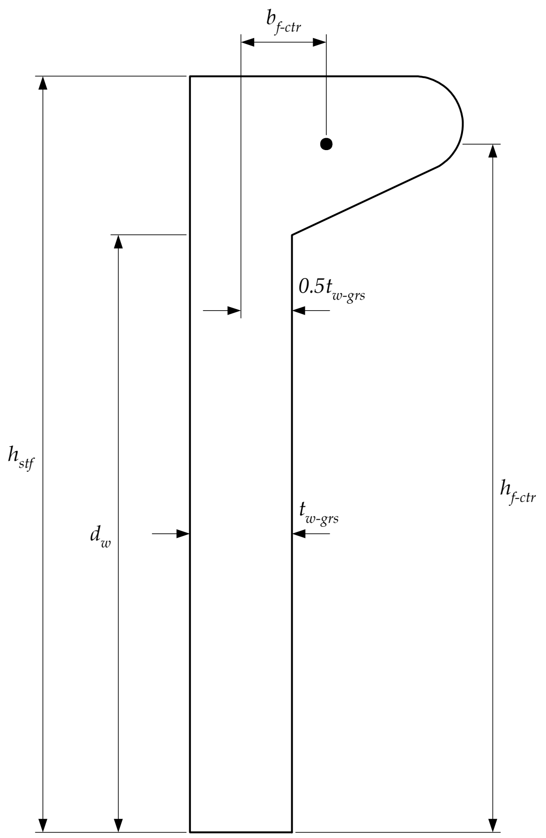
1. Characteristic flange data converted to net scantlings are given as:

$b_f \cong b_{f\text{-}grs}^* + 2\, t_{w\text{-}net}$

$t_{f\text{-}net} = t_{f\text{-}grs}^* - t_{corr}$

$t_{w\text{-}net} = t_{w\text{-}grs} - t_{corr}$

Fig. 4.2.15 Characteristic Data for Bulb Profiles



2.5 Geometrical Properties of Primary Support Members

2.5.1 Effective web area of primary support members

2.5.1.1 For calculation of the shear area of primary support members the web height, h_w, is to be taken as the moulded height of the primary support member.

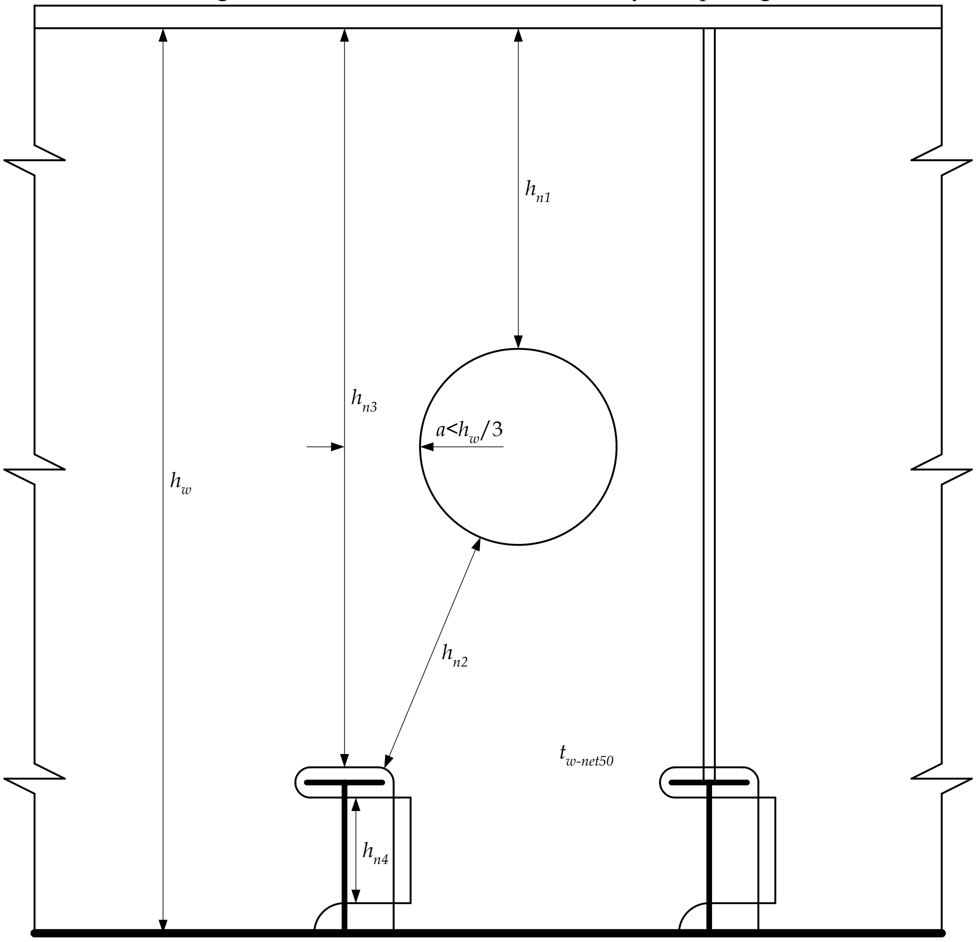
2.5.1.2 For single and double skin primary support members, the effective net web area, $A_{w-net50}$, is to be taken as:

$$A_{w-net50} = 0.01\, h_n\, t_{w-net50} \qquad (cm^2)$$

Where:

h_n	: for a single skin primary support member, see **Fig. 4.2.16**, the effective web height, in *mm*, is to be taken as the lesser of (a) h_w (b) $h_{n3} + h_{n4}$ (c) $h_{n1} + h_{n2}$: for a double skin primary support member, the same principle is to be adopted in determining the effective web height.
h_w	: web height of primary support member, in *mm*
h_{n1}, h_{n2}, h_{n3}, h_{n4}	: as shown in **Fig. 4.2.16**
$t_{w-net50}$	: net web thickness $= t_{w-grs} - 0.5\, t_{corr}$ (mm)
t_{w-grs}	: gross web thickness, in *mm*
t_{corr}	: corrosion addition, as given in **Section 6/3.2**, in *mm*

Fig. 4.2.16 Effective Web Area in way of Openings



Note :

The figure shows effective web height for a single skin primary support member. The effective web height of a double skin primary support member follows the same principles.

2.5.1.3 Where an opening is located at a distance less than $h_w/3$ from the cross-section considered, h_n is to be taken as the smaller of the net height and the net distance through the opening. See **Fig. 4.2.16**.

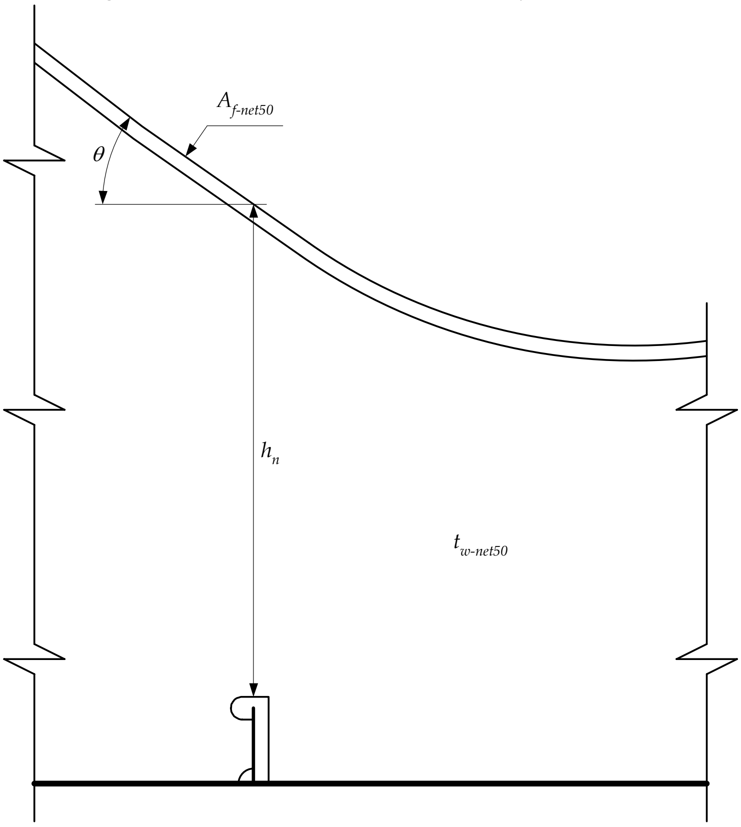
2.5.1.4 Where a girder flange of a single skin primary support member is not parallel to the axis of the attached plating, the effective net web area, $A_{w\text{-}net50}$, is to be taken as:

$$A_{w\text{-}net50} = 0.01\, h_n\, t_{w\text{-}net50} + 1.3\, A_{f\text{-}net50} \sin 2\theta \sin\theta \qquad (cm^2)$$

Where:

$A_{f\text{-}net50}$	: net flange/face plate area $= 0.01\, b_f\, t_{f\text{-}net50}$ (cm^2)
b_f	: breadth of flange or face plate, in *mm*
$t_{f\text{-}net50}$	: net flange thickness $= t_{f\text{-}grs} - 0.5t_{corr}$ (mm)
$t_{f\text{-}grs}$	: gross flange thickness, in *mm*
t_{corr}	: corrosion addition, as given in **Section 6/3.2**, in *mm*
θ	: angle of slope of continuous flange, see **Fig. 4.2.17**
$t_{w\text{-}net50}$	: net web thickness, as defined in **2.5.1.2**, in *mm*
h_n	: effective web height, as defined in **Fig. 4.2.16**, in *mm*

Fig. 4.2.17 Effective Web Area in way of Brackets



2.5.2 Effective section modulus of primary support members

2.5.2.1 The net section modulus of primary support members is to be calculated using the net thicknesses of the attached plate, web and face plate (or top attached plate for double skin girders), where the net thicknesses are to be taken as:

$t_{w\text{-}net50} = t_{w\text{-}grs} - 0.5t_{corr}$ *mm*, for the net web thickness

$t_{p\text{-}net50} = t_{p\text{-}grs} - 0.5t_{corr}$ *mm*, for the net lower attached plate thickness

$t_{f\text{-}net50} = t_{f\text{-}grs} - 0.5t_{corr}$ *mm*, for the net upper attached plate or face plate

Where:

$t_{w\text{-}grs}$: gross web thickness, in *mm*

$t_{p\text{-}grs}$: gross thickness of lower attached plate, in *mm*

$t_{f\text{-}grs}$: gross thickness of upper attached plate or face plate, in *mm*

t_{corr} : corrosion addition, as given in **Section 6/3.2**, in *mm*

Note :

See **2.3.4** for curved face plates of primary support members

2.6 Geometrical Properties of the Hull Girder Cross-Section

2.6.1 Vertical hull girder section modulus

2.6.1.1 The effective vertical hull girder section modulus, Z_v, at any vertical distance, z, above the baseline is defined by:

$$Z_v = \frac{I_v}{|z - z_{NA}|} \qquad (m^3)$$

where:

I_v : vertical hull girder moment of inertia, of all longitudinally continuous members in cross section under consideration, after deduction of openings as given in **2.6.3**, in m^4

z : distance from the structural member under consideration to the baseline, in *m*

z_{NA} : distance from the baseline to the horizontal neutral axis of the hull girder cross-section, in m

2.6.1.2 For calculation of the vertical net hull girder section modulus for the strength assessment, $Z_{v\text{-}net50}$, required by **Section 8**, the vertical net hull girder moment of inertia and position of horizontal neutral axis is to be calculated based on gross thickness minus the corrosion addition $0.5t_{corr}$ of all effective structural members comprising the hull girder section, where t_{corr} is as defined in **Section 6/3.2**.

2.6.1.3 For calculation of vertical net hull girder section modulus for the fatigue assessment, $Z_{v\text{-}net75}$, required by **Section 9/3**, the vertical net hull girder moment of inertia and position of horizontal neutral axis is to be calculated based on gross thickness minus the corrosion addition $0.25t_{corr}$ of all effective structural members comprising the hull girder section, where t_{corr} is as defined in **Section 6/3.2**.

2.6.2 Horizontal hull girder section modulus

2.6.2.1 The effective horizontal hull girder section modulus, Z_h, at any transverse coordinate, y, is to be taken as:

$$Z_h = \frac{I_h}{|y - y_{NA}|} \qquad (m^3)$$

where:

I_h : horizontal hull girder moment of inertia, of all longitudinally continuous members in cross section under consideration, after deduction of openings as given in **2.6.3**, in m^4

y : transverse coordinate, in m

y_{NA} : distance from the centreline to the vertical neutral axis of the hull girder cross section, in m

2.6.2.2 For calculation of the horizontal net hull girder section modulus for the strength assessment, $Z_{h\text{-}net50}$, required by **Section 8**, the horizontal net hull girder moment of inertia and position of vertical neutral axis is to be calculated based on gross thickness minus the corrosion addition $0.5t_{corr}$ of all effective structural members comprising the hull girder section, where t_{corr} is as defined in **Section 6/3.2**.

2.6.2.3 For calculation of the horizontal net hull girder section modulus for fatigue assessment, $Z_{h\text{-}net75}$, as required in **Section 9/3**, the net horizontal hull girder moment of inertia and position of vertical neutral axis is to be calculated based on gross thickness minus the corrosion addition $0.25t_{corr}$ of all effective structural members comprising the hull girder section, where t_{corr} is as defined in **Section 6/3.2**.

2.6.3 Effective area for calculation of hull girder moment of inertia and section modulus

2.6.3.1 The effective hull girder sectional area includes all the longitudinally continuous structural members after deduction of openings. The structural members given in **2.6.3.2** are not to be included in the effective hull girder sectional area. The definition of openings to be deducted and deduction free openings are given in **2.6.3.4** – **2.6.3.9**. The definition of effective area in way of non-continuous bulkheads and decks is given in **2.6.3.10**.

2.6.3.2 The following structural members are not to be considered as effectively contributing to the hull girder sectional area as they do not provide sufficient structural continuity and are therefore to be excluded in the calculation:

(a) superstructures which do not form a strength deck
(b) deck houses
(c) vertically corrugated bulkheads
(d) bulwarks and gutter plates
(e) bilge keels
(f) sniped or non-continuous longitudinal stiffeners if the cross-section under consideration is closer than twice the height of the stiffener from the end of the stiffener.

2.6.3.3 The following definitions of opening are to be applied:

(a) large openings are openings exceeding 2.5m in length and/or 1.2m in breadth, where the length is measured along the global x-axis of the ship as defined in **Fig. 4.1.1**
(b) small openings are openings that are not large openings i.e. manholes, lightening holes, etc.
(c) isolated openings are openings spaced not less than 1m apart in the ship's transverse/vertical direction

2.6.3.4 Large openings and small openings that are not isolated are to be deducted from the sectional area used in the section modulus calculation.
2.6.3.5 Isolated small openings in longitudinal stiffeners or girders are to be deducted if their depth exceeds 25% of the web depth.
2.6.3.6 When several openings are located in or adjacent to the same cross-section, the total equivalent breadth of the combined openings, Σb_{ded}, is to be deducted, see **2.6.3.7** to **2.3.6.8** and **Fig. 4.2.18**.
2.6.3.7 Isolated small openings need not be deducted provided that the sum of their breadths, or shadow area breadths, in one transverse section does not reduce the hull girder section modulus at deck or baseline by more than 3%. Alternatively isolated small openings need not to be deducted provided the total equivalent breadth of small openings, Σb_{sm}, is less than:

$$\sum b_{sm} = 0.06\left(B_{sect} - \sum b_{ded}\right) \qquad (m)$$

Where:

Σb_{sm} : total equivalent breadth of small openings, see **Fig. 4.2.18**
$= b_{sm1} + b_{sm2} + b_{sm3} \qquad (m)$

B_{sect} : the breadth of the ship at the section being considered, in m

Σb_{ded} : total equivalent breadth of combined openings specified in **2.6.3.7**, in m

The effect of the shadow area of deductible openings is to be taken into account.
2.6.3.8 When calculating the total equivalent breadth of small openings, Σb_{sm}, each opening is assumed to have a longitudinal shadow area, see **Fig. 4.2.18**. This shadow area is obtained by drawing two tangent lines with an angle of 15 *degrees* to the longitudinal axis of the ship.
2.6.3.9 Full or partial compensation of openings may be provided by increasing the sectional area of the plating, longitudinal stiffeners or girders, or other suitable structure. The compensation area is to extend well beyond the forward and aft end of the opening. Any local edge reinforcement of the opening is not to be included in the effective area of the hull girder section modulus calculations. Compensation is not necessary for openings which are not required to be deducted in accordance with **2.6.3.7**.
2.6.3.10 When calculating the ineffective area in way of large openings and in way of non-continuous decks and longitudinal bulkheads, the effective area is to be taken as shown in **Fig. 4.2.19**. The shadow area, which indicates the area that is not effective, is obtained by drawing two tangent lines with an angle of 15 *degrees* to the longitudinal axis of the ship.

Fig. 4.2.18 Calculation of equivalent Breadth

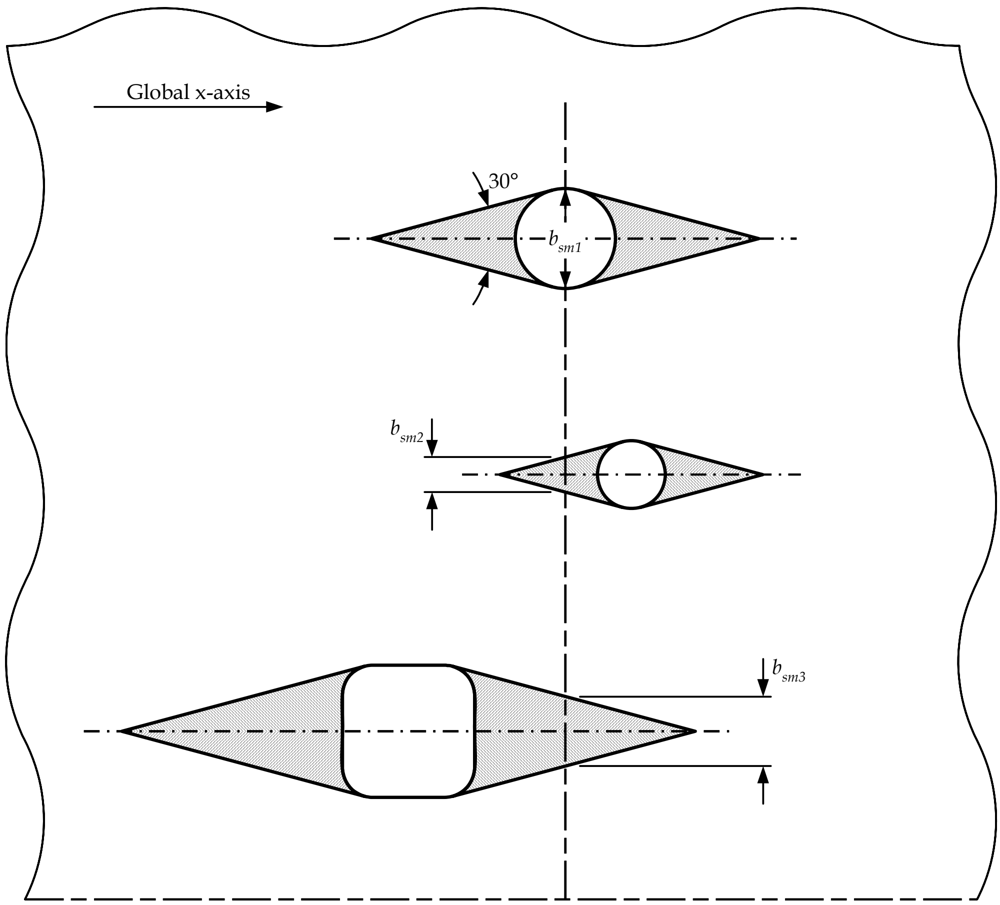
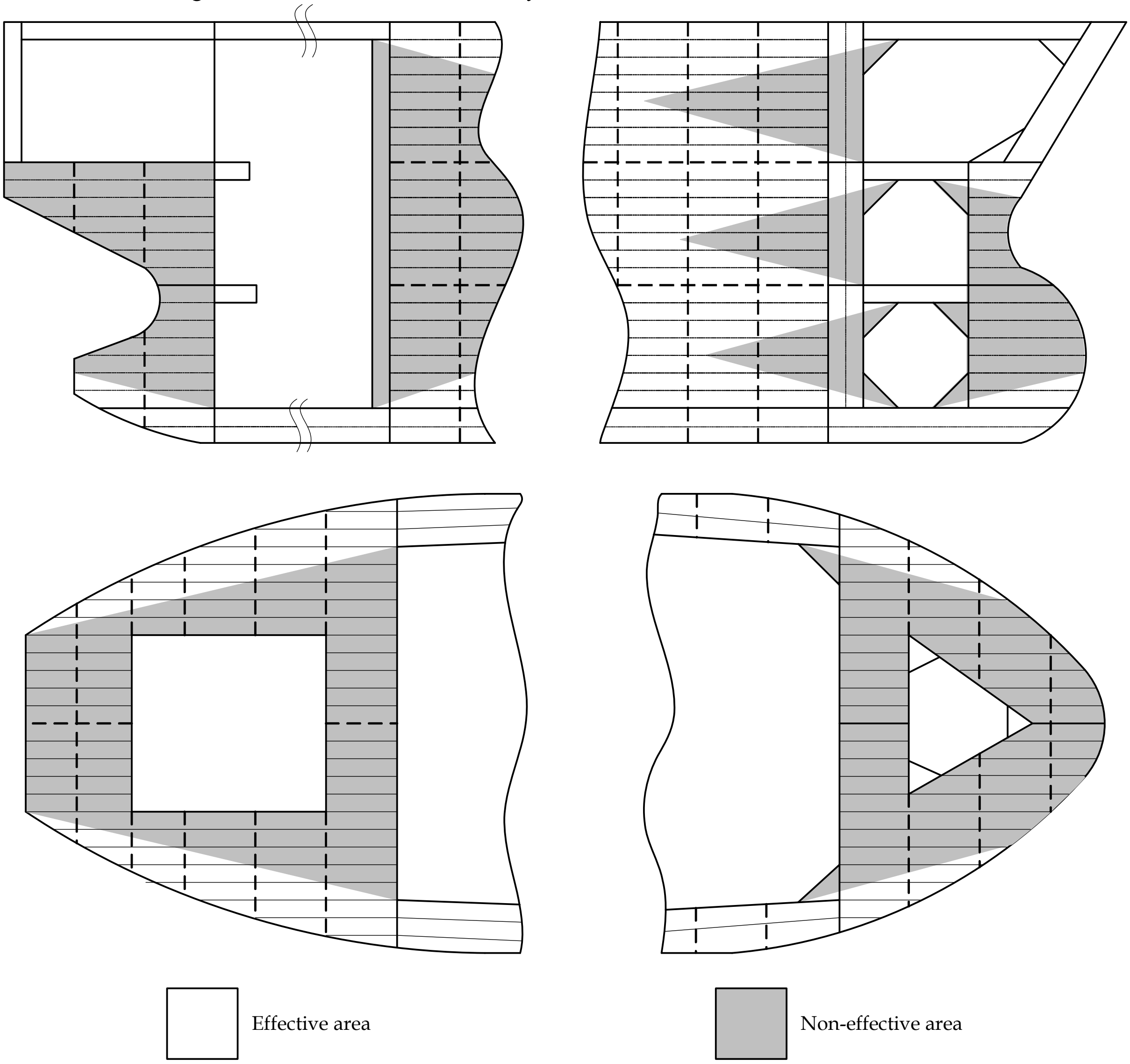


Fig. 4.2.19 Effective Area in way of Non-Continuous Decks and Bulkheads



2.6.4 Effective vertical hull girder shear area

2.6.4.1 The effective net hull girder vertical shear area includes the net plating area of the side shell including the bilge, the inner hull including the hopper side and the outboard girder under and the longitudinal bulkheads including the double bottom girders in line.

2.6.4.2 For calculation of the net hull girder vertical shear area, the net plating area is to be calculated based on the net thickness, t_{net50}, given by the gross thickness minus the corrosion addition $0.5t_{corr}$ of all effective structural members given in **2.6.4.1**. Where t_{corr} is as defined in **Section 6/3.2**.

2.6.4.3 For longitudinal strength members forming the web of the hull girder which are inclined to the vertical, the area of the member to be included in the shear force calculation is to be based on the projected area onto the vertical plane. See **Fig. 4.2.20**.

2.6.4.4 The calculation of the net effective shear area for vertical and horizontal corrugated bulkheads is to be based on the net effective equivalent thickness, $t_{cg-net50}$, given by:

$$t_{cg-net50} = \left[0.5\left(t_{w-grs} + t_{f-grs}\right)\frac{b_{cg}}{b_{w-cg} + b_{f-cg}} \right] - 0.5t_{corr} \qquad (mm)$$

Where:

t_{w-grs} : gross corrugation web thickness, in *mm*

t_{f-grs} : gross corrugation flange thickness, in *mm*

b_{cg} : projected length of one corrugation, in *mm*, as defined in **Fig. 4.2.20**

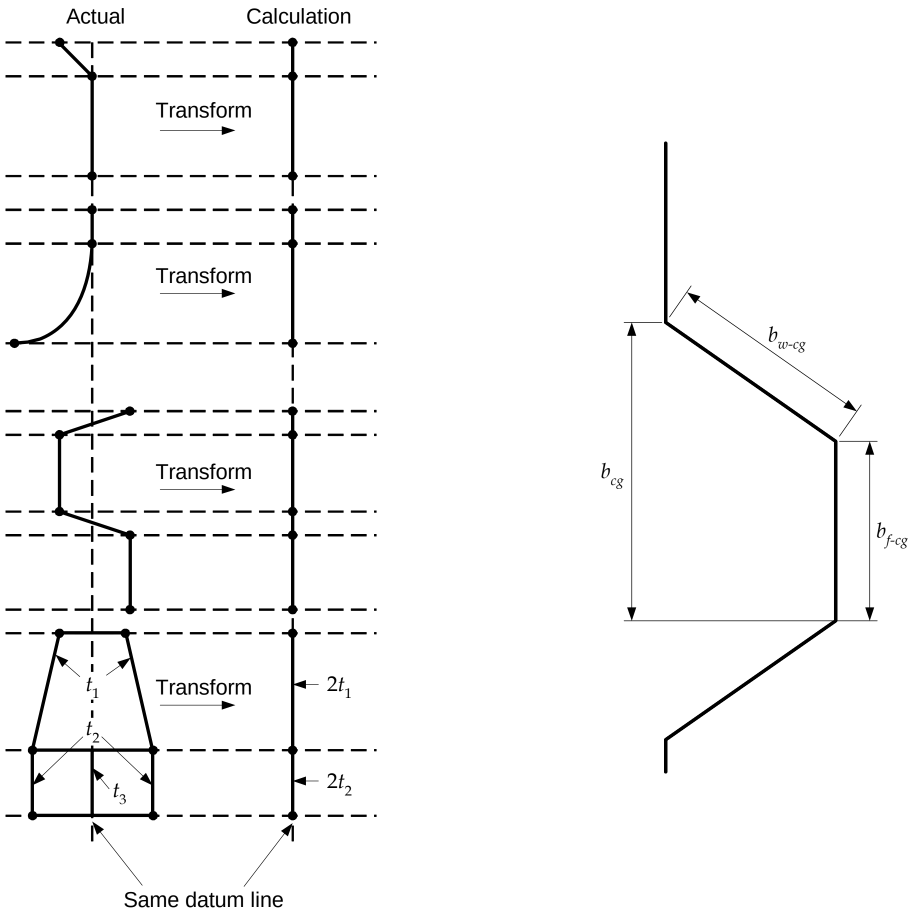
b_{w-cg} : breadth of corrugation web, in *mm*, as defined in **Fig. 4.2.20**

b_{f-cg} : breadth of corrugation flange, in *mm*, as defined in **Fig. 4.2.20**

t_{corr} : corrosion addition, as defined in **Section 6/3.2**

2.6.4.5 The equivalent net corrugation thickness, $t_{cg-net50}$, is only applicable for the calculation of the effective area, $A_{eff-net50}$, and shear force distribution factor, f_i.

Fig. 4.2.20 Effective Shear Area



3. Structure Design Details

3.1 Standard Construction Details

3.1.1 Details to be submitted

3.1.1.1 A booklet of standard construction details is to be submitted for review. It is to include the following:

(a) the proportions of built-up members to demonstrate compliance with established standards for structural stability, see **Section 10**

(b) the design of structural details which reduce the harmful effects of stress concentrations, notches and material fatigue; such as:

- details of the ends, at the intersections of members and associated brackets
- shape and location of air, drainage, and/or lightening holes
- shape and reinforcement of slots or cut-outs for internals
- elimination or closing of weld scallops in way of butts, 'softening' of bracket toes, reduction of abrupt changes of section or structural discontinuities
- proportion and thickness of structural members to reduce fatigue response due to engine, propeller or wave induced cyclic stresses, particularly for higher strength steels.

3.2 Termination of Local Support Members

3.2.1 General

3.2.1.1 In general, structural members are to be effectively connected to adjacent structures to avoid hard spots, notches and stress concentrations.

3.2.1.2 Where a structural member is terminated, structural continuity is to be maintained by suitable back-up structure fitted in way of the end connection of frames, or the end connection is to be effectively extended with additional structure and integrated with an adjacent beam, stiffener, etc.

3.2.1.3 All types of stiffeners (longitudinals, beams, frames, bulkhead stiffeners) are to be connected at their ends. However, in special cases sniped ends may be permitted. Requirements for the various types of connections (bracketed, bracketless or sniped ends) are given in **3.2.3** to **3.2.5**.

3.2.2 Longitudinal members

3.2.2.1 All longitudinals are to be kept continuous within the $0.4L$ amidships cargo tank region. In special cases, in way of large openings, foundations and partial girders, the longitudinals may be terminated, but end connection and welding is to be specially considered.

3.2.2.2 Where continuity of strength of longitudinal members is provided by brackets, the correct alignment of the brackets on each side of the primary support member is to be ensured, and the scantlings of the brackets are to be such that the combined stiffener/bracket section modulus and effective cross-sectional area are not less than those of the member.

3.2.3 Bracketed connections

3.2.3.1 At bracketed end connections, continuity of strength is to be maintained at the stiffener connection to the bracket and at the connection of the bracket to the supporting member. The brackets are to have scantlings sufficient to compensate for the non-continuous stiffener flange or non-continuous stiffener.

3.2.3.2 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection, the section modulus is less than that required for the stiffener.

3.2.3.3 Minimum net bracket thickness, $t_{bkt-net}$, is to be taken as:

$$t_{bkt-net} = \left(2 + f_{bkt}\sqrt{Z_{rl-net}}\right)\left(\sqrt{\frac{\sigma_{yd-stf}}{\sigma_{yd-bkt}}}\right)$$

(mm), but is not to be less than $6mm$ and need not be greater than $13.5mm$

Where:

f_{bkt} 0.2 for brackets with flange or edge stiffener
0.3 for brackets without flange or edge stiffener

$Z_{rl\text{-}net}$: net rule section modulus, for the stiffener, in cm^3. In the case of two stiffeners connected, it need not be taken as greater than that of the smallest connected stiffener

$\sigma_{yd\text{-}stf}$: specified minimum yield stress of the material of the stiffener, in N/mm^2

$\Sigma_{yd\text{-}bkt}$: specified minimum yield stress of the material of the bracket, in N/mm^2

3.2.3.4 Brackets to provide fixity of end rotation are to be fitted at the ends of discontinuous local support members, except as otherwise permitted by **3.2.4**. The end brackets are to have arm lengths, $l_{bkt,}$ not less than:

$$l_{bkt} = c_{bkt}\sqrt{\frac{Z_{rl-net}}{t_{bkt-net}}}$$ *mm*, but is not to be less than:

1.8 times the depth of the stiffener web for connections where the end of the stiffener web is supported and the bracket is welded in line with the stiffener web, see **Fig. 4.3.1(c)**

2.0 times for other cases, see **Fig. 4.3.1**

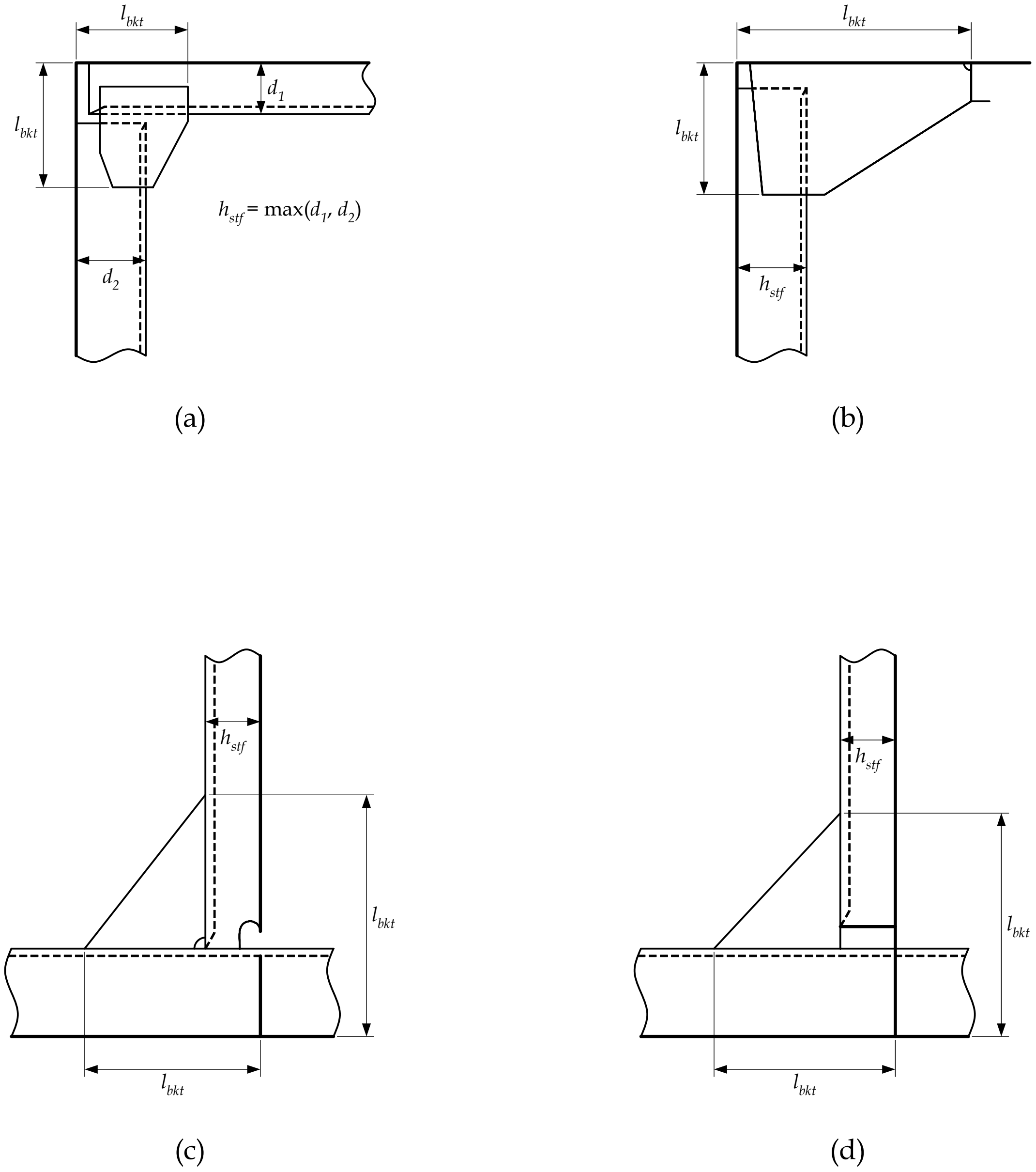
Where:

c_{bkt} 65 for brackets with flange or edge stiffener
70 for brackets without flange or edge stiffener

$Z_{rl\text{-}net}$: net rule section modulus, for the stiffener, in cm^3. In the case of two stiffeners connected, it need not be taken as greater than that of the smallest connected stiffener

$t_{bkt\text{-}net}$: minimum net bracket thickness, as defined in **3.2.3.3**

Fig. 4.3.1 Bracket Arm Length



3.2.3.5 The proportions and edge stiffening of brackets are to be in accordance with the requirements of **Section 10/2.4**. Where an edge stiffener is required, the depth of stiffener web, d_w, is not to be less than:

$$d_w = 45\left(1 + \frac{Z_{rl-net}}{2000}\right) \quad mm\text{, but is not to be less than } 50mm$$

Where:

Z_{rl-net} : net rule section modulus, for the stiffener, in cm^3. In the case of two stiffeners connected, it need not be taken as greater than that of the smallest connected stiffener

3.2.4 Bracketless connections

3.2.4.1 Local support members, for example longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure, are generally to be connected at their ends, in accordance with the requirements of **3.2.2** and **3.2.3**.

3.2.4.2 Where alternative connections are adopted, the proposed arrangements will be specially considered.

3.2.4.3 The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.

3.2.5 Sniped ends

3.2.5.1 Stiffeners with sniped ends may be used where dynamic loads are small and where the incidence of vibration is considered to be small, i.e. structure not in the stern area and structure not in the vicinity of engines or generators, provided the net thickness of plating supported by the stiffener, t_{p-net}, is not less than:

$$t_{p-net} = c_1 \sqrt{\left(1000\, l - \frac{s}{2}\right)\frac{sPk}{1000}} \qquad (mm)$$

Where:

l : stiffener span, in *m*

s : stiffener spacing, in *mm*, as defined in **2.2**

P : design pressure for the stiffener for the design load set being considered, in kN/m^2. The design load sets and method to derive the design pressure are to be taken in accordance with the following criteria, which define the acceptance criteria set to be used
Table 8.2.5 in the cargo tank region
Section 8/3.9.2.2 in the area forward of the forward cargo tank, and in the aft end
Section 8/4.8.1.2 in the machinery space

k : higher strength steel factor, as defined in **Section 6/1.1.4**

c_1 : coefficient for the design load set being considered, to be taken as
=1.2 for acceptance criteria set AC1
=1.0 for acceptance criteria set AC2

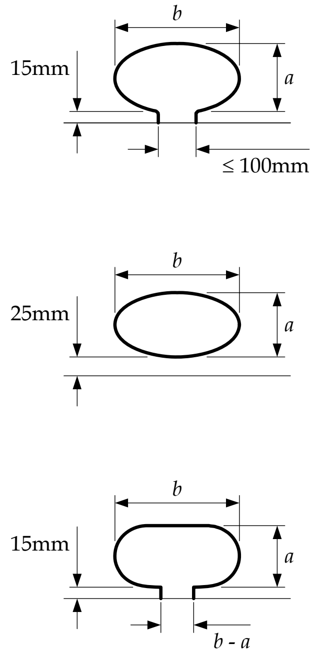
3.2.5.2 Bracket toes and sniped end members are, in general, to be kept within 25*mm* of the adjacent member. The maximum distance is not to exceed 40*mm* unless the bracket or member is supported by another member on the opposite side of the plating. Special attention is to be given to the end taper by using a sniped end of not more than 30 *degrees*. The depth of toe or sniped end is, generally, not to exceed the thickness of the bracket toe or sniped end member, but need not be less than 15*mm*.

3.2.5.3 The end attachments of non-load bearing members may be snipe ended. The sniped end is to be not more than 30 *degrees* and is generally to be kept within 50*mm* of the adjacent member unless it is supported by a member on the opposite side of the plating. The depth of the toe is generally not to exceed 15*mm*.

3.2.6 Air and drain holes and scallops

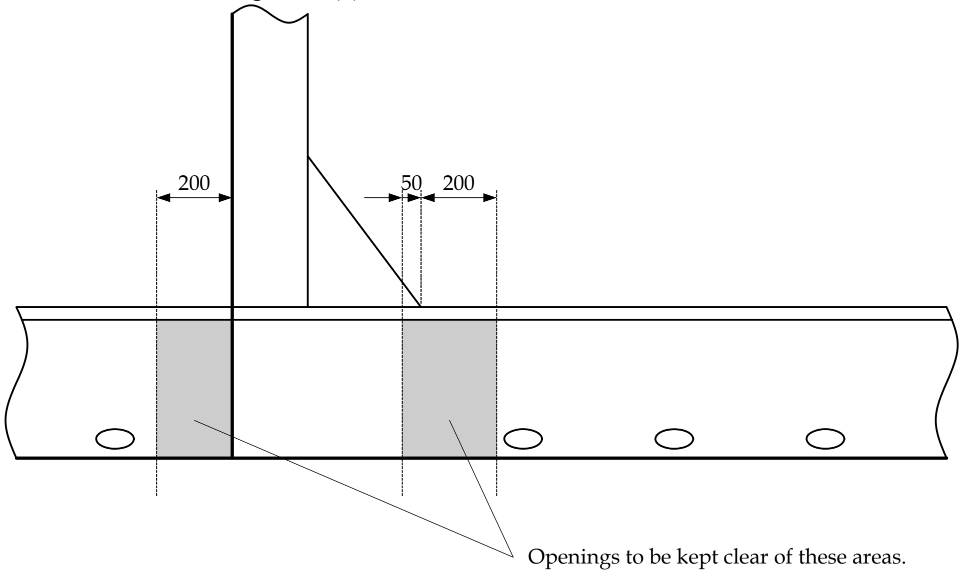
3.2.6.1 Air, drain holes, scallops and block fabrication butts are to be kept at least 200*mm* clear of the toes of end brackets, end connections and other areas of high stress concentration measured along the length of the stiffener toward the mid-span and 50*mm* measured along the length in the opposite direction. See **Fig. 4.3.2(b)**. In areas where the shear stress is less than 60 *percent* of the allowable limit, alternative arrangements may be accepted. Openings are to be well-rounded. **Fig. 4.3.2(a)** shows some examples of air and drain holes and scallops. In general, the ratio of *a/b*, as defined in **Fig. 4.3.2(a)**, is to be between 0.5 and 1.0. In fatigue sensitive areas further consideration may be required with respect to the details and arrangements of openings and scallops.

Fig. 4.3.2(a) Examples of Air and Drain Holes and Scallops



Note
The details shown in this figure are for guidance and illustration only.

Fig. 4.3.2(b) Location of Air and Drain Holes



3.2.7 Special requirements

3.2.7.1 Closely spaced scallops or drain holes, i.e. where the distance between scallops/drain holes is less than twice the width *b* as shown in **Fig. 4.3.2(a)**, are not permitted in longitudinal strength members or within 20% of the stiffener span measured from the end of the stiffener. Widely spaced air or drain holes may be permitted provided that they are of elliptical shape or equivalent to minimise stress concentration and are, in general, cut clear of the weld connection.

3.3 Termination of Primary Support Members

3.3.1 General

3.3.1.1 Primary support members are to be arranged to ensure effective continuity of strength. Abrupt changes of depth or section are to be avoided. Primary support members in tanks are to form a continuous line of support and, wherever possible, a complete ring system.
3.3.1.2 The members are to have adequate lateral stability and web stiffening, and the structure is to be arranged to minimise hard spots and other sources of stress concentration. Openings are to have well-rounded corners and are to be located considering the stress distribution and buckling strength of the panel.

3.3.2 End connection

3.3.2.1 Primary support members are to be provided with adequate end fixity by brackets or equivalent structure. The design of end connections and their supporting structure is to provide adequate resistance to rotation and displacement of the joint and effective distribution of the load from the member.
3.3.2.2 Brackets are generally to be radiused or well-rounded at their toes. The free edges of the brackets are to be stiffened. Scantlings and details are given in **3.3.3**.
3.3.2.3 Where primary support members are subject to concentrated loads additional strengthening may be required, particularly if these are out of line with the member web.
3.3.2.4 In general, ends of primary support members or connections between primary support members forming ring systems are to be provided with brackets. Bracketless connections may be applied provided that there is adequate support of the adjoining face plates.

3.3.3 Brackets

3.3.3.1 In general, the arm lengths of brackets connecting primary support members are not to be less than the web depth of the member, and need not be taken as greater than 1.5 times the web depth. The two arms of a bracket are to be of approximately equal lengths. The thickness of the bracket is, in general, not to be less than that of the girder web plate.
3.3.3.2 For a ring system where the end bracket is integral with the webs of the members and the face plate is carried continuously along the edges of the members and the bracket, the full area of the largest face plate is to be maintained close to the mid point of the bracket and gradually tapered to the smaller face plates. Butts in face plates are to be kept well clear of the radius ends.
3.3.3.3 Where a wide face plate abuts a narrower one, the taper is generally not to be greater than 1 in 4. Where a thick face plate abuts against a thinner one and the difference in thickness is greater than 4*mm*, the taper of the thickness is not to be greater than 1 in 3.
3.3.3.4 Face plates of brackets (typical brackets similar to those indicated in **Fig. 4.2.7b)** are to have a net cross-sectional area, $A_{f\text{-}net}$, which is not to be less than:

$$A_{f-net} = l_{bkt-edge} t_{bkt-net} \qquad (cm^2)$$

Where:

$l_{bkt\text{-}edge}$: length of free edge of bracket, in *m*. For brackets that are curved the length of the free edge may be taken as the length of the tangent at the midpoint of the free edge. If $l_{bkt\text{-}edge}$ is greater than 1.5*m*, 40 *percent* of the face plate area is to be in a stiffener fitted parallel to the free edge and a maximum 0.15*m* from the edge

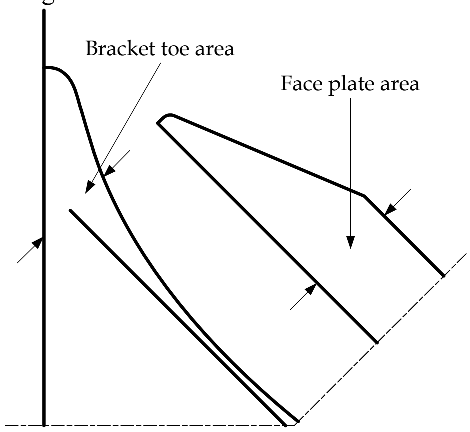
$t_{bkt\text{-}net}$: minimum net bracket thickness, in *mm*, as defined in **3.2.3.3**

3.3.4 Bracket toes

3.3.4.1 The toes of brackets are not to land on unstiffened plating. Notch effects at the toes of brackets may be reduced by making the toe concave or otherwise tapering it off. In general, the toe height is not to be greater than the thickness of the bracket toe, but need not be less than 15*mm*. The end brackets of large primary support members are to be soft-toed. Where any end bracket has a face plate, it is to be sniped and tapered at an angle not greater than 30°.

3.3.4.2 Where primary support members are constructed of higher strength steel, particular attention is to be paid to the design of the end bracket toes in order to minimise stress concentrations. Sniped face plates, which are welded onto the edge of primary support member brackets, are to be carried well around the radiused bracket toe and are to incorporate a taper not greater than 1 in 3. Where sniped face plates are welded adjacent to the edge of primary support member brackets, adequate cross-sectional area is to be provided through the bracket toe at the end of the snipe. In general, this area, measured perpendicular to the face plate is to be not less than 60 *percent* of the full cross-sectional area of the face plate, see **Fig. 4.3.3**.

Fig. 4.3.3 Bracket Toe Construction



Note :
The details shown in this figure are only used to illustrate items described in the text and are not intended to represent design guidance or recommendations.

3.4 Intersections of Continuous Local Support Members and Primary Support Members

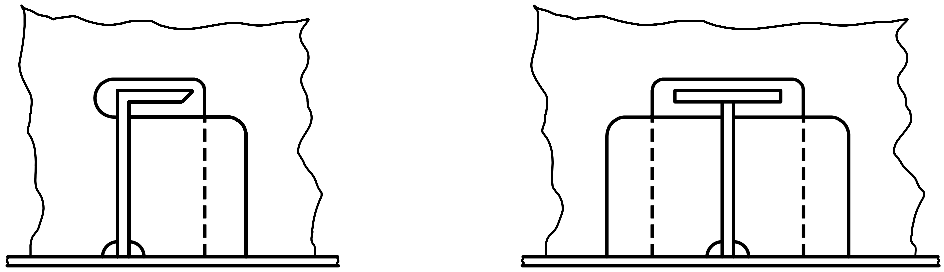
3.4.1 General

3.4.1.1 Cut-outs for the passage of stiffeners through the web of primary support members, and the related collaring arrangements, are to be designed to minimize stress concentrations around the perimeter of the opening and on the attached web stiffeners.
3.4.1.2 Cut-outs in way of cross-tie ends and floors under bulkhead stools or in high stress areas are to be fitted with "full" collar plates, see **Fig. 4.3.4**.
3.4.1.3 Lug type collar plates are to be fitted in cut-outs where required for compliance with the requirements of **3.4.3**, and in areas of significant stress concentrations, e.g., in way of primary support member toes. See **Fig. 4.3.5** for typical lug arrangements.
3.4.1.4 When, in the following locations, the calculated direct stress, σ_w, in the primary support member web stiffener according to **3.4.3.5** exceeds 80% of the permissible values a soft heel is to be provided in way of the heel of primary support member web stiffeners:

(a) connection to shell envelope longitudinals below the scantling draught, T_{sc}
(b) connection to inner bottom longitudinals.

A soft heel is not required at the intersection with watertight bulkheads, where a back bracket is fitted or where the primary support member web is welded to the stiffener face plate. The soft heel is to have a keyhole, similar to that shown in **Fig. 4.3.6(c)**.

Fig. 4.3.4 Collars for Cut-outs in Areas of High Stress



3.4.2 Details of cut-outs

3.4.2.1 Cut-outs are to have rounded corners and the corner radii are to be as large as practicable, with a minimum of 20 *percent* of the breadth of the cut-out or 25*mm*, whichever is greater, but need not be greater than 50*mm*.

3.4.3 Connection between primary support members and intersecting stiffeners (local support members)

3.4.3.1 The cross-sectional areas of the connections are to be determined from the proportion of load transmitted through each component in association with its appropriate permissible stress.

3.4.3.2 The total load, *W*, transmitted through the connection to the primary support member is given by:

$$W = P\,s\left(S - \frac{s}{2000}\right)10^{-3} \qquad (kN)$$

Where:

P : design pressure for the stiffener for the design load set being considered, in kN/m^2. The design load sets, method to derive the design pressure and applicable acceptance criteria set are to be taken in accordance with the following criteria, which define the Acceptance Criteria Set to be used
Table 8.2.5 in the cargo tank region
Section 8/3.9.2.2 in the area forward of the forward cargo tank
Section 8/3.9.2.2 in the aft end
Section 8/4.8.1.2 in the machinery space
Section 8/6.2.4.1 if subjected to sloshing loads
Section 8/6.3.5.1 if subjected to bottom slamming loads
Section 8/6.4.5.1 if subjected to bow impact loads

S : primary support member spacing, in *m*, as defined in **Section 4/2.2**

s : stiffener spacing, in *mm*, as defined in **Section 4/2.2**

For stiffeners having different primary support member spacing, *S*, and/or different pressure, *P*, at each side of the primary support member, the average load for the two sides is to be applied, e.g. vertical stiffeners at transverse bulkhead.

3.4.3.3 The load, W_1, transmitted through the shear connection is to be taken as:

$$W_1 = W\left(\alpha_a + \frac{A_{1-net}}{4 f_c A_{w-net} + A_{1-net}}\right) \qquad (kN)$$

$W_1 = W$ if the web stiffener is not connected to the intersecting stiffener

Where:

W : the total load, in *kN*, as defined in **3.4.3.2**

α_a : panel aspect ratio, not to be taken greater than 0.25

$$= \frac{s}{1000\,S}$$

S : primary support member spacing, in *m*

s : stiffener spacing, in *mm*

A_{1-net} : effective net shear area of the connection, to be taken as the sum of the components of the connection

$$A_{1d-net} + A_{1c-net} \qquad (cm^2)$$

in case of a slit type slot connections area, $A_{1\text{-}net}$, is given by:

$$A_{1-net} = 2 l_d t_{w-net} 10^{-2} \qquad (cm^2)$$

in case of a typical double lug or collar plate connection area, $A_{1\text{-}net}$, is given by:

$$A_{1-net} = 2 f_1 l_c t_{c-net} 10^{-2} \qquad (cm^2)$$

$A_{1d\text{-}net}$: net shear connection area excluding lug or collar plate, as given by the following and **Fig. 4.3.5**

$$A_{1d-net} = l_d t_{w-net} 10^{-2} \qquad (cm^2)$$

l_d : length of direct connection between stiffener and primary support member web, in *mm*

$t_{w\text{-}net}$: net web thickness of the primary support member, in *mm*

$A_{1c\text{-}net}$: net shear connection area with lug or collar plate, given by the following and **Fig. 4.3.5**

$$A_{1c-net} = f_1 l_c t_{c-net} 10^{-2} \qquad (cm^2)$$

l_c : length of connection between lug or collar plate and primary support member, in *mm*

$t_{c\text{-}net}$: net thickness of lug or collar plate, not to be taken greater than the thickness of the adjacent primary support member web, in *mm*

f_1 : shear stiffness coefficient

= 1.0 for stiffeners of symmetrical cross section

= 140/w for stiffeners of asymmetrical cross section but is not to be taken as greater than 1.0

w : the width of the cut-out for an asymmetrical stiffener, measured from the cut-out side of the stiffener web, in *mm*, as indicated in **Fig. 4.3.5**

$A_{w\text{-}net}$: effective net cross-sectional area of the primary support member web stiffener in way of the connection including backing bracket where fitted, as shown in **Fig. 4.3.6**, in cm^2. If the primary support member web stiffener incorporates a soft heel ending or soft heel and soft toe ending, $A_{w\text{-}net}$, is to be measured at the throat of the connection, as shown in **Fig. 4.3.6**.

f_c : the collar load factor defined as follows

for intersecting stiffeners of symmetrical cross section

= 1.85	for	$A_{w\text{-}net} \le 14$
= 1.85 – 0.0441($A_{w\text{-}net}$ – 14)	for	$14 < A_{w\text{-}net} \le 31$
= 1.1 – 0.013($A_{w\text{-}net}$ – 31)	for	$31 < A_{w\text{-}net} \le 58$
= 0.75	for	$A_{w\text{-}net} > 58$

for intersecting stiffeners of asymmetrical cross section

$$= 0.68 + 0.0172 \frac{l_s}{A_{w-net}}$$

where:

$l_s = l_c$ for a single lug or collar plate connection to the primary support member

= l_d for a single sided direct connection to the primary support member

= mean of the connection length on both sides, i.e., in the case of a lug or collar plus a direct connection, $l_s = 0.5(l_c + l_d)$

3.4.3.4 The load, W_2, transmitted through the primary support member web stiffener is to be taken as:

$$W_2 = W\left(1 - \alpha_a - \frac{A_{1-net}}{4 f_c A_{w-net} + A_{1-net}}\right) \qquad (kN)$$

Where:

W : the total load, in kN, as defined in **3.4.3 2**

α_a : panel aspect ratio

$$= \frac{s}{1000S}$$

S	: primary support member spacing, in *m*
s	: stiffener spacing, in *mm*
$A_{1\text{-}net}$	: effective net shear area of the connection, in cm^2, as defined in **3.4.3.3**
f_c	: collar load factor, as defined in **3.4.3.3**
$A_{w\text{-}net}$	: effective net cross-sectional area of the primary support member web stiffener , in cm^2, as defined in **3.4.3.3**

3.4.3.5 The values of $A_{w\text{-}net}$, $A_{wc\text{-}net}$ and $A_{1\text{-}net}$ are to be such that the calculated stresses satisfy the following criteria:

for the connection to the primary support member web stiffener away from the weld:

$$\sigma_w \le \sigma_{perm}$$

for the connection to the primary support member web stiffener in way of the weld:

$$\sigma_{wc} \le \sigma_{perm}$$

for the shear connection to the primary support member web:

$$\tau_w \le \tau_{perm}$$

Where:

σ_w	: direct stress in the primary support member web stiffener at the minimum bracket area away from the weld connection $= \frac{10W_2}{A_{w-net}}$ (N/mm^2)
σ_{wc}	: direct stress in the primary support member web stiffener in way of the weld connection $= \frac{10W_2}{A_{wc-net}}$ (N/mm^2)
τ_w	: shear stress in the shear connection to the primary support member $= \frac{10W_1}{A_{1-net}}$ (N/mm^2)
$A_{w\text{-}net}$	: effective net cross-sectional area of the primary support member web stiffener, in cm^2, as defined in **3.4.3.3**
$A_{wc\text{-}net}$	: effective net area of the web stiffener in way of the weld as shown in **Fig. 4.3.6**, in cm^2
$A_{1\text{-}net}$	: effective net shear area of the connection, in cm^2, as defined in **3.4.3.3**
W_1	: load transmitted through the shear connection, in *kN*, as defined in **3.4.3.3**
W_2	: load transmitted through the web stiffener, in *kN*, as defined in **3.4.3.4**
σ_{perm}	: permissible direct stress given in **Table 4.3.1** for the applicable acceptance criteria, see **3.4.3.2**, in N/mm^2
τ_{perm}	: permissible shear stress given in **Table 4.3.1** for the applicable acceptance criteria, see **3.4.3.2**, in N/mm^2

3.4.3.6 Where a backing bracket is fitted in addition to the primary support member web stiffener, it is to be arranged on the opposite side to, and in alignment with the web stiffener. The arm length of the bracket is to be not less than the depth of the web stiffener and its net cross-sectional area through the throat of the bracket is to be included in the calculation of $A_{w\text{-}net}$ as shown in **Fig. 4.3.6**.

3.4.3.7 Lapped connections of primary support member web stiffeners or tripping brackets to local support members are not permitted in the cargo tank region, e.g., lapped connections between transverse and longitudinal local support members.

3.4.3.8 Fabricated stiffeners having their face plate welded to the side of the web, leaving the edge of the web exposed, are not recommended for side shell and longitudinal bulkhead longitudinals. Where such sections are connected to the primary support member web stiffener, a symmetrical arrangement of connection to the transverse members is to be incorporated. This may be implemented by fitting backing brackets on the opposite side of the transverse web or bulkhead. In way of the cargo tank region, the primary support member web stiffener and backing brackets are to be butt welded to the intersecting stiffener web.

3.4.3.9 Where the web stiffener of the primary support member is parallel to the web of the intersecting stiffener, but not connected to it, the offset primary support member web stiffener may be located as shown in **Fig. 4.3.7**. The offset primary support member web stiffener is to be located in close proximity to the slot edge. See also **Fig. 4.3.7**. The ends of the offset web stiffeners are to be suitably tapered and softened.

3.4.3.10 Alternative arrangements will be specially considered on the basis of their ability to transmit load with equivalent effectiveness. Details of calculations made and/or testing procedures and results are to be submitted.

3.4.3.11 The size of the fillet welds is to be calculated according to **Section 6/5** based on the weld factors given in **Table 4.3.2**. For the welding in way of the shear connection the size is not to be less than that required for the primary support member web plate for the location under consideration.

Table 4.3.1 Permissible Stresses for Connection between Stiffeners and Primary Support Members

Item	Direct Stress, σ_{perm}, in N/mm^2			Shear Stress, τ_{perm}, in N/mm^2		
	Acceptance Criteria Set See **3.4.3.2**			Acceptance Criteria Set See **3.4.3.2**		
	AC1	AC2	AC3	AC1	AC2	AC3
Primary support member web stiffener	$0.83\ \sigma_{yd}$ (3)	σ_{yd}	σ_{yd}	-	-	-
Primary support member web stiffener to intersecting stiffener in way of weld connection:						
double continuous fillet	$0.58\ \sigma_{yd}$ (3)	$0.70\sigma_{yd}$ (3)	σ_{yd}	-	-	-
partial penetration weld	$0.83\sigma_{yd}$ (2)(3)	σ_{yd} (2) (3)	σ_{yd}	-	-	-
Primary support member stiffener to intersecting stiffener in way of lapped welding	$0.50\sigma_{yd}$	$0.60\sigma_{yd}$	σ_{yd}	-	-	-
Shear connection including lugs or collar plates:						
single sided connection	-	-	-	$0.71\ \tau_{yd}$	$0.85\ \tau_{yd}$	τ_{yd}
double sided connection	-	-	-	$0.83\tau_{yd}$	τ_{yd}	τ_{yd}

Where:

τ_{perm} permissible shear stress, in N/mm^2

σ_{perm} permissible direct stress, in N/mm^2

σ_{yd} minimum specified material yield stress, in N/mm^2

τ_{yd} $\frac{\sigma_{yd}}{\sqrt{3}}$, in N/mm^2

Note :

The stress computation on plate type members is to be performed on the basis of net thicknesses, whereas gross values are to be used in weld strength assessments, see **3.4.3.11**.

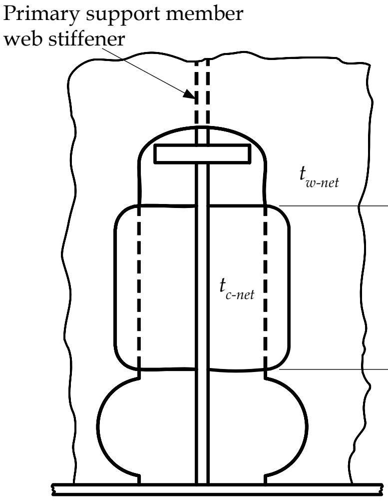
The root face is not to be greater than one third of the gross thickness of the primary support member stiffener.

Allowable stresses may be increased by 5 *percent* where a soft heel is provided in way of the heel of the primary support member web stiffener.

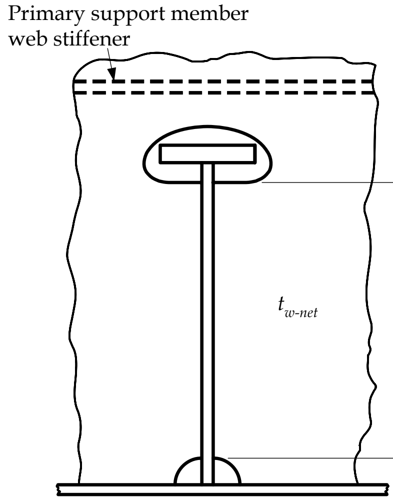
Table 4.3.2 Weld Factors for Connection between Stiffeners and Primary Support Members

Item	WELD FACTOR
Primary support member stiffener to intersecting stiffener	0.6 σ_w / σ_{perm} not to be less than 0.38
Shear connection inclusive lug or collar plate	0.38
Shear connection inclusive lug or collar plate, where the web stiffener of the primary support member is not connected to the intersection stiffener	0.6 τ_w / τ_{perm} not to be less than 0.44
Where: τ_w shear stress, as defined in **3.4.3.5** σ_w as defined in **3.4.3.5** τ_{perm} permissible shear stress, in N/mm^2, see **Table 4.3.1** σ_{perm} permissible direct stress, in N/mm^2, see **Table 4.3.1**	

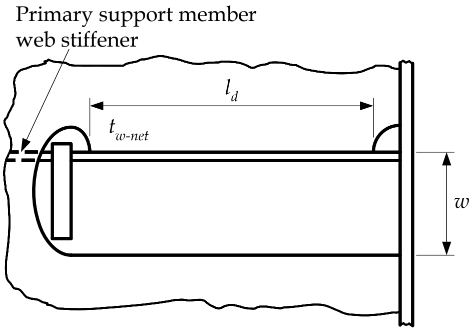
Fig. 4.3.5 Symmetric and Asymmetric Cut outs



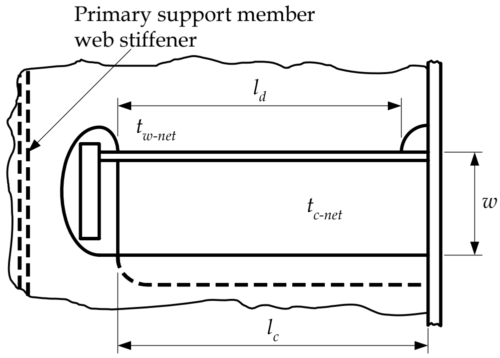
(a) double lug or collar plates



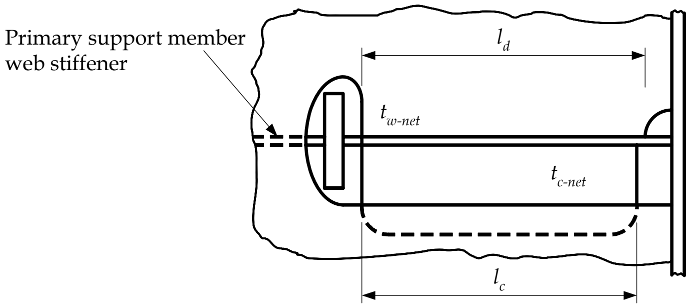
(b) slit type slot connection



(c) direct connection without
lug or collar plate



(d) lug or collar plate and
direct connection

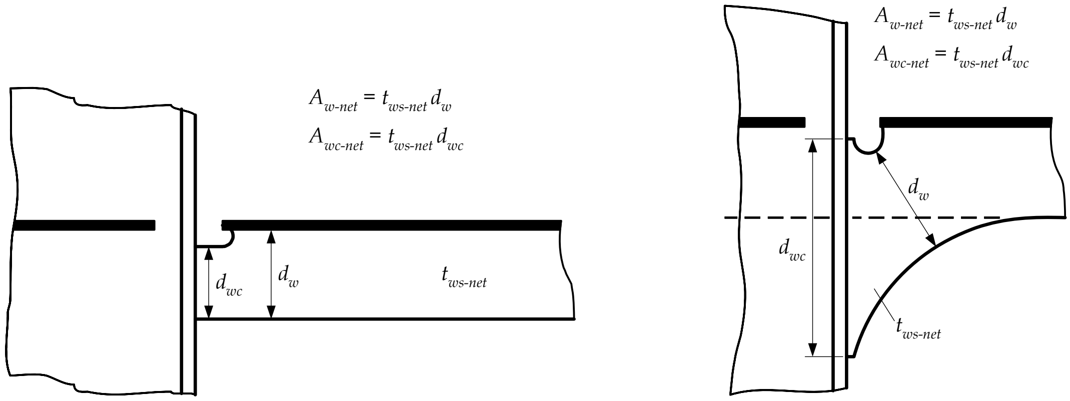


(e) lug or collar plate and
direct connection

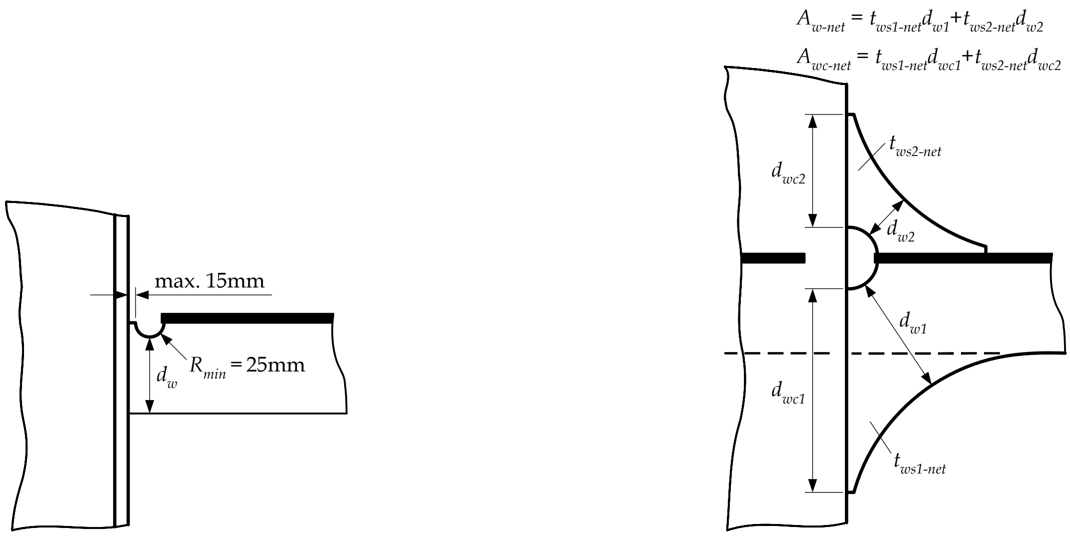
Note :

The details shown in this figure are only used to illustrate symbols and definitions and are not intended to represent design guidance or recommendations.

Fig. 4.3.6 Primary Support Member Web Stiffener Details



(a) straight heel no bracket (b) soft toe and soft heel



(c) keyhole in way of soft heel (d) symmetrical soft toe brackets

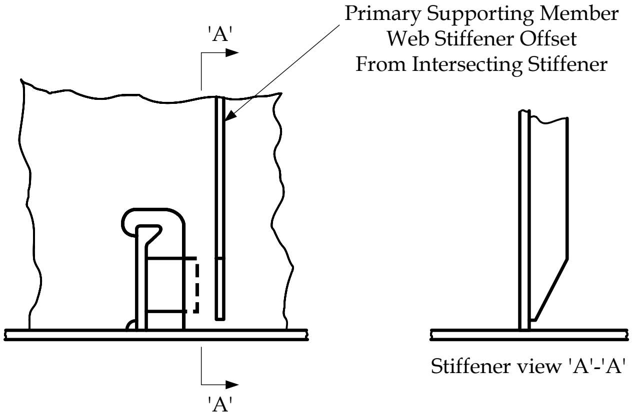
Where:

$t_{ws\text{-}net}$, $t_{ws1\text{-}net}$ and $t_{ws2\text{-}net}$	: net thickness of the primary support member web stiffener/backing bracket, in *mm*
d_w, d_{w1} and d_{w2}	: minimum depth of the primary support member web stiffener/backing bracket, in *mm*
d_{wc}, d_{wc1} and d_{wc2}	: length of connection between the primary support member web stiffener/backing bracket and the local support stiffener, in *mm*

Note :

Except where specific dimensions are noted for the details of the keyhole in way of the soft heel, see **3.4.1.4**, the details shown in this figure are only used to illustrate symbols and definitions and are not intended to represent design guidance or recommendations.

Fig. 4.3.7 Offset Primary Support Member Web Stiffeners



3.5 Openings

3.5.1 General

3.5.1.1 Openings are to have well rounded corners.

3.5.1.2 Manholes, lightening holes and other similar openings are to be avoided in way of concentrated loads and areas of high shear. In particular, manholes and similar openings are to be avoided in high stress areas unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory. Examples of high stress areas include:

(a) in vertical or horizontal diaphragm plates in narrow cofferdams/double plate bulkheads within one-sixth of their length from either end
(b) in floors or double bottom girders close to their span ends
(c) above the heads and below the heels of pillars.

Where larger openings than given by **3.5.2** or **3.5.3** are proposed, the arrangements and compensation required will be specially considered.

3.5.2 Manholes and lightening holes in single skin sections not requiring reinforcement

3.5.2.1 Openings cut in the web with depth of opening not exceeding 25 *percent* of the web depth and located so that the edges are not less than 40 *percent* of the web depth from the faceplate do not generally require reinforcement. The length of opening is not to be greater than the web depth or 60 *percent* of the local support member spacing, whichever is greater. The ends of the openings are to be equidistant from the corners of cut outs for local support members.

3.5.3 Manholes and lightening holes in double skin sections not requiring reinforcement

3.5.3.1 Where openings are cut in the web and are clear of high stress areas, reinforcement of these openings is not required provided that the depth of the opening does not exceed 50 *percent* of the web depth and is located so that the edges are well clear of cut outs for the passage of local support members.

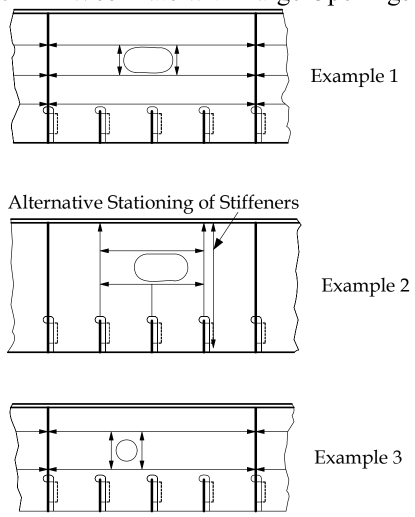
3.5.4 Manholes and lightening holes requiring reinforcement

3.5.4.1 Manholes and lightening holes are to be stiffened as required by **3.5.3.2** and **3.5.3.3.** The stiffening requirements of **3.5.3.2** and **3.5.3.3** may be modified where alternative arrangements are demonstrated as satisfactory with regards to stress and stability, in accordance with analysis methods described in **Section 9/2**.

3.5.4.2 The web plate is to be specially stiffened at openings when the mean shear stress, as determined by application of the requirements of **Section 8** or **Section 9/2**, is greater than 50N/mm^2 for acceptance criteria set AC1 or greater than 60N/mm^2 for acceptance criteria set AC2. The stiffening arrangement is to ensure buckling strength as required by **Section 10** under application of the loading as required in **Section 8** or **Section 9/2**.

3.5.4.3 On members contributing to longitudinal strength, stiffeners are to be fitted along the free edges of the openings parallel to the vertical and horizontal axis of the opening. Stiffeners may be omitted in one direction if the shortest axis is less than 400*mm*, and in both directions if length of both axes is less than 300*mm*. Edge reinforcement may be used as an alternative to stiffeners. See **Fig. 4.3.8**.

Fig. 4.3.8 Web Plate with Large Openings



3.6 Local Reinforcement

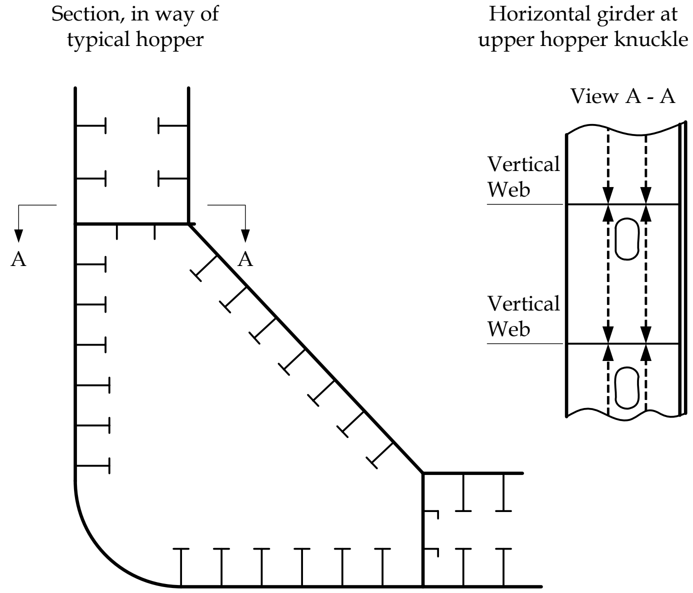
3.6.1 Reinforcement at knuckles

3.6.1.1 Whenever a knuckle in a main member (shell, longitudinal bulkhead etc.) is arranged, adequate stiffening is to be fitted at the knuckle to transmit the transverse load. This stiffening, in the form of webs, brackets or profiles, is to be connected to the transverse members to which they are to transfer the load (in shear). See **Fig. 4.3.9**.

3.6.1.2 In general, for longitudinal shallow knuckles, closely spaced carlings are to be fitted across the knuckle, between longitudinal members above and below the knuckle. Carlings or other types of reinforcement need not be fitted in way of shallow knuckles that are not subject to high lateral loads and/or high in-plane loads across the knuckle, such as deck camber knuckles.

3.6.1.3 Generally, the distance between the knuckle and the support stiffening described in **3.6.1.1** is not to be greater than 50*mm*.

Fig. 4.3.9 Example of Reinforcement at Knuckles



3.6.2 Reinforcement for openings and attachments associated with means of access for inspection purposes

3.6.2.1 Local reinforcement is to be provided taking into account proper location and strength of all attachments to the hull structure for access for inspection purposes.

3.7 Fatigue Strength

3.7.1 General

3.7.1.1 Structural details are to be designed for compliance with the requirements of fatigue strength as specified in **Section 9/3**.