For ice class IA Super, ship with a bulb, C_1 and C_2 shall be calculated as follows:

$$C_1 = f_1 \frac{BL}{2\frac{T}{B}+1} + 2.89(f_2 B + f_3 L + f_4 BL),$$

$$C_2 = 6.67(g_1 + g_2 B) + g_3 \left(1 + 1.2\frac{T}{B}\right)\frac{B^2}{\sqrt{L}}.$$

Coefficients f_1-f_4 and g_1-g_3 are given in Table 3-3.

Table 3-3: Values of coefficients f_1-f_4 and g_1-g_3 for the determination of C_1 and C_2

f_1 = 10.3 N/m^2	g_1 = 1530 N
f_2 = 45.8 N/m	g_2 = 170 N/m
f_3 = 2.94 N/m	g_3 = 400 N/m$^{1.5}$
f_4 = 5.8 N/m^2	

C_3 = 460 kg/(m^{2}s^2)

C_4 = 18.7 kg/(m^{2}s^2)

C_5 = 825 kg/s^2

If the value of the term $\left(\frac{LT}{B^2}\right)^3$ is less than 5, the value 5 shall be used and if the value of the term is more than 20, the value 20 shall be used.

3.2.5 Other methods of determining K_e or R_{CH}

For an individual ship, in lieu of the K_e or R_{CH} values defined in sections 3.2.2 and 3.2.3, the use of K_e or R_{CH} values based on more precise calculations or values based on model tests may be approved. Such approval will be given on the understanding that it can be revoked if experience of the ship's performance provides grounds for this in practice.

The design requirement for ice classes is a minimum speed of 5 knots in the following brash ice channels:

IA Super H_M = 1.0 m and a 0.1 m thick consolidated layer of ice
IA = 1.0 m
IB = 0.8 m
IC = 0.6 m.

4 HULL STRUCTURAL DESIGN

4.1 General

The method for determining hull scantlings is based on certain assumptions concerning the nature of the ice load on the structure. These assumptions are based on full-scale observations made in the northern Baltic.

It has thus been observed that the local ice pressure on small areas can reach rather high values. This pressure may well be in excess of the normal uniaxial crushing strength of sea ice. This is explained by the fact that the stress field is in fact multiaxial.

Furthermore, it has been observed that the ice pressure on a frame can be higher than on the shell plating at the midspacing between frames. This is due to the different flexural stiffness of frames and shell plating. The load distribution is assumed to be as shown in Figure 4-1.

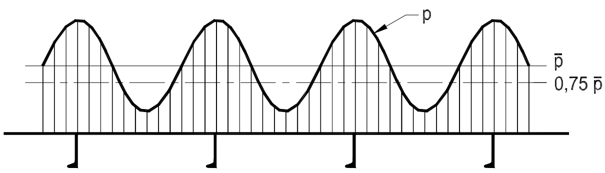


Figure 4-1. Ice load distribution on a ship's side.

Direct analysis may be substituted for the formulae and values given in this section if they are deemed by the Administration or the classification society to be invalid or inapplicable for a given structural arrangement or detail. Otherwise, direct analysis is not to be used as an alternative to the analytical procedures prescribed by the explicit requirements in sections 4.3 – 4.5.

Direct analyses are to be carried out using the load patch defined in section 4.2 (p, h and l_a). The pressure to be used is 1.8p where p is determined according to 4.2.2. The load patch must be applied at locations where the capacity of the structure under the combined effects of bending and shear is minimised. In particular, the structure must be checked with a load centred at the UIWL, 0.5h_0 below the LIWL, and positioned at several vertical locations in between. Several horizontal locations shall also be checked, especially the locations centred at the mid-span or -spacing. Furthermore, if the load length l_a cannot be determined directly from the arrangement of the structure, several values of l_a shall be checked using corresponding values for c_a.

The acceptance criterion for designs is that the combined stresses from bending and shear, when using the von Mises yield criterion, are lower than the yield point σ_y. When the direct calculation is based on beam theory, the allowable shear stress must be no larger than $0.9 \cdot \tau_y$, where $\tau_y = \sigma_y/\sqrt{3}$.

If scantlings derived from these regulations are less than those required by the classification society for a ship that has not been ice strengthened, the latter shall be used.

NB1. The frame spacings and spans defined in the following text are normally (in accordance with the appropriate classification society rules for the ship in question) assumed to be measured along the plate and perpendicular to the axis of the stiffener for plates, along the flange for members with a flange, and along the free edge for flat bar stiffeners. For curved members the span (or spacing) is defined as the chord length between span (or spacing) points. The span points are defined by the intersection between the flange or upper edge of the member and the supporting structural element (stringer, web frame, deck or bulkhead). Figure 4-2 illustrates the determination of the span and spacing for curved members.

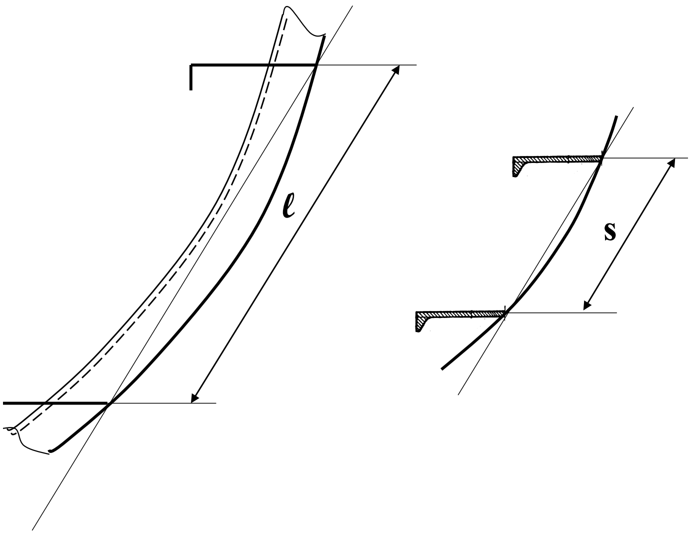


Figure 4-2. Definition of the frame span (left) and frame spacing (right) for curved members.

NB2. The effective breadth of the attached plate to be used for calculating the combined section modulus of the stiffener, stringer and web frame and attached plate must be given the value which the appropriate classification society rules require. The effective breadth shall in no case be more than what is stated in the appropriate classification society rules for the ship in question.

NB3. The requirements for the section modulus and shear area of the frames, stringers and web frames in 4.4, 4.5 and 4.6 are in accordance with the effective member cross section. For cases where the member is not normal to the plating, the section properties must be calculated in accordance with the appropriate classification society rules for the ship in question.

4.1.1 Hull regions

For the purpose of this section, the ship's hull is divided into regions as follows (see also Figure 4-3):

Bow region: From the stem to a line parallel to and $0.04 \cdot L$ aft of the forward borderline of the part of the hull where the waterlines run parallel to the centerline. For ice classes IA Super and IA, the overlap over the borderline need not exceed 6 metres, for ice classes IB and IC this overlap need not exceed 5 metres.

Midbody region: From the aft boundary of the Bow region to a line parallel to and $0.04 \cdot L$ aft of the aft borderline of the part of the hull where the waterlines run parallel to the centerline. For ice classes IA Super and IA, the overlap over the borderline need not exceed 6 metres, for ice classes IB and IC this overlap need not exceed 5 metres.

Stern region: From the aft boundary of the Midbody region to the stern.

L shall be taken as the ship's rule length used by the classification society.

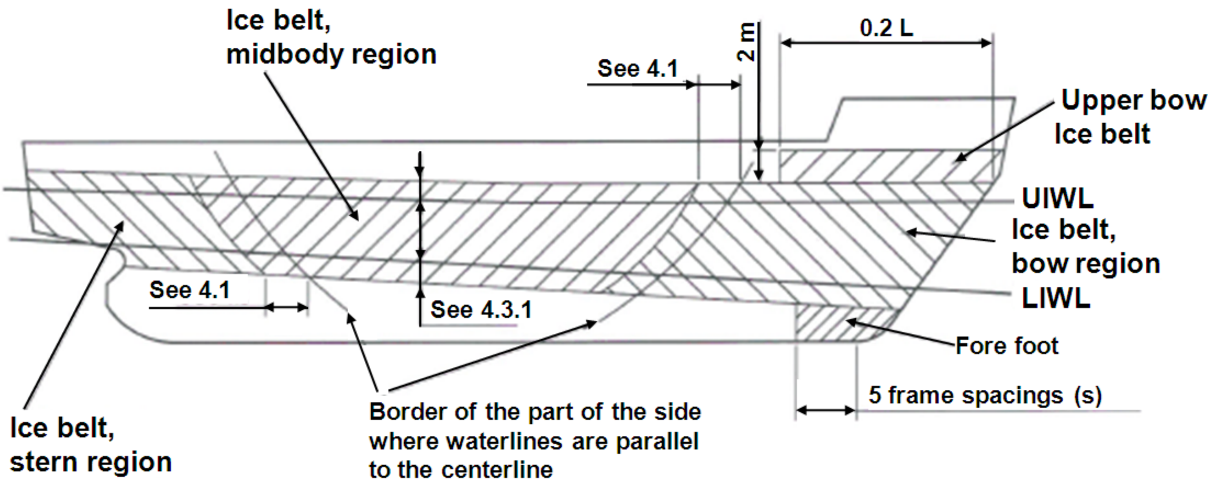


Figure 4-3. Ice strengthened regions of the hull.

4.2 Ice load

4.2.1 Height of the ice load area

An ice-strengthened ship is assumed to operate in open sea conditions corresponding to a level ice thickness not exceeding h_i. The design ice load height (h) of the area actually under ice pressure at any particular point of time is, however, assumed to be only a fraction of the ice thickness. The values for h_i and h are given in Table 4-1.

Table 4-1: Values of h_i and h for the different ice classes

Ice Class	h_i [m]	h [m]
IA Super	1.0	0.35
IA	0.8	0.30
IB	0.6	0.25
IC	0.4	0.22

4.2.2 Ice pressure

The design ice pressure is determined by the formula:

$$p = c_d c_p c_a p_0 \text{ [MPa]}, \tag{4.1}$$

where

c_d is a factor which takes account of the influence of the size and engine output of the ship. The value of this factor is a maximum of c_d = 1. It is calculated using the formula:

$$c_d = \frac{ak+b}{1000}, \tag{4.2}$$

where

$$k = \frac{\sqrt{\Delta P}}{1000}. \qquad (4.3)$$

The values of *a* and *b* are given in Table 4-2.

Table 4-2: Values of a and b for different hull areas.

	Bow		Midbody and Stern	
	k≤12	*k*>12	*k*≤12	*k*>12
a	30	6	8	2
b	230	518	214	286

Δ is the displacement of the ship at a maximum ice class draught [t] (see section 2.2).

P is the actual continuous engine output of the ship [kW] (see section 3.1) available when sailing in ice. If additional power sources are available for propulsion power (e.g. shaft motors) in addition to the power of the main engine(s), they shall also be included in the total engine output used as the basis for hull scantling calculations. The engine output used for the calculation of the hull scantlings shall be clearly stated on the shell expansion drawing.

c_p is a factor that reflects the magnitude of the load expected in the hull area in question relative to the bow area.

The value of c_p is given in Table 4-3.

Table 4-3: Values of c_p for different hull areas.

	Bow	Midbody	Stern
IA Super	1.0	1.0	0.75
IA	1.0	0.85	0.65
IB	1.0	0.70	0.45
IC	1.0	0.50	0.25

c_a is a factor which takes account of the probability that the full length of the area under consideration will be under pressure at the same time. It is calculated using the formula:

$$c_a = \sqrt{\frac{l_0}{l_a}}, \text{ maximum 1.0, minimum 0.35, } l_0 = 0.6 \text{ m}. \qquad (4.4)$$

Values of l_a are given in Table 4-4.

p_o is the nominal ice pressure; the value 5.6 MPa shall be used.

Table 4-4: Values of l_a for different structural elements.

Structure	Type of framing	l_a [m]
Shell	Transverse	Frame spacing
	Longitudinal	1.7×Frame spacing
Frames	Transverse	Frame spacing
	Longitudinal	Span of frame
Ice Stringer		Span of stringer
Web frame		2×Web frame spacing

4.3 Shell plating

4.3.1 Vertical extension of ice strengthening for plating (ice belt)

The vertical extension of the ice belt shall be as given in Table 4-5 (see Figure 4-3).

Table 4-5: Vertical extension of the ice belt.

<table>
<tr><th>Ice class</th><th>Hull region</th><th>Above UIWL</th><th>Below LIWL</th></tr>
<tr><td rowspan="3">IA Super</td><td>Bow</td><td rowspan="3">0.60 m</td><td rowspan="2">1.20 m</td></tr>
<tr><td>Midbody</td></tr>
<tr><td>Stern</td><td>1.0 m</td></tr>
<tr><td rowspan="3">IA</td><td>Bow</td><td rowspan="3">0.50 m</td><td>0.90 m</td></tr>
<tr><td>Midbody</td><td rowspan="2">0.75 m</td></tr>
<tr><td>Stern</td></tr>
<tr><td rowspan="3">IB and IC</td><td>Bow</td><td rowspan="3">0.40 m</td><td>0.70 m</td></tr>
<tr><td>Midbody</td><td rowspan="2">0.60 m</td></tr>
<tr><td>Stern</td></tr>
</table>

In addition, the following areas shall be strengthened:

Fore foot: For ice class IA Super, the shell plating below the ice belt from the stem to a position five main frame spacings abaft of the point where the bow profile departs from the keel line shall be ice-strengthened in the same way as the bow region.

Upper bow ice belt: For ice classes IA Super and IA on ships with an open water service speed equal to or exceeding 18 knots, the shell plate from the upper limit of the ice belt to 2 m above it and from the stem to a position at least 0.2 *L* abaft of the forward perpendicular shall be ice-strengthened in the same way as the midbody region. A similar strengthening of the bow region is also advisable for a ship with a lower service speed when, on the basis of the model tests, for example, it is evident that the ship will have a high bow wave.

Sidescuttles shall not be situated in the ice belt. If the weather deck on any part of the ship is situated below the upper limit of the ice belt (e.g. in the way of the well of a raised quarter decker), the bulwark shall be provided with at least the same strength as is required for the shell in the ice belt. The strength of the construction of the freeing ports shall meet the same requirements.

4.3.2 Plate thickness in the ice belt

For transverse framing, the thickness of the shell plating shall be determined by the formula:

$$t = 667s\sqrt{\frac{f_1 p_{pl}}{\sigma_y}} + t_c \text{ [mm]}, \tag{4.5}$$

and for longitudinal framing, the thickness of the shell plating shall be determined by the formula:

$$t = 667s\sqrt{\frac{p}{f_2 \sigma_y}} + t_c \text{ [mm]}, \tag{4.6}$$

where

s is the frame spacing [m]

$p_{pl} = 0.75p$ [MPa], where p is as given in 4.2.2

$f_1 = 1.3 - \frac{4.2}{(h/s+1.8)^2}$, maximum 1.0,

$$f_2 = \begin{cases} 0.6 + \dfrac{0.4}{h/s}, when\ h/s \le 1 \\ 1.4 - 0.4(h/s), when\ 1 \le h/s \le 1.8, \end{cases}$$

where h is as given in section 4.2.1

σ_y is the yield stress of the material [N/mm^2], for which the following values shall be used:

σ_y = 235 N/mm^2 for normal-strength hull structural steel

σ_y = 315 N/mm^2 or higher for high-strength hull structural steel

If steels with different yield stress are used, the actual values may be substituted for the above ones if accepted by the classification society.

t_c is the increment for abrasion and corrosion [mm]; t_c shall normally be 2 mm; if a special surface coating, shown by experience to be capable of withstanding abrasion by ice, is applied and maintained, lower values may be approved.

4.4 Frames

4.4.1 Vertical extension of ice strengthening for framing

The vertical extension of the ice strengthening of framing shall be at least as given in Table 4-6.

Table 4-6: Vertical extension of the ice strengthening of framing.

Ice class	Hull region	Above UIWL	Below LIWL
IA Super	Bow	1.2 m	Down to tank top or below top of the floors
	Midbody		2.0 m
	Stern		1.6 m
IA, IB and IC	Bow	1.0 m	1.6 m
	Midbody		1.3 m
	Stern		1.0 m

Where an upper bow ice belt is required (see 4.3.1), the ice-strengthened part of the framing shall be extended to at least the top of this ice belt.

Where the ice-strengthening would go beyond a deck, the top or bottom plating of a tank or tank top by no more than 250 mm, it can be terminated at that deck, top or bottom plating of the tank or tank top.

4.4.2 Transverse frames

4.4.2.1 Section modulus and shear area

The section modulus of a main or intermediate transverse frame shall be calculated using the formula:

$$Z = \frac{pshl}{m_t \sigma_y} 10^6 \ [\mathrm{cm}^3], \tag{4.7}$$

and the effective shear area will be calculated from

$$A = \frac{\sqrt{3} f_3 phs}{2\sigma_y} 10^4 \ [\mathrm{cm}^2], \tag{4.8}$$

where

p is the ice pressure as given in 4.2.2 [MPa]

s is the frame spacing [m]

h is the height of the load area as given in 4.2.1 [m]

l is the span of the frame [m]

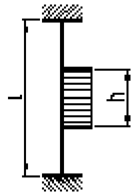
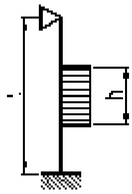
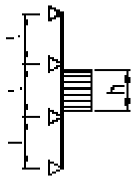
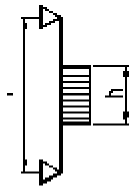
$m_t = \frac{7m_0}{7-5h/l}$,

f_3 is a factor which takes account of the maximum shear force versus the load location and the shear stress distribution, $f_3 = 1.2$

σ_y is the yield stress as in 4.3.2 [N/mm^2]

m_o takes the boundary conditions into account. The values of m_o are given in Table 4-7.

Table 4-7: Values of m_o for different boundary conditions.

Boundary condition	m_o	Example
	7	Frames in a bulk carrier with top wing tanks
	6	Frames extending from the tank top to the main deck of a single-decked vessel
	5.7	Continuous frames between several decks or stringers
	5	Frames extending between two decks only

The boundary conditions are those for the main and intermediate frames. Load is applied at mid span.

Where less than 15% of the span, *l*, of the frame is situated within the ice-strengthening zone for frames as defined in 4.4.1, ordinary frame scantlings may be used.

4.4.2.2 Upper end of transverse framing

The upper end of the strengthened part of a main frame and of an intermediate ice frame shall be attached to a deck, top or bottom plating of a tank or an ice stringer (section 4.5).

Where a frame terminates above a deck or a stringer which is situated at or above the upper limit of the ice belt (section 4.3.1), the part above the deck or stringer may have the scantlings required by the classification society for an non ice-strengthened ship and the upper end of an intermediate frame may be connected to the adjacent frames by a horizontal member with the same scantlings as the main frame.

4.4.2.3 Lower end of transverse framing

The lower end of the strengthened part of a main frame and of an intermediate ice frame shall be attached to a deck, top or bottom plating of a tank, tank top or an ice stringer (section 4.5).

Where an intermediate frame terminates below a deck, top or bottom plating of a tank, tank top or ice stringer which is situated at or below the lower limit of the ice belt (section 4.3.1), the lower end may be connected to the adjacent main frames by a horizontal member of the same scantlings as the main frames. Note that the main frames below the lower edge of the ice belt must be ice strengthened, see 4.4.1.

4.4.3 Longitudinal frames

The following requirements are intended for longitudinal frames with all end conditions.

The section modulus of a longitudinal frame shall be calculated using the formula:

$$Z = \frac{f_4 p h l^2}{m \sigma_y} 10^6 \text{ [cm}^3\text{]}. \quad (4.9)$$

The effective shear area of a longitudinal frame shall be:

$$A = \frac{\sqrt{3} f_4 f_5 p h l}{2 \sigma_y} 10^4 \text{[cm}^2\text{]}. \quad (4.10)$$

In calculating the actual shear area of the frames, the shear area of the brackets should not be taken into account.

In the formulae given above:

f_4 is a factor which takes account of the load distribution over adjacent frames:

$$f_4 = (1 - 0.2\, h/s)$$

f_5 is a factor which takes account of the maximum shear force versus the load location and the shear stress distribution:

$$f_5 = 2.16$$

p is the ice pressure as given in section 4.2.2 [MPa]

h is the height of load area as given in section 4.2.1 [m]

s is the frame spacing [m]

l is the total span of the frame [m]

m is a boundary condition factor and m = 13.3 for a continuous beam with brackets; where the boundary conditions deviate significantly from those of a continuous beam with brackets, e.g. in an end field, a smaller boundary condition factor may be required.

σ_y is the yield stress as in 4.3.2 [N/mm^2].

4.4.4 General on framing

4.4.4.1 The attachment of frames to supporting structures

Within the ice-strengthened area, all frames shall be effectively attached to all of the supporting structures. A longitudinal frame shall be attached by brackets to all supporting web frames and bulkheads. When a transversal frame terminates at a stringer or deck, a bracket or similar construction must be fitted. When a frame is running through the supporting structure, both sides of the web plate of the frame must be connected to the structure (by direct welding, collar plate or lug). When a bracket is installed, it must have at least the same thickness as the web plate of the frame and the edge must be appropriately stiffened against buckling.

4.4.4.2 Support of frames against instability, in particular tripping

The frames shall be attached to the shell by a double continuous weld. No scalloping is allowed (except when crossing shell plate butts).

The web thickness of the frames shall be at least the maximum of the following:

- $\frac{h_w\sqrt{\sigma_y}}{C}$, h_w is the web height and C = 805 for profiles and C = 282 for flat bars;
- half of the net thickness of the shell plating, $t - t_c$. For the purpose of calculating the minimum web thickness of frames, the required thickness of the shell plating must be calculated according to 4.3.2 using the yield strength σ_y of the frames;
- 9 mm.

Where there is a deck, top or bottom plating of a tank, tank top or bulkhead in lieu of a frame, the plate thickness of it shall be calculated as above, to a depth corresponding to the height of the adjacent frames. In such a case, the material properties of the deck, top or bottom plating of the tank, tank top or bulkhead and the frame height h_w of the adjacent frames shall be used in the calculations, and the constant C shall be 805.

Asymmetrical frames and frames which are not at right angles to the shell (web less than 90 degrees to the shell) shall be supported against tripping by brackets, intercoastals, stringers or similar, at a distance not exceeding 1,300 mm. For frames with spans greater than 4 m, the extent of antitripping supports must be applied to all regions and for all ice classes. For frames with spans less than or equal to 4 m, the extent of antitripping supports must be applied to all regions for ice class IA Super, to the bow and midbody regions for ice class IA, and to the bow region for ice classes IB and IC. Direct calculation methods may be applied to demonstrate the equivalent level of support provided by alternative arrangements.

4.5 Ice stringers

4.5.1 Stringers within the ice belt

The section modulus of a stringer situated within the ice belt (see 4.3.1) shall be calculated using the formula:

$$Z = \frac{f_6 f_7 p h l^2}{m\sigma_y} 10^6 \text{ [cm}^3\text{]}, \tag{4.11}$$

and the effective shear area shall be:

$$A = \frac{\sqrt{3} f_6 f_7 f_8 phl}{2\sigma_y} 10^4 \ [\text{cm}^2], \tag{4.12}$$

where

p is the ice pressure as given in section 4.2.2 [MPa]

h is the height of the load area as given in section 4.2.1 [m]

If the product $p \cdot h$ is less than 0.15, value 0.15 [MN/m] shall be used.

l is the span of the stringer [m]

m is a boundary condition factor as defined in section 4.4.3

f_6 is a factor which takes account of the distribution of load over the transverse frames; $f_6 = 0.9$

f_7 is the safety factor of the stringers; $f_7 = 1.8$

f_8 is a factor that takes account of the maximum shear force versus the load location and the shear stress distribution; $f_8 = 1.2$

σ_y is the yield stress as in section 4.3.2.

4.5.2 Stringers outside the ice belt

The section modulus of a stringer situated outside the ice belt but supporting ice-strengthened frames shall be calculated using the formula:

$$Z = \frac{f_9 f_{10} phl^2}{m\sigma_y}(1 - h_s/l_s) \ 10^6 \ [\text{cm}^3], \tag{4.13}$$

and the effective shear area shall be:

$$A = \frac{\sqrt{3} f_9 f_{10} f_{11} phl}{2\sigma_y}(1 - h_s/l_s) \ 10^4 \ [\text{cm}^2], \tag{4.14}$$

where

p is the ice pressure as given in section 4.2.2 [MPa]

h is the height of the load area as given in section 4.2.1 [m]

If the product $p \cdot h$ is less than 0.15, value 0.15 [MN/m] shall be used.

l is the span of the stringer [m]

m is the boundary condition factor as defined in section 4.4.3

l_s is the distance to the adjacent ice stringer [m]

h_s is the distance to the ice belt [m]

f_9 is a factor which takes account of the distribution of load over the transverse frames; $f_9 = 0.80$

f_{10} is the safety factor of the stringers; $f_{10} = 1.8$

f_{11} is a factor that takes account of the maximum shear force versus the load location and shear stress distribution; $f_{11} = 1.2$

σ_y is the yield stress of material as in section 4.3.2.

4.5.3 Deck strips

Narrow deck strips abreast of hatches and serving as ice stringers shall comply with the section modulus and shear area requirements given in 4.5.1 and 4.5.2 respectively. In the case of very long hatches, the classification society may permit the product $p \cdot h$ to be given a value of less than 0.15 but in no case less than 0.10.

Regard shall be paid to the deflection of the ship's sides due to ice pressure with respect to very long (more than $B/2$) hatch openings, when designing weatherdeck hatch covers and their fittings.

4.6 Web frames

4.6.1 Ice load

The ice load transferred to a web frame from an ice stringer or from longitudinal framing shall be calculated using the formula:

$$F = f_{12} phS \quad \text{[MN]}, \tag{4.15}$$

where

p is the ice pressure as given in section 4.2.2 [MPa], in calculating c_a, however, l_a shall be 2S.

h is the height of the load area as given in section 4.2.1 [m]

If the product $p \cdot h$ is less than 0.15, value 0.15 [MN/m] shall be used.

S is the distance between the web frames [m]

f_{12} is the safety factor of web frames; $f_{12} = 1.8$.

If the supported stringer is outside the ice belt, the force F shall be multiplied by $(1- h_s/l_s)$, where h_s and l_s shall be as defined in section 4.5.2.

4.6.2 Section modulus and shear area

The section modulus and shear area of the web frames shall be calculated using the formulae:

The effective shear area:

$$A = \frac{\sqrt{3}\alpha f_{13} Q}{\sigma_y} 10^4 \text{ [cm}^2\text{]}, \tag{4.16}$$

where

Q is the maximum calculated shear force under the ice load F, as given in section 4.6.1

f_{13} is a factor that takes account of the shear force distribution, $f_{13} = 1.1$

α is as given in Table 4-8

σ_y is the yield stress of the material as in section 4.3.2.

Section modulus:

$$Z = \frac{M}{\sigma_y}\sqrt{\frac{1}{1-(\gamma A/A_a)^2}}\,10^6\ [\mathrm{cm}^3], \tag{4.17}$$

where

M is the maximum calculated bending moment under the ice load F; this must be given the value $M = 0.193Fl$

γ is given in Table 4-8

A is the required shear area

A_a is the actual cross-sectional area of the web frame, $A_a = A_f + A_w$

Table 4-8: Values of factors α and γ

A_f/A_w	0	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
α	1.5	1.23	1.16	1.11	1.09	1.07	1.06	1.05	1.05	1.04	1.04
γ	0	0.44	0.62	0.71	0.76	0.80	0.83	0.85	0.87	0.88	0.89

where

A_f is the actual cross-sectional area of the free flange

A_w is the actual effective cross-sectional area of the web plate.

4.7 Stem

The stem shall be made of rolled, cast or forged steel, or of shaped steel plates as shown in Figure 4-4.

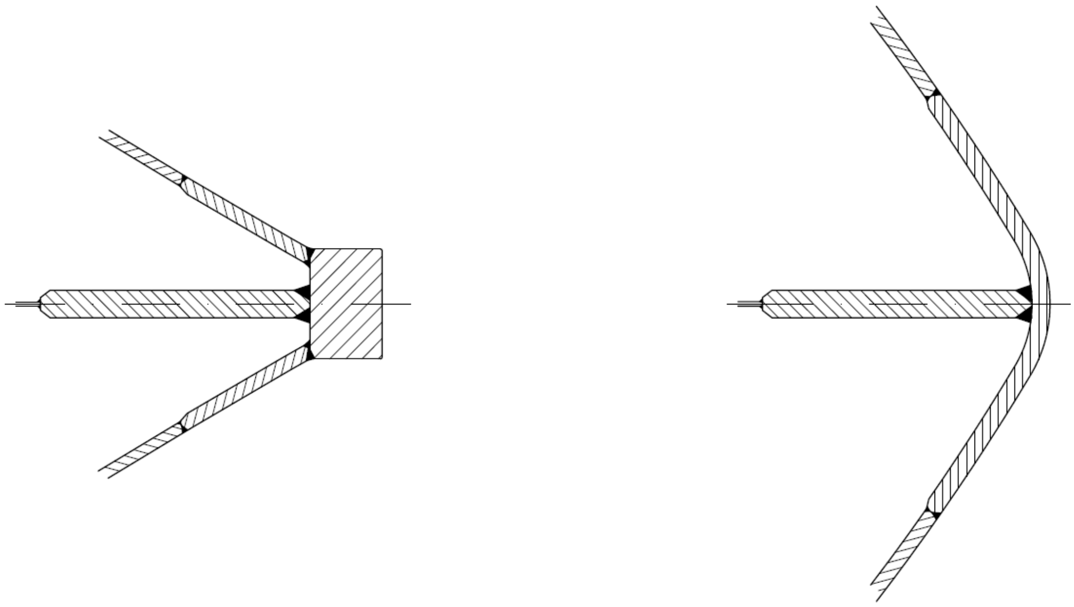


Figure 4-4. Examples of suitable stems.

The plate thickness of a shaped plate stem and, in the case of a blunt bow, any part of the shell where $\alpha \geq 30°$ and $\psi \geq 75°$ (see section 3.2.1 for angle definitions), shall be calculated according to formula 4.5, assuming that:

s is the spacing of elements supporting the plate [m]

$p_{PL} = p$ [MPa] (see section 4.3.2)

l_a is the spacing of vertical supporting elements [m].

The stem and the part of a blunt bow defined above shall be supported by floors or brackets spaced no more than 0.6 m apart and with a thickness of at least half the plate thickness. The reinforcement of the stem shall extend from the keel to a point 0.75 m above the UIWL or, if an upper bow ice belt is required (see section 4.3.1), to the upper limit of this.

4.8 Stern

The introduction of new propulsion arrangements with azimuthing thrusters, which provide improved manoeuvrability, will result in increased ice loading of the Stern region and the stern area. This fact should be considered in the design of the aft/stern structure.

In order to avoid very high loads on propeller blade tips, the minimum distance between the propeller(s) and the hull (including stern frame) should be no less than h_0 (see 4.2.1).

On twin and triple screw ships, the ice strengthening of the shell and framing shall be extended to the tank top 1.5 metres forward and aft of the side propellers.

The shafting and stern tubes of side propellers shall normally be enclosed within plated bossings. If detached struts are used, due consideration shall be taken of their design, strength and attachments to the hull.

5 RUDDER AND STEERING ARRANGEMENTS

The scantlings of the rudder post, rudder stock, pintles, steering engine etc. as well as the capability of the steering engine shall be determined according to the rules of the classification society. The maximum service speed of the ship to be used in these calculations shall, however, not be given a value lower than that stated below:

IA Super	20 knots
IA	18 knots
IB	16 knots
IC	14 knots

If the actual maximum service speed of the ship is higher, that speed shall be used.

The local scantlings of rudders must be determined assuming that the whole rudder belongs to the ice belt. Furthermore, the rudder plating and frames are to be designed using the ice pressure *p* for the plating and frames in the midbody region.

For ice classes IA and IA Super, the rudder (the rudder stock and the upper part of the rudder) shall be protected from direct contact with intact ice by an ice knife that extends below the LIWL, if practicable (or equivalent means). Special consideration shall be given to the design of the rudder and the ice knife for ships with flap-type rudders.

For ice classes IA and IA Super, due regard shall be paid to the large loads that arise when the rudder is forced out of the midship position when sailing astern in ice or into ice ridges. Suitable arrangements such as rudder stoppers shall be installed to absorb such loads.

Relief valves for the hydraulic pressure in rudder turning mechanism(s) shall be installed. The components of the steering gear (e.g. rudder stock, rudder coupling, rudder horn etc.) shall be dimensioned to withstand loads causing yield stresses within the required diameter of the rudder stock.

6 PROPULSION MACHINERY

6.1 Scope

These regulations apply to propulsion machinery covering open- and ducted-type propellers with a controllable pitch or fixed pitch design for ice classes IA Super, IA, IB and IC. The given propeller loads are the expected ice loads for the entire ship’s service life under normal operational conditions, including loads resulting from the changing rotational direction of FP propellers. However, these loads do not cover off-design operational conditions, for example when a stopped propeller is dragged through ice. However, the load models of the regulations do not include propeller/ice interaction loads when ice enters the propeller of a turned azimuthing thruster from the side (radially).

The regulations also apply to azimuthing and fixed thrusters for main propulsion, taking consideration of loads resulting from propeller/ice interaction and loads on the thruster body/ice interaction. The given azimuthing thruster body loads are the expected ice loads for the ship’s