MAIN PARTICULARS

$L_{WL} = 100{,}0$ m.
$L_{bp} = 98{,}0$ m.
$B = 16{,}0$ m.
$T = 6{,}5$ m.
$D = H = 9{,}0$ m.
$C_B = 0{,}6$
$v_0 = 16$ knots
$a = 600$ [mm]
$e = 2{,}4$ m.

The scantling length = ? ⇒ L = ?
(Hesap boyu)

$\%96 \cdot L_{WL} \leq L \leq \%97 \cdot L_{WL}$

$\therefore \quad L = 97$ m.

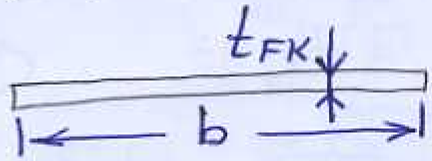
Let us find the thickness of outer shell.

Go to <u>Section 6 "Shell Structures"</u>

<u>B. Bottom Plating</u>

<u>5. Flat Plate Keel</u> and garboard strake

5.1 The width of the flat plate keel is not to be less than:



$$b = 800 + 5 \cdot L \quad [mm]$$
$$b = 1285 \ [mm]$$

$\therefore$ Let us take it 1300 [mm] ⇒ $b = 1300$ [mm]

The thickness of the plate keel is not to be less than:

$$t_{FK} = t_B + 2 \ [mm]$$ ⇒ (Within 0,7 L amidships and in way of engine seating)

or $t_{FK} = t_B$ ⇒ (otherwise)

t_B: thickness of the bottom plating (according to Section 6 - B - 1.1 or 1.2)

For ships with length $L \geq 90$ m.

$$t_{B1} = 18{,}3 \cdot n_f \cdot a \cdot \sqrt{\frac{P_B}{\sigma_{pl}}} + t_K \ [mm]$$

$$t_{B2} = 1{,}21 \cdot a \cdot \sqrt{P_B \cdot k} + t_K \ [mm]$$

whichever is greater, considered!

P_B: load on bottom [kN/m^2] (Section 4; B.3)

P_B : Load on the ship's bottom (S-6, B.3)

$$P_B = 10 \cdot T + P_0 \cdot C_F \quad [kN/m^2]$$

P_0: basic external dynamic load $[kN/m^2]$

$$P_0 = 2{,}1 \cdot (C_B + 0{,}7) \cdot C_0 \cdot C_L \cdot f \quad \text{(for heading waves)}$$

or $$P_{01} = 2{,}6 \cdot (C_B + 0{,}7) \cdot C_0 \cdot C_L \quad \text{(for side waves)}$$

C_0 : wave coefficient

for $90\,m \leq L \leq 300\,m$. $C_0 = \left[10{,}75 - \left(\frac{300 - L}{100}\right)^{1{,}5}\right] \cdot C_{RW}$

C_{RW} : service range coefficient. Let us take it 1,0 (for unlimited service range assumption)

$$C_0 = \left[10{,}75 - \left(\frac{300 - 97}{100}\right)^{1{,}5}\right] \cdot 1{,}0 = 7{,}86$$

f: probability factor

$f = 1$, for plate panels of the outer shell.

C_L: length coefficient $C_L = 1{,}0$ for $L \geq 90\,m$.

$\therefore$ $$P_0 = 2{,}1 \cdot (0{,}6 + 0{,}7) \cdot 7{,}86 \cdot 1{,}0 \cdot 1{,}0 = 21{,}45 \, [kN/m^2]$$

$$P_{01} = 2{,}6\,(0{,}6 + 0{,}7) \cdot 7{,}86 \cdot 1{,}0 = 26{,}56 \, [kN/m^2]$$

Let us consider $P_0 = 21{,}45\,[kN/m^2]$ for bottom thickness calculation.

$$P_B = 10 \cdot 6{,}5 + 21{,}45 \cdot 1{,}0 = 86{,}45 \, [kN/m^2]$$

Note that ($C_F = 1{,}0$) from Table 4.1 for the region of amidships, that is, region M.

Now, we may go back to S-6, B.1.2

$$\sigma_{PL} = \sqrt{\sigma_{perm}^2 - 3 \cdot \tau_L^2} - 0{,}89 \cdot \sigma_{LB} \quad [N/mm^2]$$

σ_{perm} : permissible design stress $[N/mm^2]$

k: material factor according to Section 2, B.2

$k = \frac{295}{R_{eH} + 60}$; R_{eH} : yield strength of steel used.

Definition: Steel with a yield strength (R_{eH}) of 235 (N/mm^2) is named as "normal strength hull structural steel".

Let us use "normal strength steel", then:

$$k = \frac{295}{235 + 60} \Rightarrow \underline{\underline{k = 1}}$$

Note that we should use the below formula, if we use "low strength steel" then:

$$k = \frac{235}{R_{eH}} \qquad (R_{eH} \leq 235) \text{ for low strength steel.}$$

$\sigma_{perm} = 230/k \Rightarrow \sigma_{perm} = 230\ [N/mm^2]$

What abaut σ_{LB} and τ_L ? As a first approximation,

$\sigma_{LB} = 120/k \Rightarrow \sigma_{LB} = 120\ [N/mm^2]$ and $\tau_L = 0$

(from S-6, B.1.2 for $L \geq 90$ m.)

$\sigma_{LB} = 120\ [N/mm^2]$

$$\sigma_{pl} = \sqrt{230^2 - 3 \cdot 0^2} - 0{,}89 \cdot 120 \Rightarrow \sigma_{pl} = 123{,}2\ [N/mm^2]$$

$n_f = 1{,}0$ for transverse framing system

$n_f = 0{,}83$ for longitudinal " "

First, let us consider that we use transverse framing system for construction, then:

$$t_{B_1} = 18{,}3 \cdot 1{,}0 \cdot 0{,}6 \cdot \sqrt{\frac{86{,}45}{123{,}2}} + t_K\ [mm]$$

$t_{B_1} = 9{,}2 + t_K\ [mm]$

$t_K = ?$; t_K : corrosion addition according to Section 3, K.

$t_K = 1,5$ [mm] for $t' \leq 10$ mm.

$t_K = \frac{0,1 \cdot t'}{\sqrt{k}} + 0,5$ [mm] for $t' > 10$ mm.

Because, $t' = 9,2 < 10$ mm. $\Rightarrow t_K = 1,5$ mm.

$\therefore\ t_{B1} = 9,2 + 1,5 \Rightarrow 10,7$ [mm] $= t_{B1}$

$t_{B2} = 1,21 \cdot 0,6 \cdot \sqrt{86,45 \cdot 1,0} + t_K$ [mm]

$t_{B2} = 6,75 + 1,5 \Rightarrow t_{B2} = 8,25$ [mm]

Which one to choose? We should consider whichever is greater! (That is t_{B1})

Because, we have steel plate panels with standart thickness, we must choose $t_B = 11,0$ [mm] For TFS

Then, $t_{FK} = t_B + 2 = 11 + 2 \Rightarrow t_{FK} = 13,0$ [mm]

What about, if we use longitudinal framing system!

Then, $n_f = 0,83$.

$t_{B1} = 18,3 \cdot 0,83 \cdot 0,6 \cdot \sqrt{86,45/123,2} + t_K = 7,6 + 1,5 = 9,1$ [mm]

$t_{B2} = 8,25$ [mm] (allready found earlier)

$t_B = 9,5$ [mm]

Here, a "last" check is made (for the minimum outer shell thickness by GL)

for $L \geq 50$ m. $t_{min} = \sqrt{L \cdot k}$ [mm] $\Rightarrow t_{min} = 9,85$ [mm]

Therefore, $t_B = 10$ [mm] (at least!)

For LFS $t_{FK} = 12$ [mm]

ALSO, THICKNESS FOUND MUST BE CHECKED FOR BUCKLING!!!

DOUBLE BOTTOM CONSTRUCTION (MEMBERS)

Section 8 - Bottom Structures

B- Double Bottom

B.2 Centre girder

B.2.2 Scantlings

$h = 350 + 45 \cdot l$ [mm]. $l = B$ (in general)

$h_{min} = 600$ [mm]

$h = 1070$ [mm] Let us take it, $h_a = 1100$ [mm]

B.2.2. The thickness of the centre girder:

$$t_m = \frac{h}{h_a}\left(\frac{h}{100} + 1{,}0\right)\sqrt{K} \quad \text{for} \quad h \leq 1200 \text{ [mm]}$$

h_a: depth of centre girder as built [mm]

$$t_m = \frac{1070}{1100}\left(\frac{1070}{100} + 1\right)\sqrt{1} \Rightarrow t_m = 11{,}4 \text{ [mm]}$$

$t_m = 11{,}5$ [mm]

B.3. Side Girders

Arrangement of side girders?

If $B/2 > 4{,}5$ m. One side girder fitted each side.

If $B/2 > 8{,}0$ m Two side girders at each side.

If $B/2 > 10{,}5$ m. Three side girders at each side.

For this ship $B = 16$ m. and $B/2 = 8$ m. ??

Let us take two side girders at each side!

B.3.2 The thickness of the side girders:

$$t = \frac{h^2}{120 \cdot h_a}\sqrt{K} \text{ [mm]} \Rightarrow t = \frac{1070^2}{120 \cdot 1100}\sqrt{1} = 8{,}7 \text{ [mm]}$$

$t = 9{,}0$ [mm]

B.6.1 Plate floors (for transverse framing system)

6.2. Scantlings

6.2.1 The thickness of ~~centre girder~~ plate floor:

$$t_{pf} = t_m - 2{,}0 \cdot \sqrt{k} \ [mm]$$

$$t_{pf} = 11{,}5 - 2{,}0 \cdot \sqrt{1{,}0} \Rightarrow \boxed{t_{pf} = 9{,}5 [mm]}$$

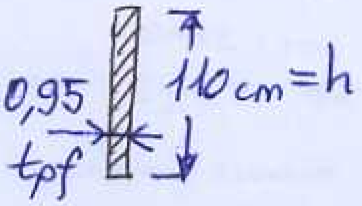
Check for "manhole" or "lightening" holes!

6.2.2 The web sectional area of the plate floors:

$$A_w = \varepsilon \cdot T \cdot l \cdot e \cdot \left(1 - \frac{2y}{l}\right) k \ [cm^2]$$

Let us check if we can open a manhole, 2 m. away from the side shell, that is, $y = 2m$.

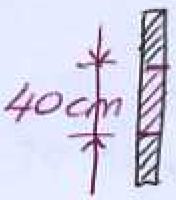
$$A_w = 0{,}3 \cdot 6{,}5 \cdot 16 \cdot 2{,}4 \cdot (1 - 2 \cdot 2/16) \cdot 1{,}0 = \underline{56{,}2 [cm^2]}$$



Real web sectional area: $A = 0{,}95 \times 110$

$$\underline{A = 104{,}5 [cm^2]}$$

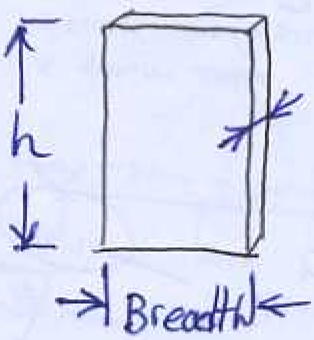
A manhole 400 x 600 or 400 x 400



$$A = 104{,}5 - 40 \times 0{,}95 = \underline{66{,}5 [cm^2]} > A_w = 56{,}2 [cm^2]$$

<u>A manhole may be opened!</u>

6.4. Brackets



6.4.1 The thickness is the same as plate floors:

$$\boxed{t = t_{pf} = 9{,}5 \, mm}$$

$$Breadth = 0{,}75 \cdot h \Rightarrow \boxed{802{,}5 \, mm}$$

B.4. Inner Bottom (Tank top) – The thickness

$$t = 1{,}1 \cdot a \cdot \sqrt{p \cdot k} + t_K \ [mm]$$

Section 8 Bottom Structures

B. Double Bottom 4. Inner bottom

The thickness of the inner bottom plating is not to be less than:

$$t = 1{,}1 \cdot a \cdot \sqrt{p \cdot k} + t_K \text{ [mm]}$$

p is the design pressure, as applicable

$p = p_i$ (section 4, C.2.) (for dry cargo ships)

or $p = p_1$ or p_2 (for tankers) (S.4 D.1.)

or $p = 10(T - h_{DB})$ (for damaged case for all ships)

Whichever greater is used!

h_{DB} : double bottom height [m]

$h_{DB} \geq h$ (height of centre girder)

Let us assume that $h_{DB} = 1{,}1$ m.

$$p = 10(6{,}5 - 1{,}1) = 54 \text{ [kN/m}^2\text{]}$$

For a dry cargo ship, inner bottom design pressure may be calculated from Section 4, C.2.

Section 4 - Design loads ; C. Cargo loads

2. Load on inner bottom (for a dry cargo ship)

2.1 $p_i = 9{,}81 \cdot \frac{G}{V} \cdot h(1 + a_v)$ [kN/m²]

a_v : acceleration addition (see C.1.1)

$a_v = F \cdot m$

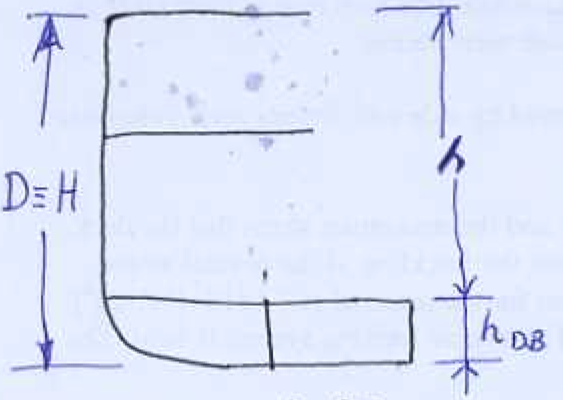
$$F = 0{,}11 \cdot \frac{v_0}{\sqrt{L}} \Rightarrow F = 0{,}11 \cdot \frac{16 \text{ [knots]}}{\sqrt{97 (m)}} \Rightarrow F = 0{,}179$$

$m = 1$ for the mid region $(0{,}2 < \frac{x}{L} \leq 0{,}7)$

$a_v = 0{,}179$

Because it is not easy to estimate G (mass of cargo in the hold) (tons) and V (volume of the hold) (m³), we make an assumption, unless we know the real value of inner bottom load!

Let us assume that $G/V = 0{,}7$! (This is a minimum value)



$h = D - h_{DB} \Rightarrow h = 9 - 1{,}1 \Rightarrow h = 7{,}9\,(m)$

$P_i = 9{,}81 \cdot 0{,}7 \cdot 7{,}9 \cdot (1 + 0{,}179)\ [kN/m^2]$

$P_i = 63{,}9\ [kN/m^2]$

$\therefore\ p = P_i$ because $P_i > 54\ [kN/m^2]$

a: stiffener spacing was 600 [mm] $\Rightarrow a = 0{,}6\,m$

$t = 1{,}1 \cdot 0{,}6 \cdot \sqrt{63{,}9 \cdot 1{,}0} + t_K = 5{,}28 + 1{,}5 = 6{,}78\,[mm]$

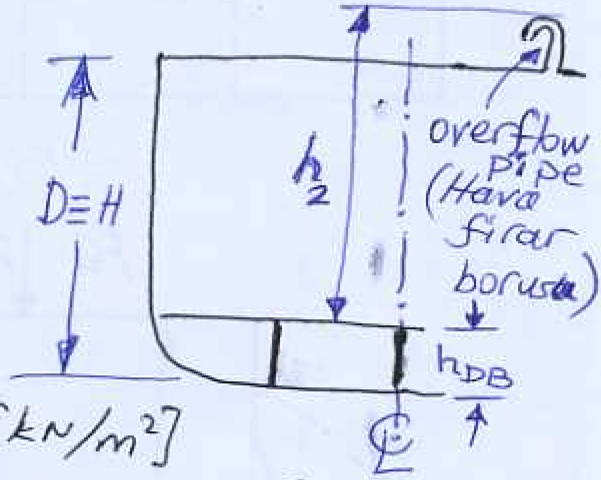
Inner bottom plating thickness should be at least:

$t = 7{,}0\,[mm]$

For a tanker, D. Load on Tank structures

Specific design pressure should be known. otherwise, we may estimate it from (D. 1.2)

$P_2 = 9{,}81 \cdot h_2\ [kN/m^2]$



Approximately,

$h_2 = D + 1 - h_{DB}$

$h_2 = 9 + 1 - 1{,}1$

$h_2 = 8{,}9\ [mm]$

$P_2 = 9{,}81 \cdot 8{,}9 \Rightarrow P_2 = 87{,}3\ [kN/m^2]$

Then, $p = P_2$, because $P_2 > 54\ [kN/m^2]$

$t = 1{,}1 \cdot 0{,}6 \cdot \sqrt{87{,}3 \cdot 1{,}0} + t_K =$ ~~9,84~~ 6,17 $+ 1{,}5$

$t =$ ~~10,84~~ $[mm]$ 7,67 [mm]

For standart thickness $\Rightarrow$ $t = 8{,}0\ [mm]$

Note that $t_K = 1{,}5$ because $t' = 6{,}17 < 10\,[mm]$ and that $k = 1{,}0$ for normal strength steel.

Bracket Floors (for transverse framing system)

Section 8, B. 6.3.3

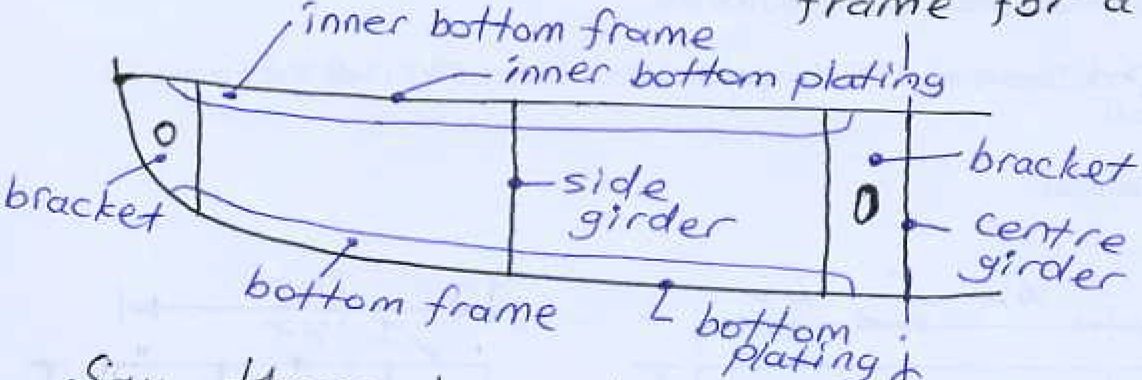
The section modulus of bottom and inner bottom frames is not to be less than:

$W = n \cdot c \cdot a \cdot l^2 \cdot p \cdot k$ [cm³]

$n = 0,7$ if $p = p_B$ (that is "bottom frame")

$n = 0,55$ if $p = p_i$ (that is inner bottom frame of a dry cargo ship)

$n = 0,44$ if $p = p_1, p_2$ (that is inner bottom frame for a tanker)



Say, there is only one side girder fitted each side.

Then, unsupported span (Length) will be approximately:

$l = B/4 \Rightarrow l = 16/4 \Rightarrow l = 4$ [m]

Let us assume that we do not use any strut!

Then, $c = 1,0$.

Required section modulus for transverse bottom frames:

$W = n \cdot c \cdot a \cdot l^2 \cdot P_B \cdot k = 0,7 \cdot 1,0 \cdot 0,6 \cdot 4^2 \cdot 81,09 \cdot 1,0$

$W = 544,9$ [cm³]

Note that $P_B = 81,09$ [kN/m²], not 86,45 [kN/m²] as earlier!

$P_B = 10 \cdot T + P_0 \cdot C_F$; $P_0 = 2,1 (C_B + 0,7) \cdot C_0 \cdot C_L \cdot f$

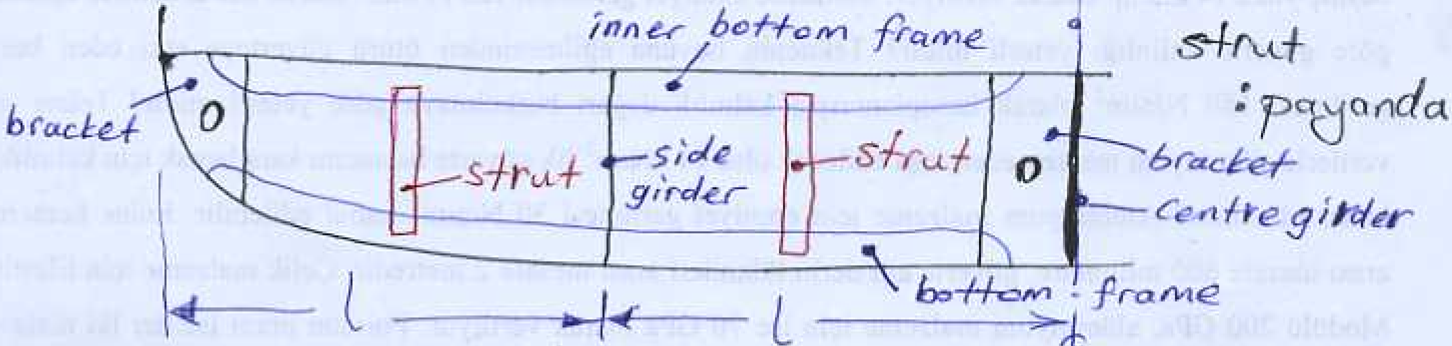
f was probability factor. For secondary stiffening members, $f = 0,75$

$\therefore P_0 = 16,09$ [kN/m²] $\Rightarrow P_B = 81,09$ [kN/m²]

Now, Let us chose a proper section from Table!

We have 160x160x19 "angle" section (with 550 cm³) and 280x21 "flat bar" section, available. However, because the thickness of these sections is quite bigger than the bottom thickness ($t_B = 11{,}0$ mm), there will be problems during welding! Therefore, we suggest that you may use 280x12 "bulb" section (with 570 cm³).

Or, alternatively, we may use a strut, and reduce the required section modulus!



When we use strut, $c = 0{,}6$

$$W = 0{,}7 \cdot 0{,}6 \cdot 0{,}6 \cdot 4^2 \cdot 81{,}09 \cdot 1{,}0 = 326{,}9 \; [cm^3]$$

The most suitable section is 240x10 "Bulb Section" (with a section modulus of 340 cm³), because the other alternative sections will have welding problems!

180x90x14 angle section has 330 cm³ section modulus, but its thickness is much greater than bottom thickness (14 mm > $t_B = 11$ mm)

Now, let us calculate the required section modulus for inner bottom (transverse) frames:

For a dry cargo ship, $p = p_i$, then $n = 0{,}55$.

Let us assume that we use a strut!

$$W = 0{,}55 \cdot 0{,}6 \cdot 0{,}6 \cdot 4^2 \cdot 63{,}9 \cdot 1{,}0 = 202 \, [cm^3]$$

The best possible choice from the table will be 200x9 Bulb section with a section modulus of 210 cm³, although the thickness of the bulb section is greater than inner bottom thickness!

9 mm > $t_i = 7{,}0$ mm ??

What about if our ship is a tanker? Then,

$p = p_2 \Rightarrow n = 0{,}44$

$W = 0{,}44 \cdot 0{,}6 \cdot 0{,}6 \cdot 4^2 \cdot 87{,}3 \cdot 1{,}0 = 221\ [cm^3]$

≈ 200x10 Bulb section may be used although required section modulus is slightly higher than real section modulus of 220 cm^3.

Double Bottom (with) Longitudinal Framing System

(all given in Section 8, B. 7)

7.2 Bottom and Inner Bottom Longitudinals

7.2.1 The scantlings are to be calculated according to Section 9, B.

Section 9 Framing System

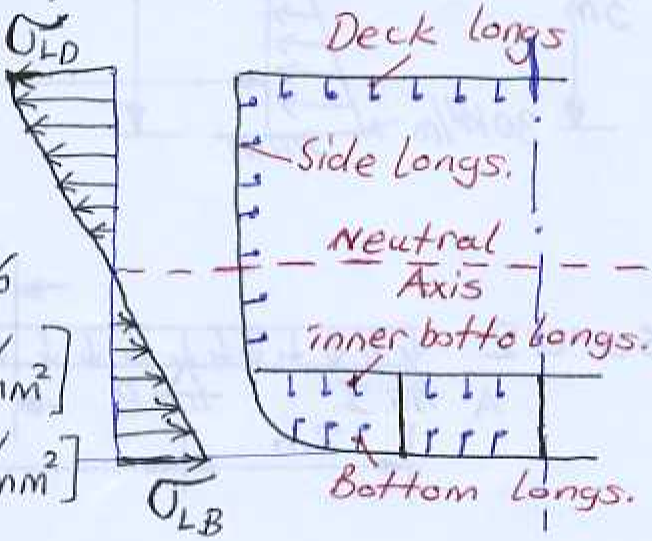
B. Bottom, Side and Deck Longitudinals

3. Scantlings of Longitudinals

3.1 Required section modulus of longitudinals:

$$W_l = \frac{83}{\sigma_{pr}} \cdot m \cdot a \cdot l^2 \cdot p \quad [cm^2]$$

For bottom longitudinals, $p = p_B = 81{,}1\ [kN/m^2]$



$\sigma_{pr} = \sigma_{perm} - |\sigma_L|$

$\sigma_L = \sigma_{LB}$; $\sigma_{LB} = 120\ [N/mm^2]$

$\sigma_{perm} = \left(0{,}8 + \frac{L}{450}\right)\frac{230}{k} = 233{,}6$

$\sigma_{perm\,max} = 230/k = 230\ [N/mm^2]$

$\sigma_{pr} = 230 - |120| = 110\ [N/mm^2]$

$m = m_k^2 - m_a^2$

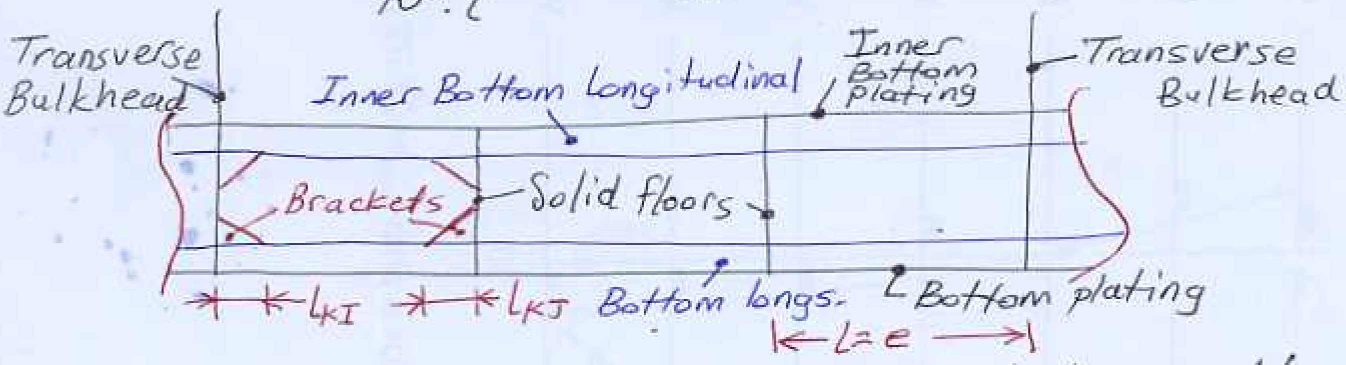
$m_a = 0{,}204\ \frac{a}{l}\left[4 - \left(\frac{a}{l}\right)^2\right]$ (from Section 3, A. 4)

l : distance between solid (plate) floors

For bottom longs. $e = l \Rightarrow e = 2{,}4\ [m]$

$m_a = 0{,}204 \cdot \frac{0{,}6}{2{,}4}\left[4 - \left(\frac{0{,}6}{2{,}4}\right)^2\right] \Rightarrow \underline{m_a = 0{,}2}$

$m_K = 1 - \frac{l_{KI} + l_{KJ}}{10^3 \cdot l}$ (from Section 3, C.1)



First, let us assume that no brackets used!

Then, $l_{KI} = l_{KJ} = 0 \Rightarrow m_K = 1{,}0$

and $m = m_K^2 - m_a^2 \Rightarrow m = 1^2 - 0{,}2^2 \Rightarrow m = 0{,}96$

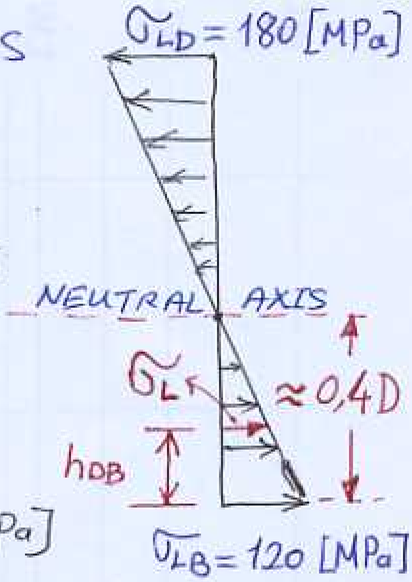
$$W_L = \frac{83}{\sigma_{pr}} \cdot m \cdot a \cdot l^2 \cdot p = \frac{83}{110} \cdot 0{,}96 \cdot 0{,}6 \cdot 2{,}4^2 \cdot 81{,}1 = 203\,[cm^3]$$

200×9 Bulb Section with a section modulus of 210 $[cm^3]$ is suitable from Table.

FOR INNER BOTTOM LONGITUDINALS

$p = p_i$ (for a dry cargo ship)
$p = p_1$ or p_2 (for a tanker)

Using the similarity of triangles



$$\frac{\sigma_L}{\sigma_{LB}} = \frac{0{,}4 \cdot D - h_{DB}}{0{,}4 \cdot D} \Rightarrow \sigma_L = 83{,}\bar{3}\,[MPa]$$

$(h_{DB} = 1{,}1\,[m])$

$$\sigma_{pr} = 230 - |\sigma_L| = 230 - 83{,}3 = 146{,}7\,[MPa]$$

For a dry cargo ship: $p = p_i = 63{,}9\,[kN/m^2]$

$$W_L = \frac{83}{146{,}7} \cdot 0{,}96 \cdot 0{,}6 \cdot (2{,}4)^2 \cdot 63{,}9 = 119{,}9\,[cm^3]$$

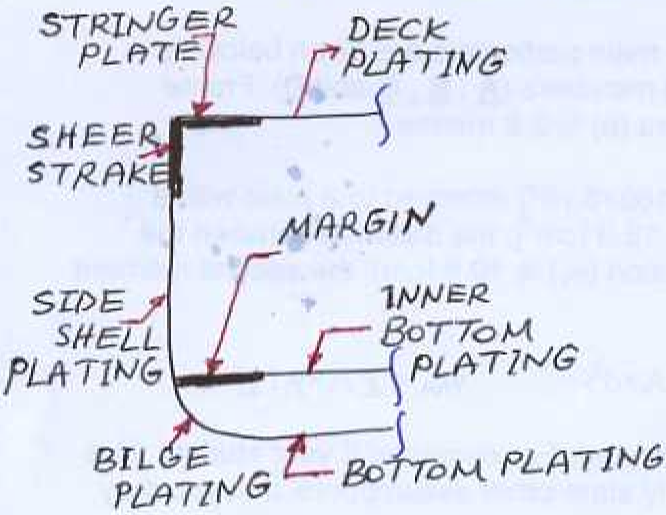
160×9 Bulb Section has a section modulus of 120 $[cm^3]$

For a tanker: $p = p_2 = 87{,}3\,[kN/m^2]$.

$$W_L = \frac{83}{146{,}7} \cdot 0{,}96 \cdot 0{,}6 \cdot (2{,}4)^2 \cdot 87{,}3 = 163{,}9\,[cm^3]$$

Angle sections, **110×110×12**, **130×75×12** have 165 $[cm^3]$.

SIDE SHELL PLATING and DECK PLATING



SECTION 6 - SHELL STRUCTURES

C- Side Shell Plating

1.2 Ships with length $L \geq 90$ m.

The thickness of the side shell plating is not to be less than:

$$t_{S_1} = 18{,}3 \cdot n_f \cdot a \cdot \sqrt{\frac{P_S}{\sigma_{PL}}} + t_K \ [mm]$$

$$t_{S_2} = 1{,}21 \cdot a \cdot \sqrt{p \cdot k} + t_K \ [mm]$$

$$t_{S_3} = 18{,}3 \cdot n_f \cdot a \cdot \sqrt{\frac{P_{SL}}{\sigma_{PL\,max}}} + t_K \ [mm]$$

$$\sigma_{PL} = \sqrt{\sigma_{perm}^2 - 3 \cdot \tau_L^2} - 0{,}89 \cdot \sigma_{LS}$$

As a first approximation

$\sigma_{LS} = 0{,}76 \cdot \sigma_{LB}$ [N/mm²]

$\sigma_{LB} = 120/k \Rightarrow \sigma_{LB} = 120$ [N/mm²]

$\sigma_{LS} = 91{,}2$ [N/mm²]

$\tau_L = 55/k \Rightarrow \tau_L = 55$ [N/mm²]

$\sigma_{perm} = 230$ [N/mm²]

$\sigma_{PL} = \sqrt{230^2 - 3 \cdot 55^2} - 0{,}89 \cdot 91{,}2$

$\sigma_{PL} = 128{,}2$ [N/mm²]

$\sigma_{PL\,max} = 128{,}2$ [N/mm²]

P_S : The external load

Section 4, B.2.1.1

$$P_S = 10(T-z) + P_0 \cdot C_F (1 + z/T) \ [kN/m^2]$$

or

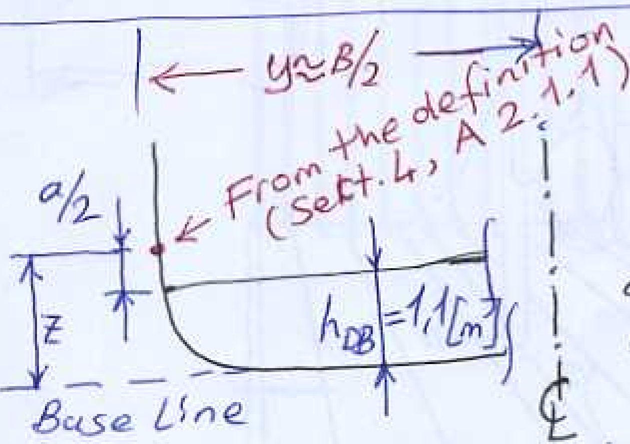
$$P_{S1} = 10(T-z) + P_{01}\left[1 + \frac{z}{T}\left(2 - \frac{z}{T}\right)\right] 2 \frac{|y|}{B} \ \left[\frac{kN}{m^2}\right]$$

z: vertical distance of the structure's load centre above base line [m]

Load centre for plates:

vertical stiffening system (that's transverse framing)

or horizontal stiffening system (that's longitudinal framing)



For side shell plating, the distance (vertical) between the load centre and base line:

$z = h_{DB} + a/2 = 1{,}1 + 0{,}6/2 = 1{,}4$ [m]

$P_S = 10(6{,}5 - 1{,}4) + 21{,}45 \cdot 1{,}0 \cdot (1 + 1{,}4/6{,}5) \Rightarrow P_S = 77{,}1$ [kN/m²]

$P_{S_1} = 10(6{,}5-1{,}4) + 26{,}56 \cdot \left[1 + \frac{1{,}4}{6{,}5}\left(2 - \frac{1{,}4}{6{,}5}\right)\right] 2 \cdot \frac{B/2}{B} \Rightarrow P_{S_1} = 87{,}8$ [kN/m²]

FOR TRANSVERSE FRAMING SYSTEM $n_f = 1{,}0$

$t_{S_1} = 18{,}3 \cdot 1{,}0 \cdot 0{,}6 \sqrt{77{,}1/128{,}2} + t_K = 8{,}51 + 1{,}5 = 10{,}01$ [mm]

$t_{S_2} = 1{,}21 \cdot 0{,}6 \cdot \sqrt{77{,}1 \cdot 1{,}0} + t_K = 6{,}37 + 1{,}5 = 7{,}87$ [mm]

$t_{S_3} = 18{,}3 \cdot 1{,}0 \cdot 0{,}6 \cdot \sqrt{87{,}8/128{,}2} + t_K = 9{,}08 + 1{,}5 = 10{,}58$ [mm]

$t_{S_3} > t_{S1} > t_{S2} \Rightarrow t_S = t_{S_3} \Rightarrow$ **$t_S = 11{,}0$ [mm]**

FOR LONGITUDINAL FRAMING SYSTEM $n_f = 0{,}83$

$t_{S1} = 7{,}06 + 1{,}5 \Rightarrow t_{S1} = 8{,}56$ [mm]

$t_{S2} = 6{,}37 + 1{,}5 \Rightarrow t_{S2} = 7{,}87$ [mm]

$t_{S3} = 9{,}08 \times 0{,}83 + 1{,}5 = 7{,}54 + 1{,}5 \Rightarrow t_{S3} = 9{,}04$ [mm]

$t_{S3} > t_{S1} > t_{S2} \Rightarrow t_S = t_{S3} \Rightarrow t_S = 9{,}5$ [mm]

But, a final check for the minimum thickness for outer shell (Section 6, B.3.1)

$t_{min} = \sqrt{L \cdot k} \Rightarrow t_{min} = \sqrt{97 \times 1{,}0} \Rightarrow$ **$t_S = t_{min} = 10{,}0$ [mm]**

SHEER STRAKE (ŞİYER SACI veya ŞİYER LEVHASI)

(Section 6, C.3.1) The width of the sheerstrake:

$b = 800 + 5 \cdot L = 1285$ [mm] (at least)

(Section 6, C.3.2) The thickness, not to be less than:

$t = 0{,}5\,(t_D + t_S)$ [mm]

$t = t_S$

t_D: required thickness of strength deck

t_S: " " " side shell

$t_D = ? \Rightarrow$ GO TO SECTION 7 – Decks

The thickness of strength deck plating

$t_{E_1} = 1{,}21 \cdot a \cdot \sqrt{P_D \cdot k} + t_K$ [mm]

$t_{E_2} = 1{,}1 \cdot a \cdot \sqrt{P_L \cdot k} + t_K$ [mm]

$t_{E\,min} = (5{,}5 + 0{,}02 \cdot L)\sqrt{k}$ [mm]

Also, check for minimum thickness of deck plating!!

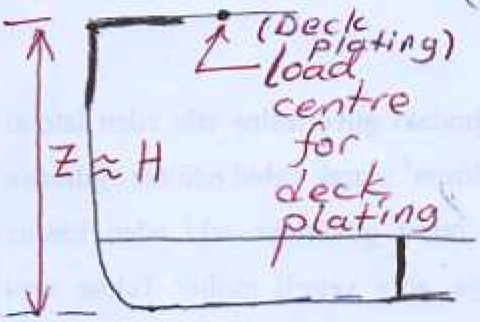
(Section 7, A.6.1) minimum thickness

$t_{min} = (4,5 + 0,05 \cdot L)\sqrt{k} \Rightarrow t_{min} = 9,35$ [mm]

or t_E (according to 7.1)

P_D: load on weather decks (Section 4, B.1.1)

$$P_D = P_0 \cdot \frac{20 \cdot T}{(10+z-T)H} \cdot C_D \; [kN/m^2]$$



$$P_D = 21,45 \cdot \frac{20 \cdot 6,5}{(10+9-6,5)9} \cdot 1,0 = 24,8 \; [kN/m^2]$$

$P_{Dmin} = 16 \cdot f \Rightarrow P_{Dmin} = 16 \times 1,0 = 16 \; [kN/m^2]$

$P_{Dmin} = 0,7 \cdot P_0 \Rightarrow P_{Dmin} = 0,7 \cdot 21,45 = 15 \; [kN/m^2]$

P_L: If there is a cargo on deck then $P = P_L$!

(Section 4, C.1.1) $P_L = P_c(1 + a_v) \; [kN/m^2]$

If cargo load is not known, $P_c = 7 \cdot h$

h: height of cargo [m] $\quad P_{cmin} = 15 \; [kN/m^2]$

a_v: acceleration addition (already calculated)

$P_L = 15(1 + 0,18) \Rightarrow P_L = 17,7 \; [kN/m^2]$

$t_{E_1} = 1,21 \cdot 0,6 \cdot \sqrt{24,8 \cdot 1,0} + t_K = 3,61 + 1,5 \Rightarrow t_{E_1} = 5,1$ [mm]

$t_{E_2} = 1,1 \cdot 0,6 \sqrt{17,7 \cdot 1,0} + t_K = 2,77 + 1,5 \Rightarrow t_{E_2} = 4,3$ [mm]

$t_{Emin} = (5,5 + 0,02 \cdot 97)\sqrt{1} \Rightarrow t_{Emin} = 7,4$ [mm]

$t_{Emin} > t_{E1} > t_{E2} \Rightarrow t_E = t_{Emin} \Rightarrow t_E = 7,5$ [mm]

Finally, t_E or t_{min}??

$t_E = 7,5$ [mm] $< t_{min} = 9,35$ [mm]

$t_D = t_{min} \Rightarrow t_D = 9,5$ [mm]

DO NOT FORGET THAT OUTER SHELL THICKNESS SHOULD NOT BE LESS THAN: $t_{min\,outer\,shell} = \sqrt{L \cdot k}$

Then, $t_D = 10$ [mm] AT LEAST.

The thickness of sheerstrake : TRANSVERSE FRAMING

$t = 0,5\,(11 + 10) = 10,5$ [mm] $\boxed{t = 11,0 \text{ [mm]}}$ AT LEAST

or $t = t_s = 11$ [mm]

For Longitudinal framing system:

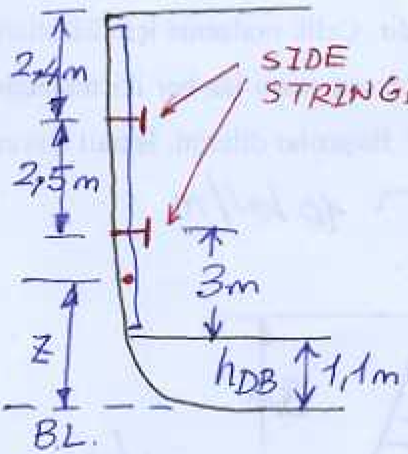
$t = 0,5\,(t_s + t_D) = 0,5(10+10) = 10$ [mm] $\Rightarrow \boxed{t = 10 \text{ [mm]}}$ AT LEAST

or $t = t_s = 10$ [mm]

SECONDARY STIFFENING MEMBERS (SIDE FRAMES FOR TFS and SIDE LONGITUDINALS FOR LFS

SECTION 9 - FRAMING SYSTEM

MAIN FRAMES (A. 2.1.1)



The section modulus:

$W_R = (1 - m_a^2) \cdot n \cdot c \cdot a \cdot l^2 \cdot p \cdot c_r \cdot k$ [cm^3]

$n = 0,9 - 0,0035 \cdot L$ for $L < 100$ m

$n = 0,56$ $l = 3$[m]

$m_a = 0,204\,\frac{a}{l}\left[4 - \left(\frac{a}{l}\right)^2\right]$

$m_a = 0,204\,\frac{0,6}{3,0}\left[4 - \left(\frac{0,6}{3,0}\right)^2\right] = 0,16$

$c = 1,0 - \left(\frac{l_{Ku}}{l} + 0,4\,\frac{l_{Ko}}{l}\right)$; If no brackets used, then $l_{Ku} = l_{Ko} = 0$

$c = 1,0$

$c_r = 1,0 - 2\,\frac{s}{l}$ (c_r: factor for curved frames)

For wall sided ships, there is no curvature ($s/l = 0$)

$P = P_s \Rightarrow P_s = 10(T - z) + P_0 \cdot c_F \cdot (1 + z/T)$ [kN/m^2]

$P_0 = 0,75 \cdot 21,45 = 16,09$ [kN/m^2] ; ($f = 0,75$ for frames)

$z = h_{DB} + l/2 \Rightarrow z = 1,1 + 3/2 \Rightarrow z = 2,6$[m]

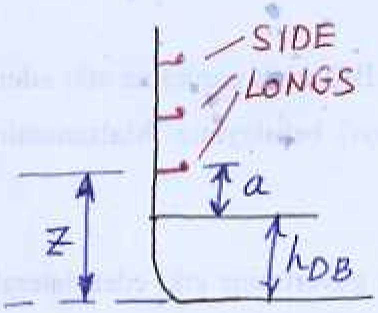
$P_s = 10(6,5 - 2,6) + 16,09 \cdot 1,0 \cdot (1 + 2,6/6,5) = 61,5$ [kN/m^2]

$W_R = (1 - 0,16^2) \cdot 0,56 \cdot 1,0 \cdot 0,6 \cdot 3^2 \cdot 61,5 \cdot 1,0 \cdot 1,0 = 181,2$ [cm^3]

180x11 Bulb section with 185 [cm³] ✓

or 150x90x10 Angle section with 190 [cm³] ✓
160x80x10

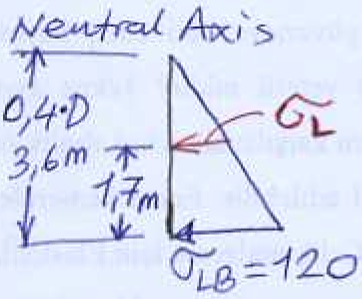
SIDE LONGITUDINALS FOR Transverse Framing



$$W_L = \frac{83}{\sigma_{pr}} \cdot m \cdot a \cdot l^2 \cdot p \ [cm^3] \quad (B\ 3.1)$$

$p = p_S$; $z = h_{DB} + a = 1{,}1 + 0{,}6 = 1{,}7\ [m]$

$$p_S = 10(6{,}5 - 1{,}7) + 16{,}1 \cdot 1{,}0 \cdot (1 + 1{,}7/6{,}5) = 68{,}3 \left[\frac{kN}{m^2}\right]$$



$\sigma_{pr} = \sigma_{perm} - |\sigma_L| = 230 - |63{,}3|$

$\sigma_{pr} = 166{,}7\ [N/mm^2]$

$\sigma_{pr} \leq 150/k = 150\ [N/mm^2] \Rightarrow \sigma_{pr} = 150 \left[\frac{N}{mm^2}\right]$

$$W_L = \frac{83}{150} \cdot 0{,}96 \cdot 0{,}6 \cdot (2{,}4)^2 \cdot 68{,}3 = 125{,}4\ [cm^3]$$

$m = m_k^2 - m_a^2$

No brackets

$m_a = 0{,}2$
(already found earlier)

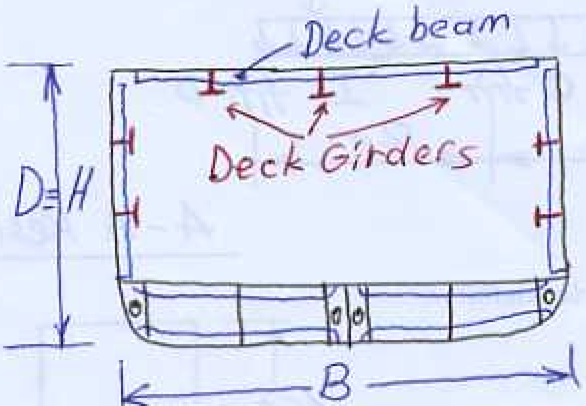
130x65x10 with 125 (cm³) Angle section

Deck Beams and Supporting Deck Structures

section 10 B. Deck Beams (Transve framing System)

Required section modulus:

$$W_d = m \cdot c \cdot a \cdot p \cdot l^2 \cdot k \ [cm^3]$$



l : Unsupported span [m]
(in general, l is the distance between deck girders)

For the configuration shown in figure : $l \cong B/4 \Rightarrow l = 4\ [m]$

$p = p_L$ (If there is cargo on deck)

otherwise, $p = p_D$ (p_D : Load on weather decks)

$p_D = 24{,}8\ [kN/m^2]$ already calculated earlier.

Because, $p_D > p_L = 17{,}7\ [kN/m^2]$ $\quad p = 24{,}8\ [kN/m^2]$

$m = m_k^2 - m_a^2$

$m_a = 0{,}204 \frac{a}{l}\left[4-\left(\frac{a}{l}\right)^2\right] = 0{,}204 \frac{0{,}6}{4{,}0}\left[4-\left(\frac{0{,}6}{4{,}0}\right)^2\right] = 0{,}122$

$m_k = 1$ (with no brackets assumption as a first approximation!)

$m = 0{,}985$

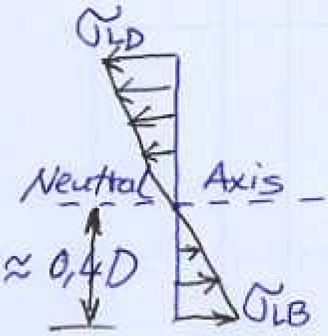
$C = 0{,}75$ (simply supported on one or both ends)

$W_d = 0{,}985 \cdot 0{,}75 \cdot 0{,}6 \cdot 24{,}8 \cdot 4^2 \cdot 1{,}0 = 176$ [cm³]

150x 75 x 11 Angle section (180 cm³) chosen.

Deck Longitudinals (for longitudinal framing system)

$W_L = \frac{83}{\sigma_{pr}} \cdot m \cdot a \cdot l^2 \cdot p$ [cm³] (Section B.3.1)



$\sigma_{LB} = 120$ [N/mm²] (as a first approximation)

$\Rightarrow \sigma_{LD} = 180$ [N/mm²] $\sigma_L = \sigma_{LD}$

$\sigma_{pr} = \sigma_{perm} - |\sigma_L| \Rightarrow \sigma_{pr} = 230 - |180| = 50 \left[\frac{N}{mm^2}\right]$

$m = 0{,}96$ (already calculated for bottom and side longs.)

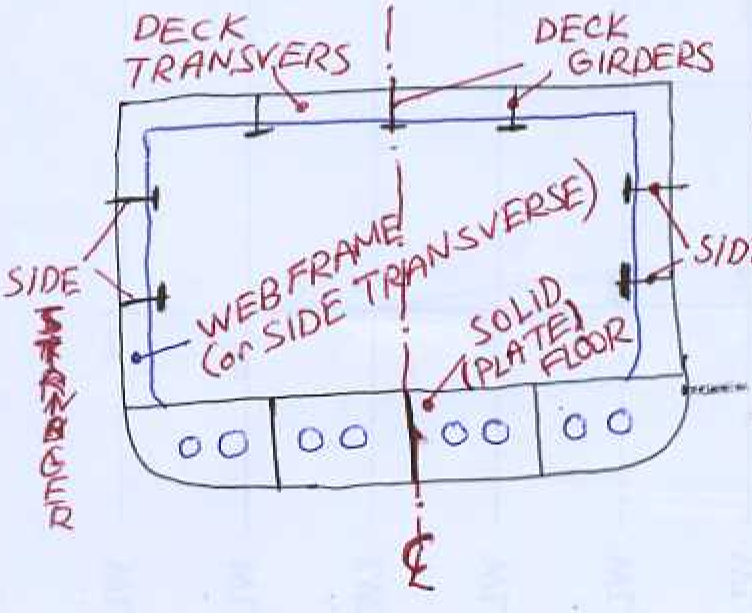
$l = e$ (distance between deck transverses)

$W_L = \frac{83}{50} \cdot 0{,}96 \cdot 0{,}6 \cdot (2{,}4)^2 \cdot 24{,}7 = 136$ [cm³]

(110x110x10) Angle section has (140 [cm³])

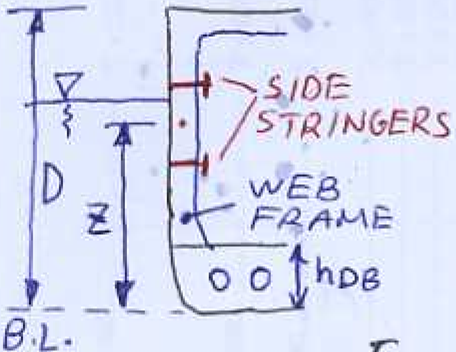
PRIMARY SUPPORTING MEMBERS FOR SIDE and DECK

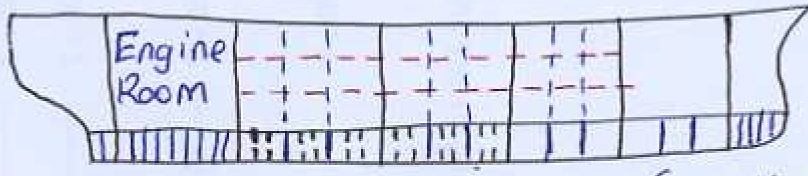
Primary supporting members at bottom structures are: Centre and side girders (longitudinal) solid (plate) floors (transverse)



Primary supporting members for side and deck structure are illustrated in Figure.

WEB FRAMES and SIDE STRINGERS (TRANSVERSE FRAMING SYSTEM)





Required section modulus (Section 9 A. 5.3.1)

$W = 0{,}55 \cdot e \cdot l^2 \cdot p \cdot n_c \cdot k$ [cm³]

For the web frame l is the distance between inner bottom and deck. For this particular problem ⇒ $l = D - h_{DB} = 9 - 1{,}1 = 7{,}9$ [m]

e is the distance between web frames (which is equal the distance between solid floors)

$p = p_S = 10(T - z) + p_0 \cdot c_F \cdot \left(1 + \frac{z}{T}\right)$ [kN/m²]

$p_0 = 12{,}87$ [kN/m²] ; $f = 0{,}6$ (for WEB frames)

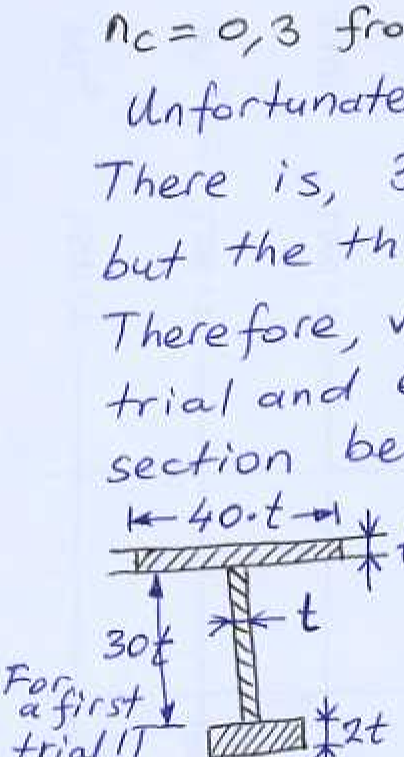
For the web frame, $z = h_{DB} + \frac{l}{2} = 1{,}1 + \frac{7{,}9}{2} = 4{,}95$ [m]

$p_S = 10(6{,}5 - 4{,}95) + 12{,}87 \cdot 1\,(1 + 4{,}95/6) = 39$ [kN/m²]

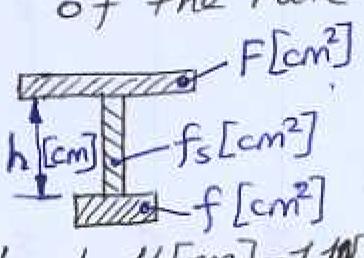
$W = 0{,}55 \cdot 2{,}4 \cdot 7{,}9^2 \cdot 39 \cdot 0{,}3 \cdot 1{,}0 = 963$ [cm³]

$n_c = 0{,}3$ from Table 9.1, because there are 2 cross ties!

Unfortunately, there are not any suitable sections! There is, 340x14 Bulb Section having 1000 [cm³], but the thickness, 14 [mm], is not suitable for welding! Therefore, we are going to seek for a section using trial and error method! Let us start with the section below:



We can calculate the section modulus of that section with usual tables. There is also an alternative way to calculate using graphs given at the end of the rule book.

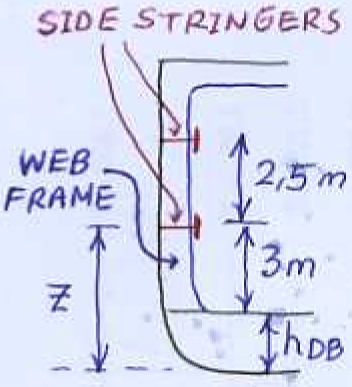


For the given section:

$F = 40t \cdot t$ $f_s / F = 0{,}75$
$f_s = t \cdot 30t$ $f / F = 1{,}0$ } using these values!
$f = 20t \cdot 2t$ ⇒ $w \cong 1{,}11$

$W = w \cdot F \cdot h$
$W = 1{,}11 \cdot 40t^2 \cdot 30t$
$W = 1332 \cdot t^3$

$t_s = t = 11$ [mm] $= 1{,}1$ [cm] ⇒ $W = 1773$ [cm³] ≥ 963 [cm³]
section much bigger than needed but OK!



SIDE STRINGER

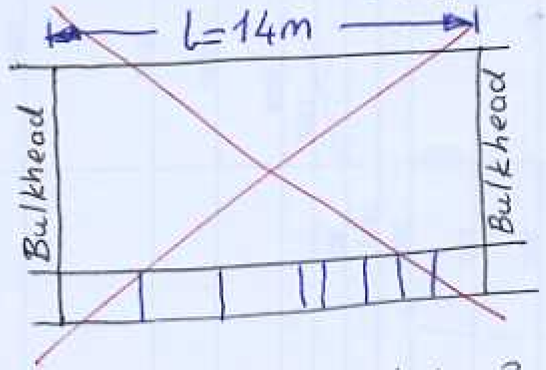
Required section modulus:

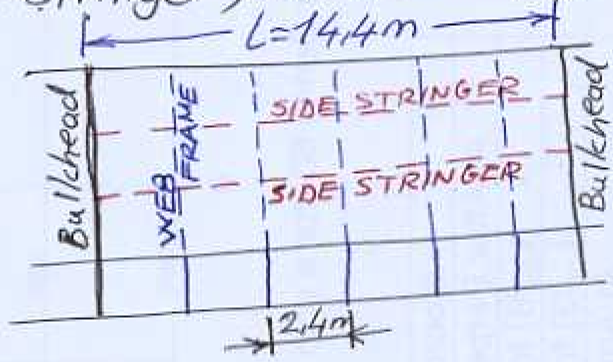
$$W = 0{,}55 \cdot e \cdot l^2 \cdot p \cdot n_c \cdot k \; [cm^3]$$

l: the distance between transverse bulkheads

Let us assume that the distance between bulkheads is 14,4[m]!

e: (for side stringer) the width of supported area





$z = h_{DB} + 3 = 1{,}1 + 3 = 4{,}1\ [m]$

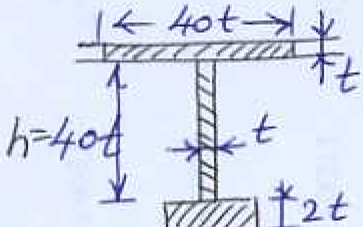
$p = p_s = 10(T - z) + p_0 \cdot c_F \left(1 + \frac{z}{T}\right)\ [kN/m^2]$

$p_s = 10(6{,}5 - 4{,}1) + 12{,}87 \cdot 1 \cdot (1 + 4{,}1/6{,}5) = 45\ [kN/m^2]$

$n_c = 0{,}2$ (because there are 5 cross ties!)

$e = 3/2 + 2{,}5/2 = 2{,}75\ [m]$

$W = 0{,}55 \cdot 2{,}75 \cdot 14{,}4^2 \cdot 45 \cdot 0{,}2 \cdot 1 = 2823\ [cm^3]$



Again, using "trial and error" method!

$F = 40t^2$ Using f/F and f_s/F values!

$f_s = 40t^2$ $w = 1{,}16$ (read from the graph!)

$f = 40t^2$ $W = w \cdot F \cdot h = 1{,}16 \cdot 40t^2 \cdot 40t$

$W = 1856 \cdot t^3 \Rightarrow W = 2470\ [cm^3]$

$t = 11\ [mm] = 1{,}1\ [cm]$

Because $2470 \leq 2823$, we need to increase "h"!, until W is equal or greater than 2823 [cm³]

WHAT ABOUT IF WE USE LONGITUDINAL FRAMING SYSTEM

NOW THERE IS NO NEED FOR SIDE STRINGERS, because use them to reduce the unsupported length (span) of main frames at side in transverse framing system.

We have "SIDE TRANVERSES" as Primaly supporting members at side.

Required section modulus for side transverse:

$W = 0{,}55 \cdot e \cdot l^2 \cdot p \cdot k\ [cm^3]$

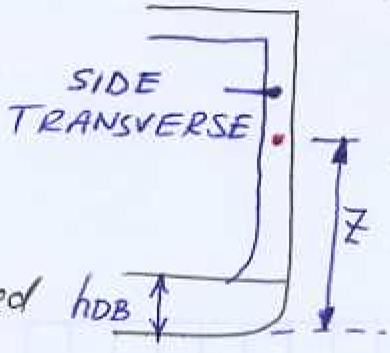
(Section 9, B.5.1)

$l = D - h_{DB} = 7{,}9\,[m]$

$e = 2{,}4\,[m]$

$z = h_{DB} + l/2 = 1{,}1 + 7{,}9/2 = 4{,}95\,[m]$

$p = p_s = 39\,[kN/m^2]$ (already calculated earlier)



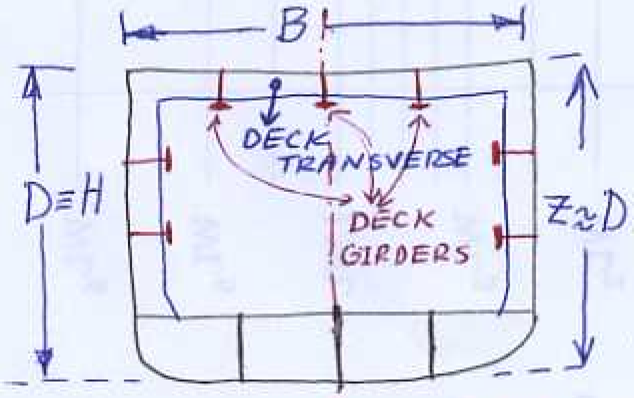
$W = 0{,}55 \cdot 2{,}4 \cdot 7{,}9^2 \cdot 39 \cdot 1 = 3213\,[cm^3]$

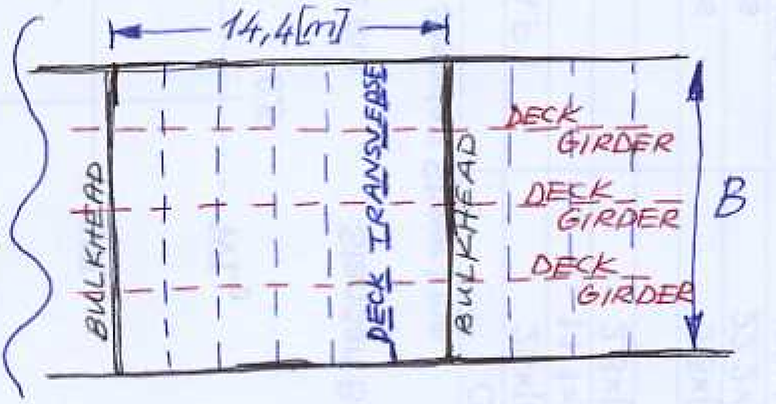
Similarly, using "trial and error" method again, we try to find a suitable section!

SUPPORTING DECK STRUCTURES - DECK TRANSVERSES AND DECK GIRDERS

Required section modulus for Girders and Transverses

$W = c \cdot e \cdot l^2 \cdot p \cdot k\ [cm^3]$ (Section 10, B.4.1)





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DECK TRANSVERSE

$p = p_D = p_0 \cdot \frac{20 \cdot T}{(10 + z - T) H} \cdot c_D\ [kN/m^2]$

$p_0 = 12{,}87\,[kN/m^2]$

$f = 0{,}6$ (for girders)

$p = 12{,}87 \cdot \frac{20 \cdot 6{,}5}{(10 + 9 - 6{,}5)\, 9} \cdot 1{,}0 = 14{,}9\,[kN/m^2]$

$l = B$ (If there is no longitudinal bulkhead!)

e: Distance between deck transverses.

$W = 0{,}55 \cdot 2{,}4 \cdot 16^2 \cdot 14{,}9 \cdot 1 = 5035\,[cm^3]$

A suitable section may be chosen by using "trial and error" method.

DECK GIRDER

Required section modulus: $W = 0{,}55 \cdot e \cdot l^2 \cdot p \cdot k$ [cm³]

l: the distance between transverse bulkheads [m]

$l = 14{,}4$ [m] (assumed for my ship!)

$e = 4$ [m] (the width of the area carried by deck girder)

$p = P_D$ (for girders and transverses)

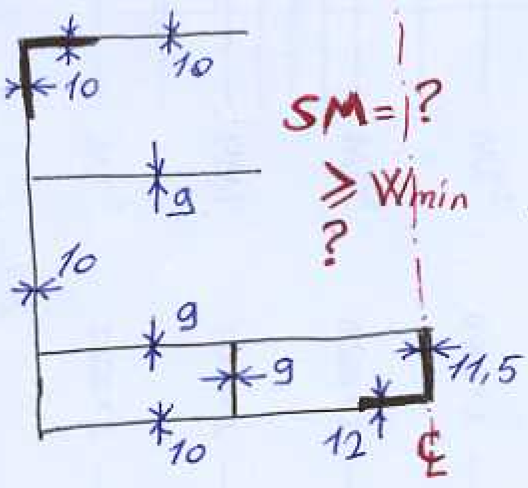
$W = 0{,}55 \cdot 4 \cdot (14{,}4)^2 \cdot 14{,}9 \cdot 1{,}0 = 6797$ [cm³]

A suitable section for this may be produced by "trial and error method"

Depending on the requirements of your Course Work particulars, you are expected to find the scantlings (of structural members-dimensions) for your ship.

A final check for midship section modulus is needed!

For instance, for my ship (with LFS-longitudinal framing sys.) (A dry cargo ship!)



Required section modulus for midship by GL Rules:

$W_{min} = k \cdot C_0 \cdot L^2 \cdot B \cdot (C_B + 0{,}7) \cdot C_{RS} \cdot 10^{-6}$ [m³]

$W_{min} = 1{,}0 \cdot 7{,}86 \cdot 97^2 \cdot 16 \cdot (0{,}6 + 0{,}7) \cdot 1{,}0 \cdot 10^{-6}$

$W_{min} = 1{,}54$ [m³]

Real section modulus of midship shown in Figure may be calculated approximately, and then it may be compared with the value above (required by GL).

* IF SM ≤ W_{MIN} (by GL), THEN PLATE THICKNESSES * MAY BE INCREASED. (* IN FACT, MUST BE INCREASED!!)

* A FINAL CHECK FOR PLATE BUCKLING MUST BE INCLUDED.