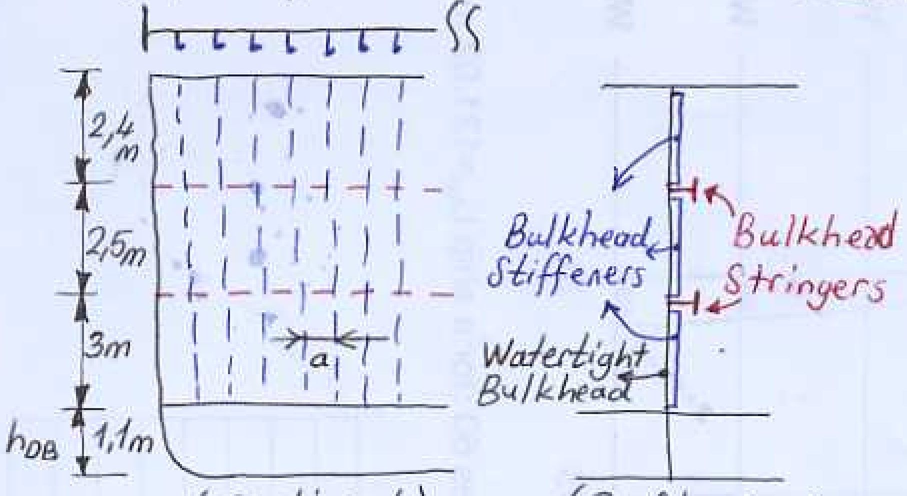
(Top view) SECTION 11 - WATERTIGHT BULKHEADS



(sectional View) (Profile view)

A typical views of a transverse bulkhead is given in Figure. Vertical stiffening system is used! (Plating + Stiffeners)

The thickness of bulkhead plating (Sect. 11, B.2.1)

$t = c_p \cdot a \cdot \sqrt{p} + t_K$ [mm]

$t_{min} = 6{,}0 \cdot \sqrt{f}$ [mm]

$f = 235/R_{eH}$ (with the assumption $R_{eH} = 235\,[N/mm^2]; f = 1$)

$c_p = 0{,}9\sqrt{f}$ (from Table 11.1 - "other bulkheads" assumption)

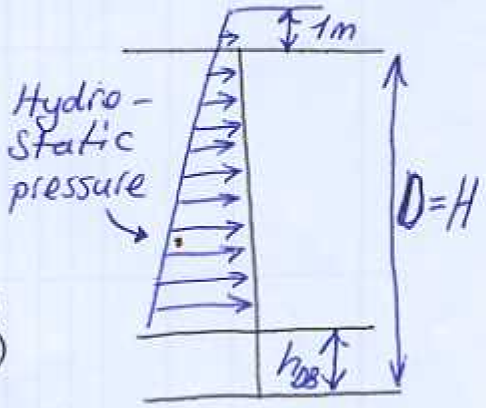
Let "a" be equal $0{,}8[m] \Rightarrow a = 0{,}8\,[m]$

$p = 9{,}81 \cdot h$

Using the definition of "load centre" for plates:

$h = D - h_{DB} + 1$ (if plate thickness changes!)

$h = D - h_{DB} - \frac{a}{2} + 1$ (unless plate thickness changes!)



Let us assume that the thickness of bulkhead plating will not change!

$h = 9 - 1{,}1 - \frac{0{,}8}{2} + 1 \Rightarrow h = 8{,}5\,[m]$

$p = 9{,}81 \cdot h \Rightarrow p = 83{,}4\,[kN/m^2]$

$t = 0{,}9 \cdot 0{,}8 \cdot \sqrt{83{,}4} + t_K \Rightarrow t = 6{,}57 + 1{,}5 = 8{,}07\,[mm]$

$t_{min} = 6{,}0 \cdot \sqrt{1} \Rightarrow t_{min} = 6{,}0\,[mm]$

then $\boxed{t = 8{,}5\,[mm]}$

The section modulus of stiffeners (Sect. 11, B.3.1)

$W = m \cdot c_s \cdot a \cdot l^2 \cdot p$ [cm³]

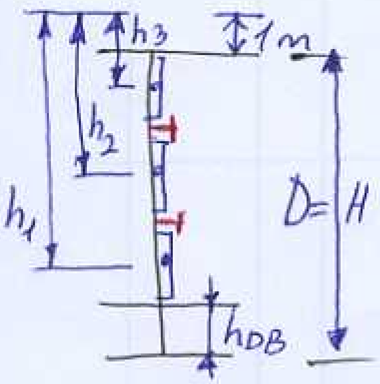
Assumptions for boundary conditions (end supports)!

- If no brackets used, then both ends simply supported
- If there is one bracket, then one end constraint, the other simply supported!
- If there are two brackets, then both sides constraint!

Let us assume that no brackets used, first!

Then, for "other bulkheads" $c_s = 0,53 \cdot f$

$m_k = 1,0$ (because $l_{kI} = l_{kJ} = 0$) $m_k = 1 - \frac{l_{kI} + l_{kJ}}{10^3 \cdot l}$



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

For the stiffeners nearest to the inner bottom (double bottom):

$l = 3,0$ [m] $\Rightarrow m_a = 0,204 \frac{0,8}{3}\left[4 - \left(\frac{0,8}{3}\right)^2\right] \Rightarrow m_a = 0,214$

$m = m_k^2 - m_a^2 \Rightarrow m = 0,954$

$l = 3$ [m] (the distance between inner bottom and the nearest bulkhead stringer)

$p = 9,81 \cdot h$; $h = D - h_{DB} - l/2 + 1 = 9 - 1,1 - 3/2 + 1 = 7,4$ [m]

$p = 72,6$ [kN/m²] $\Rightarrow W = 0,954 \cdot 0,53 \cdot 0,8 \cdot 3^2 \cdot 72,6 = 264,3$ [cm³]

Unfortunately, we cannot find a suitable section from Table!!

Then, let us assume that we use a bracket at one side.

$c_s = 0,36 \cdot f$ (from Table 11.1)

$W = 0,954 \cdot 0,36 \cdot 0,8 \cdot 3^2 \cdot 72,6 = 179,5$ [cm³]

We still cannot find a suitable section. Then, we assume that both ends constrained (two brackects).

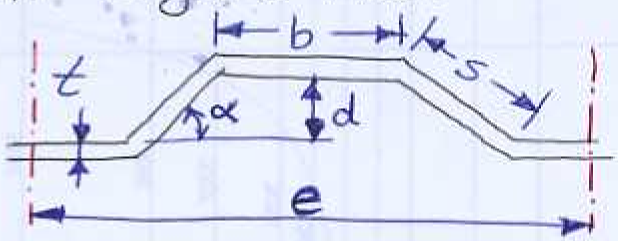
$c_s = 0,265 \cdot f \Rightarrow W = 132$ [cm³]

Now, 180x8 Bulb section having a section modulus of 145 [cm³] is suitable and we choose it!

Similarly, we can repeat the SM calculations for other stiffeners, where h_2 and h_3 should be considered!!

Corrugated Bulkheads (Section 11, B.4)

Alternatively, instead of plate + stiffeners, corrugated type bulkheads may be constructed. There are some alternative sections, one may be seen in Figure 11.2.



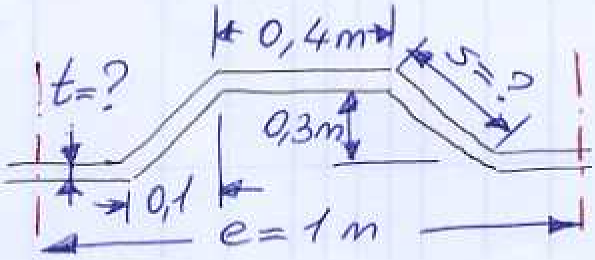
The plate thickness of the corrugated bulkhead to be found according to (B.2.1)

$$t = C_p \cdot a \cdot \sqrt{p} + t_k \text{ [mm]}$$
$$t_{min} = 6{,}0\sqrt{f} \text{ [mm]}$$

Note that a is b or s, whichever greater!

That means we have to select a section first!

Let us consider a section like this:



Again, using, trial and error method!

$$s = \sqrt{0{,}3^2 + 0{,}1^2} \Rightarrow s = 0{,}316 \text{ [m]}$$

Then, $a = b = 0{,}4$ [m]

$$t = 0{,}9 \cdot 0{,}4 \cdot \sqrt{83{,}4} + t_k \Rightarrow t = 3{,}3 + 1{,}5 = 4{,}8 \text{ [mm]}$$
$$t_{min} = 6{,}0 \cdot \sqrt{1} \Rightarrow t_{min} = 6 \text{ [mm]} \Rightarrow \therefore \boxed{t = 6 \text{ [mm]}}$$

at least!

What about the required section modulus? (B.3.1)

$$W = m \cdot C_s \cdot a \cdot l^2 \cdot p \text{ [cm}^3\text{]}$$

We, first, assume that no brackets, no stringers either!

Then, $l = D - h_{DB}$. $l = 9{,}0 - 1{,}1 = 7{,}9$ [m]

$$h = l/2 + 1 \Rightarrow h = 3{,}95 + 1 = 4{,}95 \text{[m]} \Rightarrow p = 9{,}81 \cdot h = 48{,}6 \text{[kN/m}^2\text{]}$$

$$m_a = 0{,}204 \cdot \frac{1}{7{,}9}\left[4 - (1/7{,}9)^2\right] = 0{,}025 \Rightarrow m = m_k^2 - m_a^2 = 0{,}999$$

$$W = 0{,}999 \cdot 0{,}53 \cdot 1 \cdot 7{,}9^2 \cdot 48{,}6 = 1607 \text{ [cm}^3\text{]}$$

NOT ENOUGH

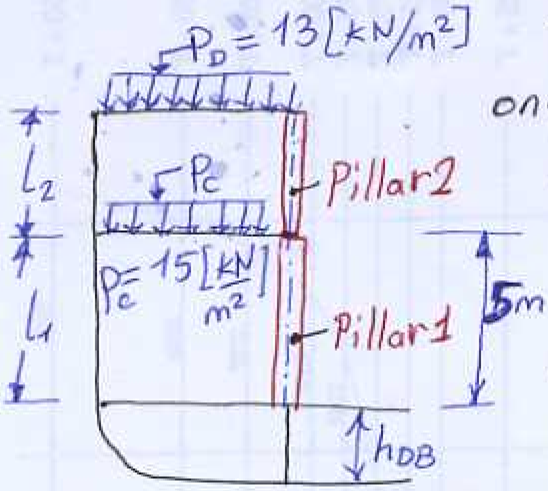
Real section modulus, on the other hand,

$$W = t \cdot d \cdot (b + s/3) = 0{,}6 \cdot 30 \cdot \left(40 + \frac{31{,}6}{3}\right) = 909{,}6 \text{ [cm}^3\text{]}$$

We may increase the thickness, t, or the depth, d!!
until we reach a section modulus of 1607[cm³]

SECTION 10 – Supporting Deck Structures

C. Pillars (Punteller)



Trial and error method is utilised once more.

Required sectional area of pillars:

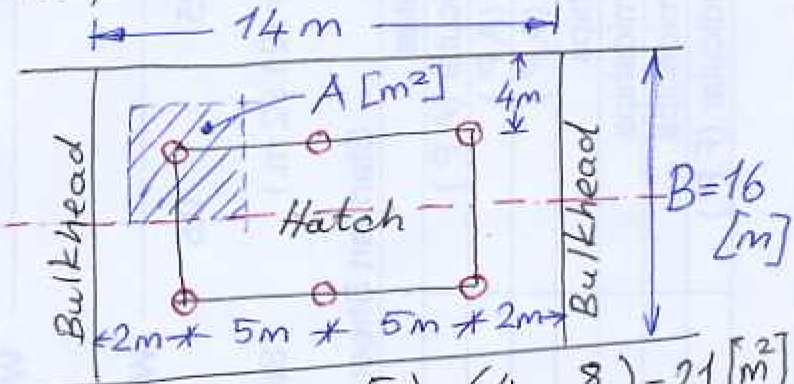
$$A_{s\,req} = 10 \cdot \frac{P_s}{\sigma_p}\ [cm^2] \quad (\text{Sec. }10,\ C.2)$$

P_s: Pillar load [kN]

$$P_s = p \cdot A + P_i\ [kN]$$

A: load area for one pillar [m^2]

P_i: load from pillars located above the pillar considered [kN]



$$A = \left(\frac{2}{2} + \frac{5}{2}\right) \times \left(\frac{4}{2} + \frac{8}{2}\right) = 21\,[m^2]$$

* Let us design "Pillar1" at hatch corner, for instance!

$$P_s = P_D \cdot A + P_C \cdot A$$

$$P_s = 13 \cdot 21 + 15 \cdot 21$$

$$P_s = 588\ [kN]$$

$$\sigma_p = \frac{\alpha}{S} \cdot R_{eH}\ [N/mm^2]$$

Now, let us start with a section!

$d_s = 15\,[cm]$ for a first try!

$$i_s = \sqrt{I_s / A_s} = \sqrt{\frac{\pi d^4/64}{\pi d^2/4}} = 0{,}25\,d$$

$R_{eH} = 235$ MPa

$E = 200$ GPa

$$\phi = 0{,}5\,[1 + n_p(\lambda_s - 0{,}2) + \lambda_s^2]$$

$$\phi = 1{,}77$$

$n_p = 0{,}34$ (for tubular)

$S = 2{,}0$ (in general)

$$\lambda_s = \frac{l_s}{i_s \cdot \pi}\sqrt{\frac{R_{eH}}{E}} \geq 0{,}2$$

$$\lambda_s = \frac{500}{3{,}75 \cdot \pi}\sqrt{\frac{235}{200000}} = 1{,}45 \geq 0{,}2 \ ✓✓$$

$$\alpha = \frac{1}{\phi + \sqrt{\phi^2 - \lambda_s^2}} = 0{,}359$$

$$\sigma_p = \frac{0{,}359}{2} \cdot 235 = 42{,}2\,\left[\frac{N}{mm^2}\right]$$

$$A_{s\,req} = 10 \cdot \frac{588}{42{,}2} = 139{,}2\,[cm^2]$$

$$A_s = \frac{\pi d_s^2}{4} = \frac{\pi\, 15^2}{4} = 176{,}7\,[cm^2] > A_{s\,req} = 139{,}2\,[cm^2]$$

SECTION ✓✓✓ SUITABLE

$$P = EI\left(\frac{\pi}{L}\right)^2 \qquad L = c \cdot l$$

An example for Euler Buckling Formula —

$c = 1$ (for both ends simply supported)

A solid circular pillar with a diameter of 15 cm and a length of 5 metres (steel material)

$E = 2\,150\,000\ [kgf/cm^2]$

$l = 500\ [cm]$

$I = \pi d^4/64 = 2485\ [cm^4]$

$P_{kr} \cong 211\ [ton\text{-}f]$

$P_{kr} = 210\,927\ [kgf]$

$P_{kr} = 2\,068\,566\ [N]$

$P_{kr} = 2068\ [kN]$

A safety factor (3-5) should be used!

Sectional area: $A = \pi d^2/4 = 176{,}7\ [cm^2]$

For a safety factor of 3 $\Rightarrow P_{kr} = 70\,309\ [kgf]$

$$\sigma_{compression} = \frac{P}{A} = 397{,}9\ [kgf/cm^2]$$

or using SI units: $\sigma = \dfrac{689\,522\ [N]}{17671\ [mm^2]} = 39\ [MPa]$

Yield stress for steel $\approx \sigma_{yield} = 235 \cdot [MPa]$

Although, normal stress due to compression is much more less than the yield stress, there is the danger of buckling!