خرسانة رابعة
انشاءات
٦

Water Tanks

UnderGround Tanks

6

Structural Department

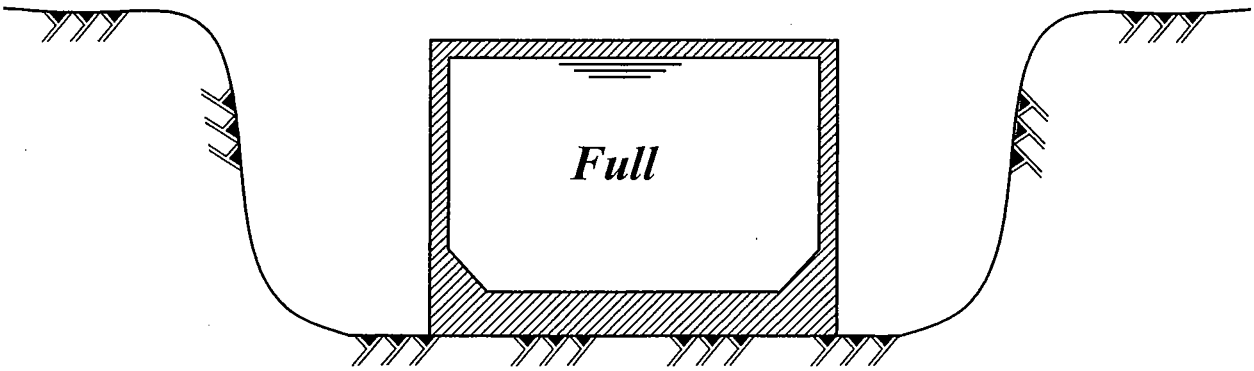
4th Year Civil
2ND TERM

③Under Ground Tanks

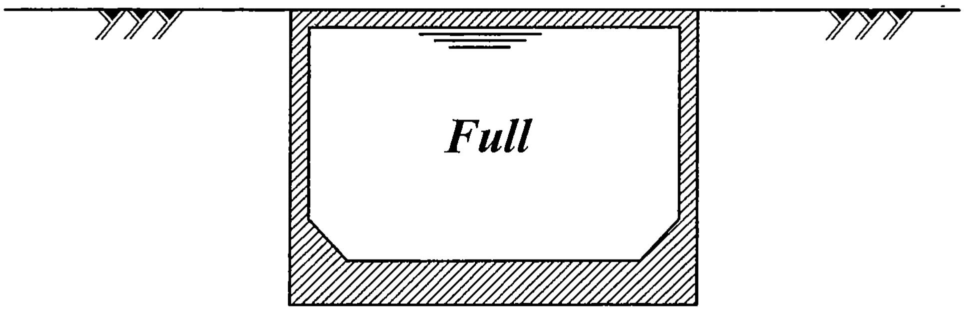
For Under Ground Tanks , There are three cases of loading

1) Just after construction

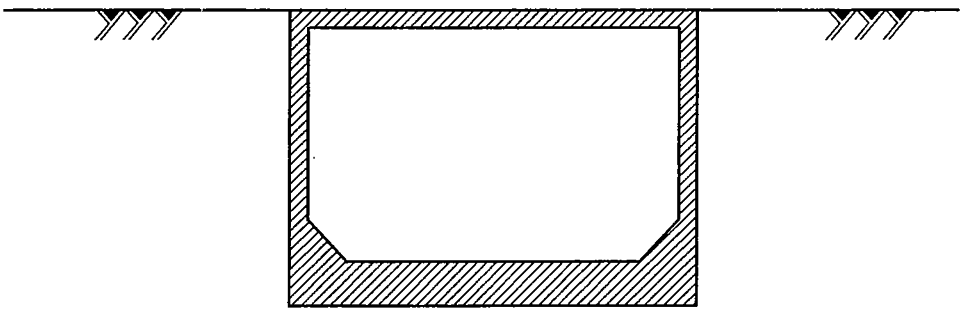
(The Tank Filled with water and No Earth Pressure)

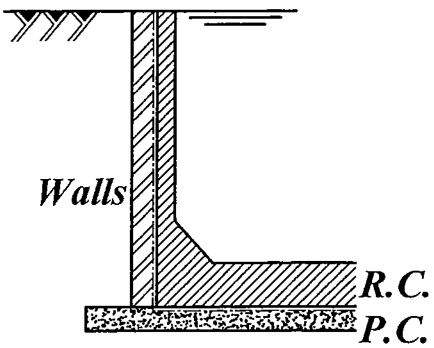


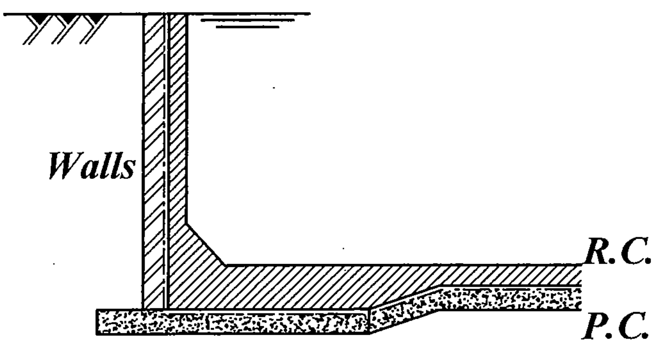
2) During Operation ***(Not Critical)***



3) During Repair







Steps of design:

1- Dimensioning

هي عملية فرض الأبعاد للعناصر الخرسانية المختلفة (الحائط و الأرضية).

walls	Cantilever	Two way	One way
t_w	$\frac{H}{10}$	$\frac{L \text{ or } H}{(15\text{-}20)}$ الأقل	$\frac{L}{15}$ or $\frac{H}{15}$ الأقل

Slabs $t_s = \frac{L}{12}$

$t_w \nless 300$ mm & $t_f \nless 400$ mm

$t_w = 300$ mm & $t_f = 400$ mm للتسهيل يمكن دائماً فرض

2- Checks

a- Check for bearing capacity

لا يتم عمل هذا الـ ***Check*** في الامتحان إلا إذا طلب في المسألة أو كانت ***Bearing capacity*** معطاه في الامتحان و لكن في جميع الأحوال يتم حساب F_{gross}

Stress under the base of the tank must be less than the allowable bearing Stresses (Bearing Capacity) of The Soil

$$F_{gross} = \frac{\Sigma W}{A}$$

$$F_{gross} < \text{Bearing Capacity}$$

(F_{gross}) *The uniform stress on the soil*

(ΣW) *Weight of (Beams+ walls + Roof + Water + Floor slab)*

(A) *Area of the base of The Tank*

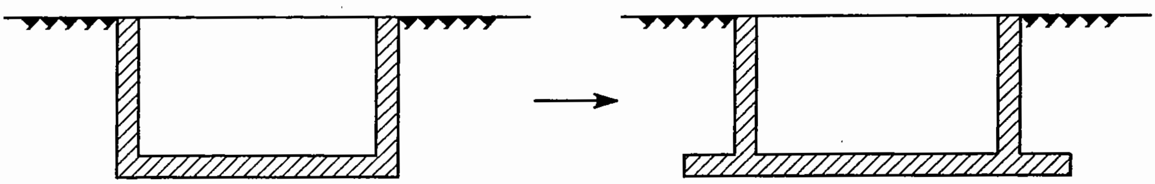
$$\text{Bearing Capacity} \simeq 150 \text{ kN/m}^2$$

If $F_{gross} \leqslant$ *Bearing capacity of soil* $\longrightarrow$ *Safe*

If $F_{gross} >$ *Bearing capacity of soil* $\longrightarrow$ *Unsafe*

↓

Increase floor dimensions



b- Check for safety against uplift

To avoid floating of under ground tanks due to up lift , factor of safety against Up Lift must be greater than this value

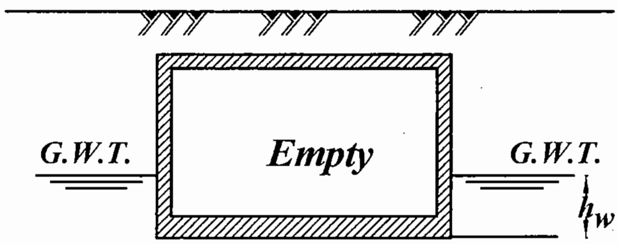
$$\text{Factor of Safety} = \frac{\text{Minimum weight of the tank}}{\text{Up Lift Force}} > \begin{cases} 1.5 \\ 1.2 \end{cases}$$

$$\text{Up Lift Force} = A \times \gamma_w h_w$$

(A) Area of The base of The Tank

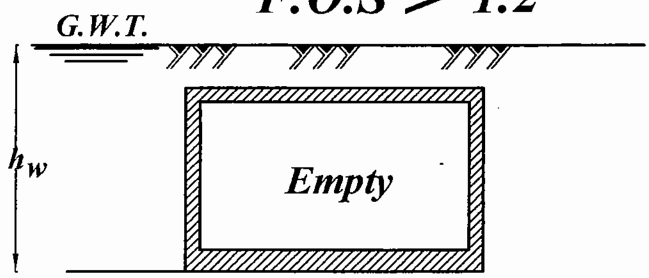
(h_w) Height of G.W.T. from the base of the tank

F.O.S > 1.5



يوجد احتمال لزيادة الـ G.W.T.

F.O.S > 1.2

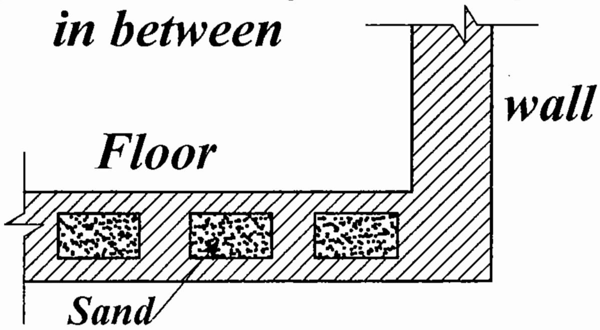


لا يمكن زيادة الـ G.W.T.

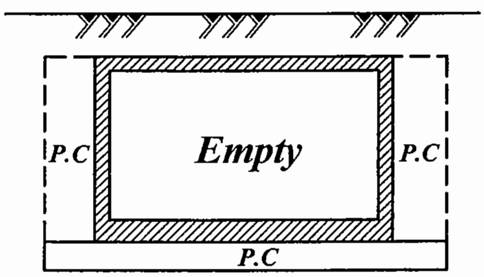
Factors to increase F.O.S. against uplift

① Increase the thickness of the slabs or walls

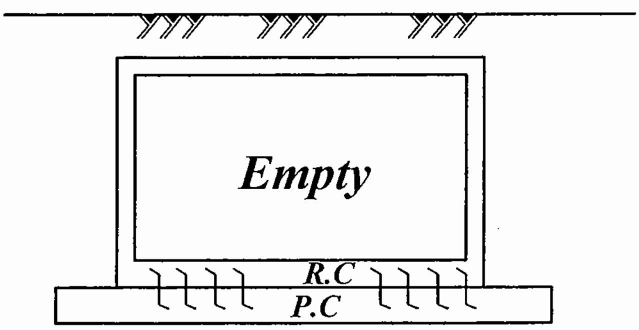
② Use double floor with filling in between



③ Use over weight around the tank



④ Anchors Between R.C. & P.C.



⑤ Use tension piles

3- Loads and straining actions

هي عملية حساب الأحمال على الشرائح المختلفة للـ **Tanks** و تكون هذه الأحمال **Working loads** و يتم حل هذه الشرائح باستخدام **Moment distribution** ثم يتم حساب القوى الداخلية في هذه الشرائح.

$$\longrightarrow \; F_{gross} = \frac{\Sigma W}{A} \;\longrightarrow\; F_{net} = F_{gross} - \text{Direct Load}$$

- ***Relative inertia between walls and floor must be taken into consideration while getting straining actions on the tank using Moment Distribution Method*** $I_{base} = (4 \rightarrow 8)\, I_{wall}$ و بالتالي نأخذ

- تتولد عزوم على قاعدة الخزان في حالة عدم انطباق مركز الأحمال مع مركز القاعدة

Loads on Under Ground Tanks

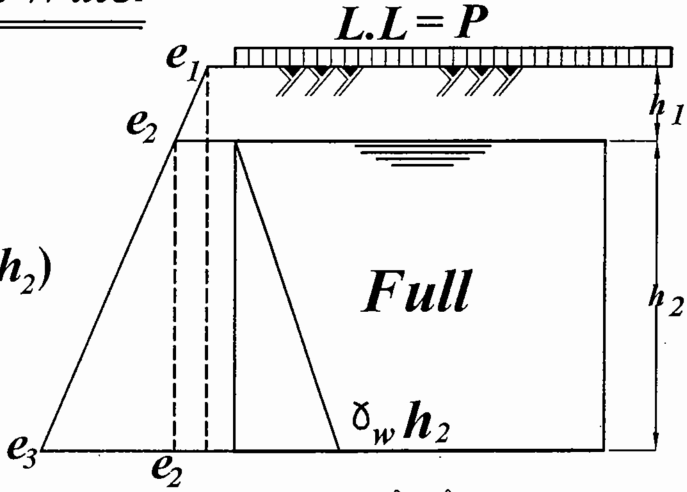
During Operation without Ground Water

$$e_1 = K_a P$$

$$e_2 = e_1 + \gamma_{soil} K_a h_1 = K_a P + \gamma_{soil} K_a h_1$$

$$e_3 = e_2 + \gamma_{soil} K_a h_2 = K_a P + \gamma_{soil} K_a (h_1 + h_2)$$

$$K_a = \frac{1 - \sin\phi}{1 + \sin\phi}$$

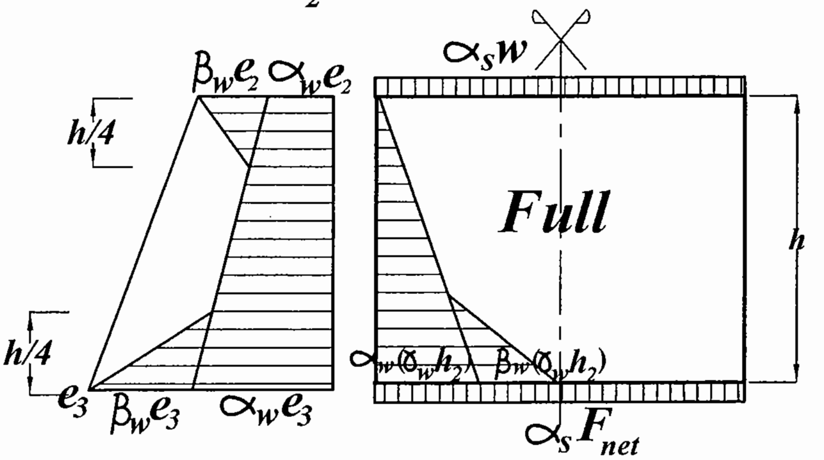


For Wall $\longrightarrow \beta_w \,\&\, \alpha_w$

For Slab $\longrightarrow \beta_s \,\&\, \alpha_s$

$$w = t_{cover}\gamma_c + \gamma_{soil} h_1 + P$$

$$F_{net} = F_{gross} - (\text{direct load})$$

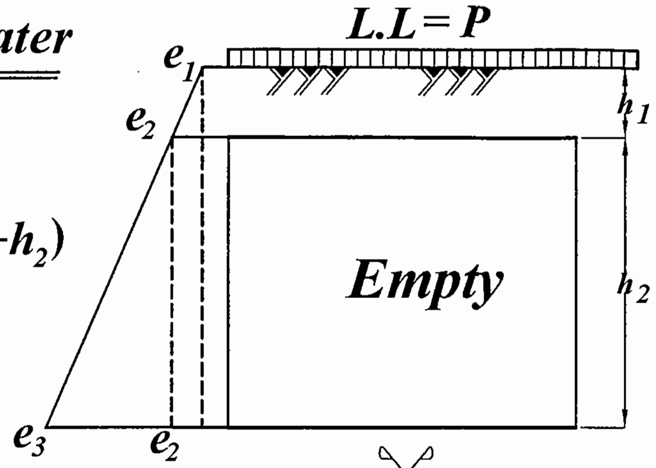


During Repair without Ground Water

$$e_1 = K_a P$$

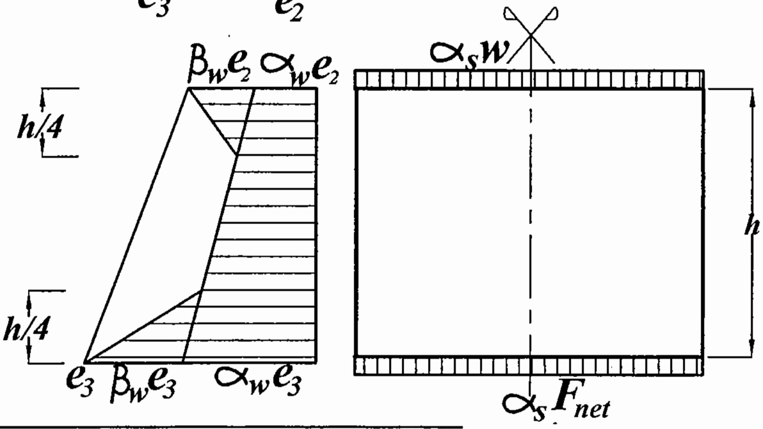
$$e_2 = e_1 + \gamma_{soil} K_a\, h_1 = K_a P + \gamma_{soil} K_a\, h_1$$

$$e_3 = e_2 + \gamma_{soil} K_a\, h_2 = K_a P + \gamma_{soil} K_a\, (h_1 + h_2)$$



$$F_{net} = F_{gross} \text{ - (direct load)}$$

$$W = t_{cover}\gamma_c + \gamma_{soil} h_1 + P$$



During Operation with Ground Water

$$e_1 = K_a P$$

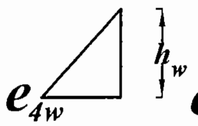
$$e_2 = e_1 + \gamma_{soil} K_a\, h_1 = K_a P + \gamma_{soil} K_a\, h_1$$

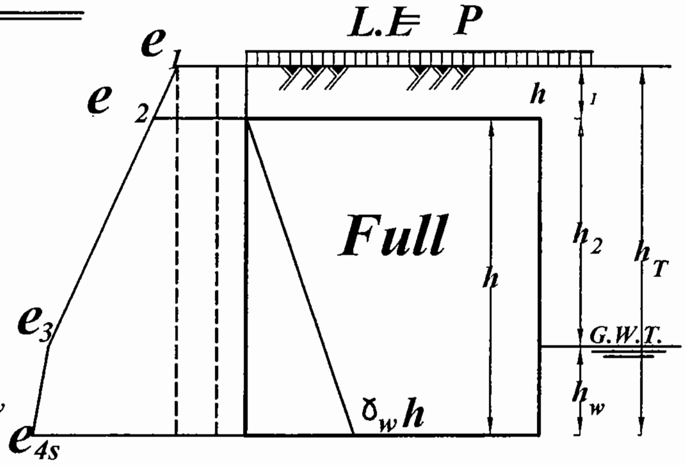
$$e_3 = e_2 + \gamma_{soil} K_a\, h_2$$

$$= K_a P + \gamma_{soil} K_a\, (h_1 + h_2)$$

$$e_4 = e_{4s} + e_{4w}$$

$$e_{4s} = e_3 + \gamma_{sub} K_a\, h_w$$

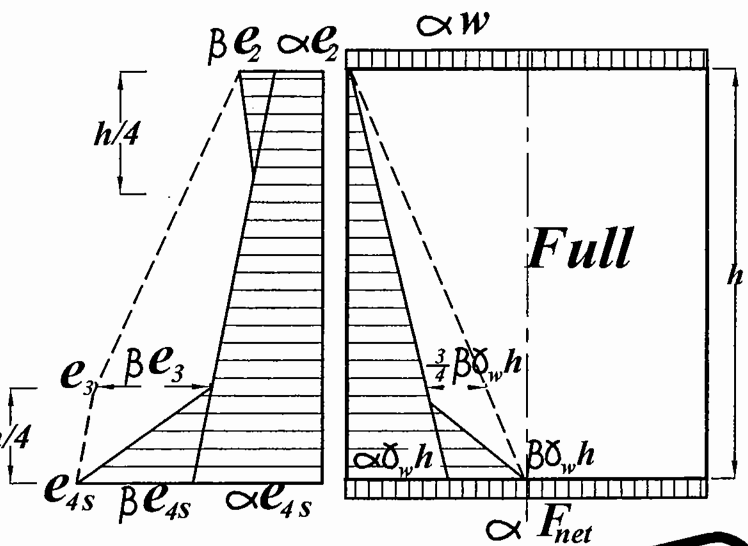




$$= K_a P + \gamma_{soil} K_a\, (h_1 + h_2) + \gamma_{sub} K_a\, (h_w)$$

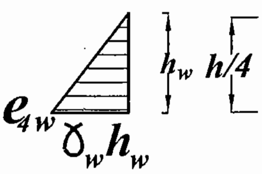
$$e_{4w} = \gamma_w\, h_w$$

$$\boxed{\gamma_{sub} = \gamma_{soil} - \gamma_w}$$



$$F_{net} = F_{gross} \text{ - (direct load)}$$

$$W = t_{cover}\gamma_c + \gamma_{soil} h_1 + P$$



Another (Easier) method

Very Important

$$e_4 = e_{4s} + e_{4w} = e_3 + \gamma_{sub} K_a h_w + \gamma_w h_w$$

$$= e_3 + \gamma_{sub} K_a h_w + \gamma_w h_w + (\gamma_{soil} K_a h_w - \gamma_{soil} K_a h_w)$$

$$= (e_3 + \gamma_{soil} K_a h_w) + (\gamma_w h_w + \gamma_{sub} K_a h_w - \gamma_{soil} K_a h_w)$$

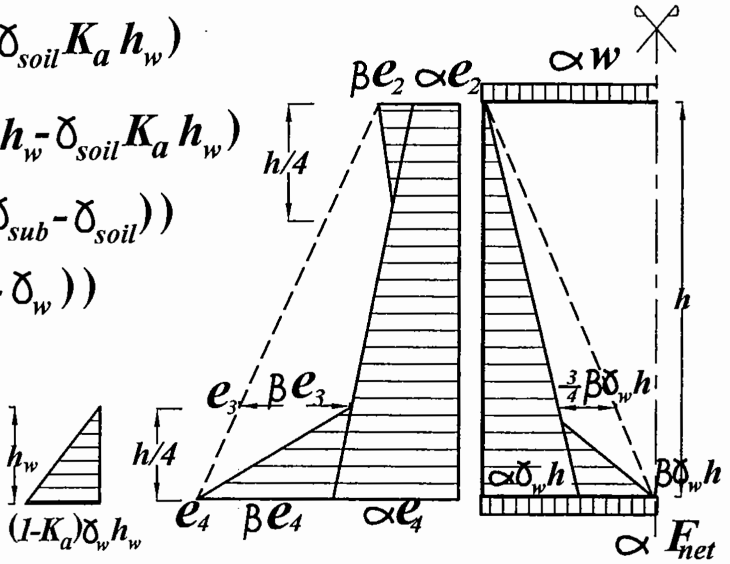
$$= (e_3 + \gamma_{soil} K_a h_w) + (\gamma_w h_w + K_a h_w (\gamma_{sub} - \gamma_{soil}))$$

$$= (e_3 + \gamma_{soil} K_a h_w) + (\gamma_w h_w + K_a h_w (-\gamma_w))$$

$$= (e_3 + \gamma_{soil} K_a h_w) + (\gamma_w h_w - \gamma_w K_a h_w)$$

$$= (e_3 + \gamma_{soil} K_a h_w) + (1 - K_a)\gamma_w h_w$$

$$\boxed{e_4 = \gamma_{soil} K_a h_T + (1-K_a)\gamma_w h_w}$$



During Repair with Ground Water

$$e_1 = K_a P$$

$$e_2 = e_1 + \gamma_{soil} K_a h_1 = K_a P + \gamma_{soil} K_a h_1$$

$$e_3 = e_2 + \gamma_{soil} K_a h_2$$

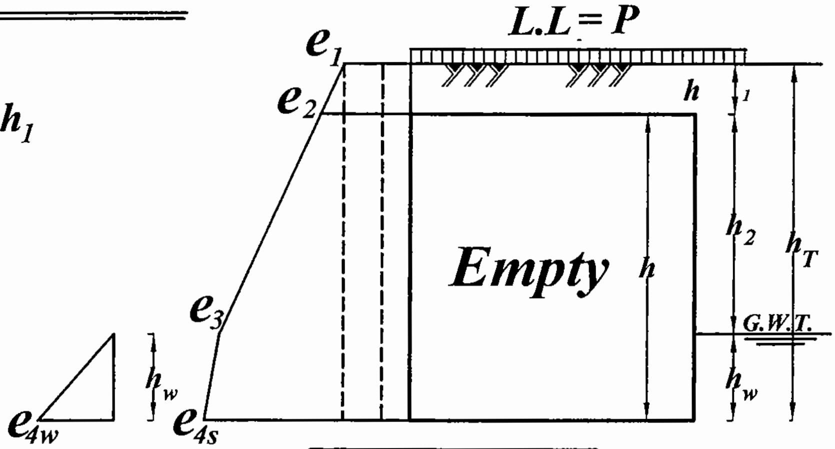
$$= K_a P + \gamma_{soil} K_a (h_1 + h_2)$$

$$e_4 = e_{4s} + e_{4w}$$

$$e_{4s} = e_3 + \gamma_{sub} K_a h_w$$

$$= K_a P + \gamma_{soil} K_a (h_1 + h_2) + \gamma_{sub} K_a (h_w)$$

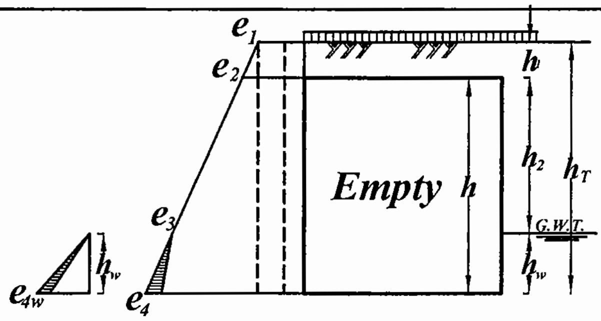
$$e_{4w} = \gamma_w h_w$$



$$\boxed{\gamma_{sub} = \gamma_{soil} - \gamma_w}$$

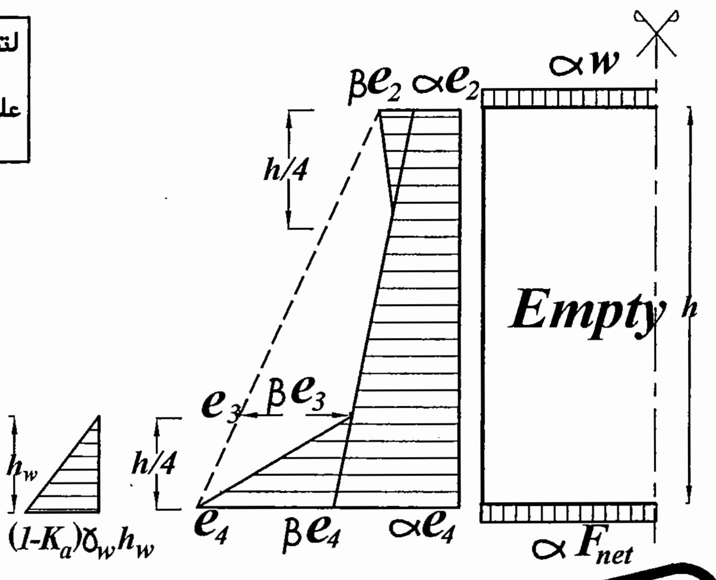
لتسهيل الحل باستخدام ال *Moment distribution* نضيف حمل مثلث

على ضغط التربة و نطرح نفس القيمة من ضغط المياة



$$F_{net} = F_{gross} - \text{(direct load)}$$

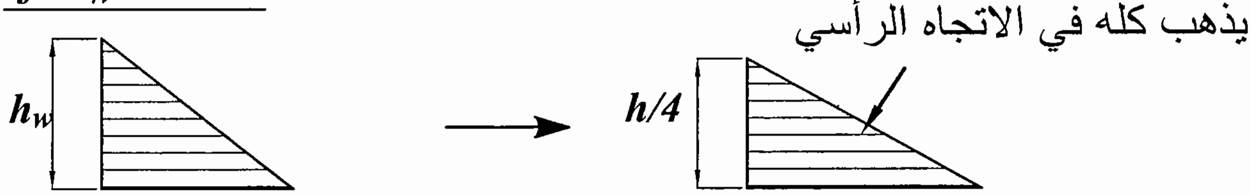
$$w = t_{cover}\gamma_c + \gamma_{soil} h_1 + P$$



*Note

عادة يكون مثلث الماء على ارتفاع ***h/4*** للحائط و بالتالي يذهب كله في التجاه الرأسي
أما في حالة أن مثلث الماء ليس على ارتفاع ***h/4*** فنقوم بتقريبه كالآتي حتى يسهل التعامل معه

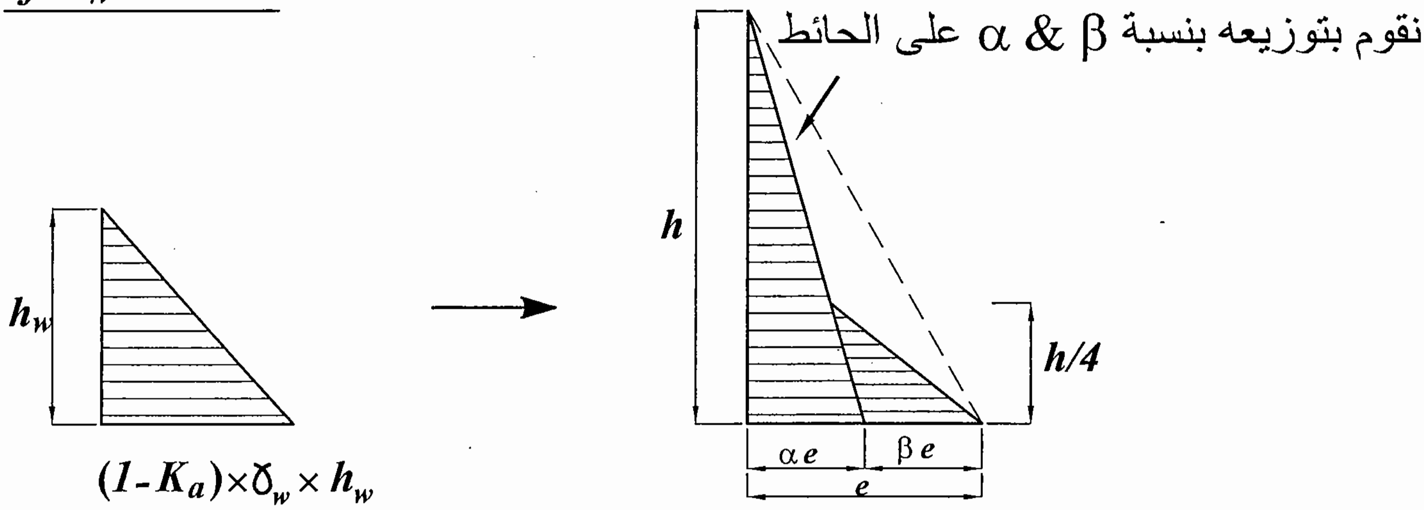
If $h_w \leqslant h/2$



$(1-K_a)\times\gamma_w\times h_w$

$$e = \frac{(1-K_a)\times\gamma_w\times h_w\times h_w}{h/4}$$

If $h_w > h/2$



$$e = \frac{(1-K_a)\times\gamma_w\times h_w\times h_w}{h/4}$$

4- Design of sections

هي مرحلة تصميم القطاعات التى تم حساب القوى الداخلية فيها .

Water sections (Cat. III) ⟶ Stage (I) & Stage (II)

Air sections (Cat. II) ⟶ Stage (II)

⟶ ***All loads are working loads at Stage (I) & ultimate loads at Stage (II)***

⟶ ***If The Tension Side At The Soil Side Or Water Side The Section Will be Designed as a Water Sections***

5- Details of RFT

Same as Rested Tanks رسم تفاصيل التسليح.

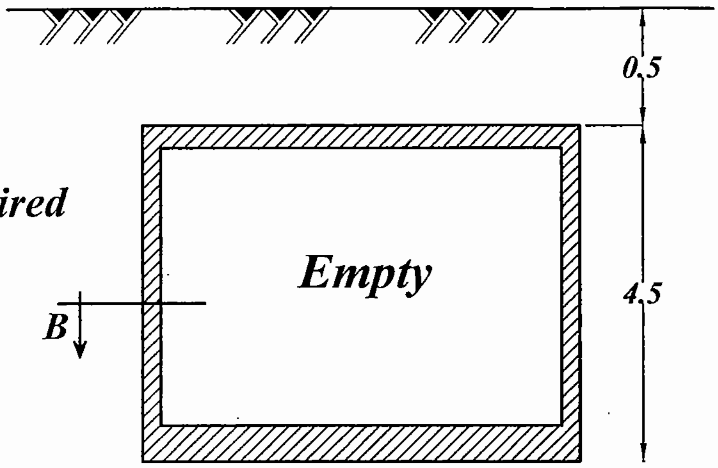
Examples

4th year Civil

Example ①

① Draw the load diagram for Vl. and Hz. sections

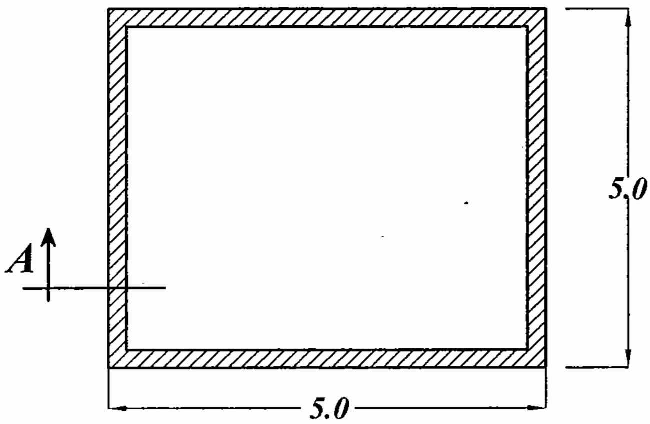
Case of During Repair is only Required



Sec A-A

$\gamma_{soil} = 18 \ kN/m^3$

$\phi = 30^\circ$



Sec B - B

Concrete Dimension

$$t_w = \frac{h}{16} = \frac{4500}{16} = 281.3 = 300 \quad mm$$

$$t_s = \frac{L}{12} = \frac{5000}{12} = 417 \quad = 500 \ mm$$

$$t_{Cover} = 250 \quad mm$$

$$(W_{Total}) = \underbrace{(18)(5\times5\times0.5)}_{Soil} + \underbrace{(0.25\times25)\times(5\times5)}_{Cover}$$
$$+ \underbrace{(0.3\times25)(5\times4.5\times4)}_{Walls} + \underbrace{(0.50\times25)\times(5\times5)}_{Floor} = 1368.8 \ kN$$

$$F_{gross} = \frac{W_{Total}}{A} = \frac{1368.8}{5\times5} = 54.75 \ kN/m^2$$

$$\text{Direct Stress} = (t_s \gamma_c) = (0.5\times25) = 12.5 kN/m^2$$

$$F_{net} = \text{Total Stress} - \text{Direct Stress}$$
$$= 54.75 - 12.5 = 42.25 \ kN/m^2$$

The Cover (5.0 & 5.0) $\alpha = \beta = 0.5$

$$w_{cover} = (t_s \gamma_c + \gamma_{soil}\, h) = 0.25\times25 + 18\times0.5 = 15.25 \;\; kN/m^2$$

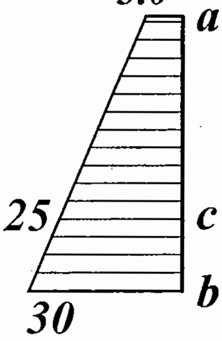
$$(\beta w) = (\alpha w) = 0.5\times 15.25 = 7.6\, kN/m^2$$

The Floor (5.0 & 5.0) $\alpha = \beta = 0.5$

$$(\beta F_{net}) = (\alpha F_{net}) = 0.5\times 42.25 = 21.1\; kN/m^2$$

The Walls (5.0 & 4.5) Two way $m' = 0.76$ $m = 0.76$

$$r = \frac{0.76\times5.0}{0.76\times4.5} = 1.11 \qquad \alpha = 0.603 \updownarrow \qquad \beta = 0.397 \leftrightarrow$$



$$K_a = \frac{1-\sin\phi}{1+\sin\phi} = \frac{1-0.5}{1+0.5} = \frac{1}{3}$$

$$P_1 = K_a\times\gamma_{soil}\times h_1 = \frac{1}{3}\times18\times0.5 = 3.0\; kN/m^2$$

$$P_2 = K_a\times\gamma_{soil}\times h_2 = \frac{1}{3}\times18\times(0.5+4.5) = 30\;\; kN/m^2$$

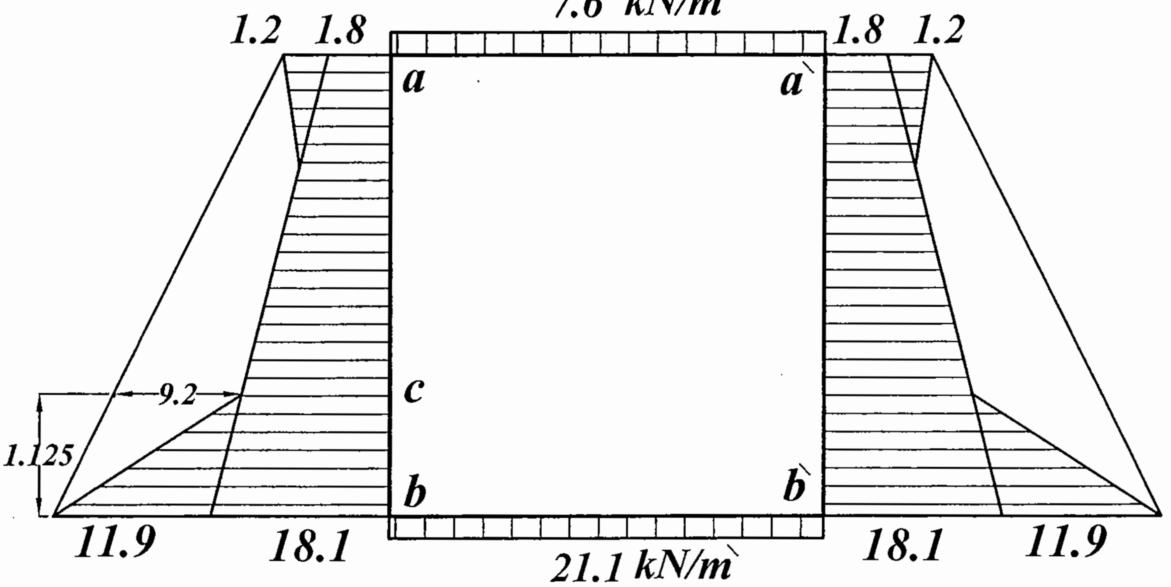
$$(\alpha P_1) = 0.603\times3.0 = 1.8 \;\; kN/m^2 \qquad (\beta P_1) = 0.397\times3.0 = 1.2 \;\; kN/m^2$$

$$(\alpha P_2) = 0.603\times30 = 18.1\; kN/m^2 \qquad (\beta P_2) = 0.397\times30 = 11.9\; kN/m^2$$

at point c

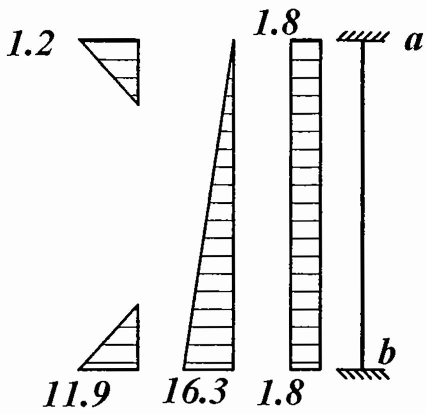
$$P_C = K_a\times\gamma_{soil}\times h_C = \frac{1}{3}\times18\times(5.0-1.125) = 23.25\;\; kN/m^2$$

$$(\beta P_C) = 0.397\times23.25 = 9.2 \;\; kN/m^2$$



Sec A-A

$$F.E.M_{a-a'} = -\frac{wL^2}{12} = -\frac{7.6 \times (5.0)^2}{12} = -15.8 \ kN.m$$



$$F.E.M_{a-b} = +\frac{1.8 \times (4.5)^2}{12} + \frac{16.3 \times (4.5)^2}{30} + \frac{1.2 \times (4.5)^2}{124} + \frac{11.9 \times (4.5)^2}{904} = +14.5 \ kN.m$$

$$F.E.M_{b-a} = -\frac{1.8 \times (4.5)^2}{12} - \frac{16.3 \times (4.5)^2}{20} - \frac{1.2 \times (4.5)^2}{904} - \frac{11.9 \times (4.5)^2}{124} = -21.5 \ kN.m$$

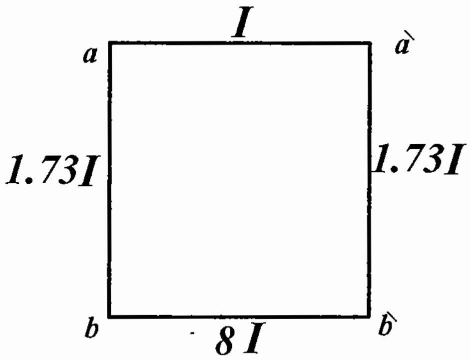
$$F.E.M_{b-b'} = +\frac{wL^2}{12} = +\frac{21.1 \times (5.0)^2}{12} = +43.9 \ kN.m$$

$$\left(\frac{t_w}{t_c}\right)^3 = \left(\frac{30}{25}\right)^3 = 1.73$$

$$\boxed{I_{a-b} = 1.73 I_{a-a'}}$$

$$\left(\frac{t_s}{t_c}\right)^3 = \left(\frac{50}{25}\right)^3 = 8$$

$$\boxed{I_{b-b'} = 8 \ I_{a-a'}}$$



Distribution Factor For joint (a)

$$D.F._{a-b} = \frac{\frac{1.73}{4.5}}{\frac{1.73}{4.5} + \frac{1}{2} \times \frac{I}{5.0}} = 0.794$$

$$D.F._{a-a'} = 1 - 0.794 = 0.206$$

Distribution Factor For joint (b)

$$D.F._{b-a} = \frac{\frac{1.73}{4.5}}{\frac{1.73}{4.5} + \frac{1}{2} \times \frac{8}{5.0}} = 0.325$$

$$D.F._{b-b'} = 1 - 0.325 = 0.675$$

Joint	a		b	
member	a - a`	a - b	b - a	b - b`
D.F.	0.206	0.794	0.325	0.675
F.E.M.	-15.8	14.5	-21.5	43.9
B.M.	0.27	1.03	-7.28	-15.12
C.O.M.	0	-3.64	0.52	0
B.M.	0.75	2.89	- 0.17	- 0.35
F.M.	-14.78	14.78	- 28.43	28.43

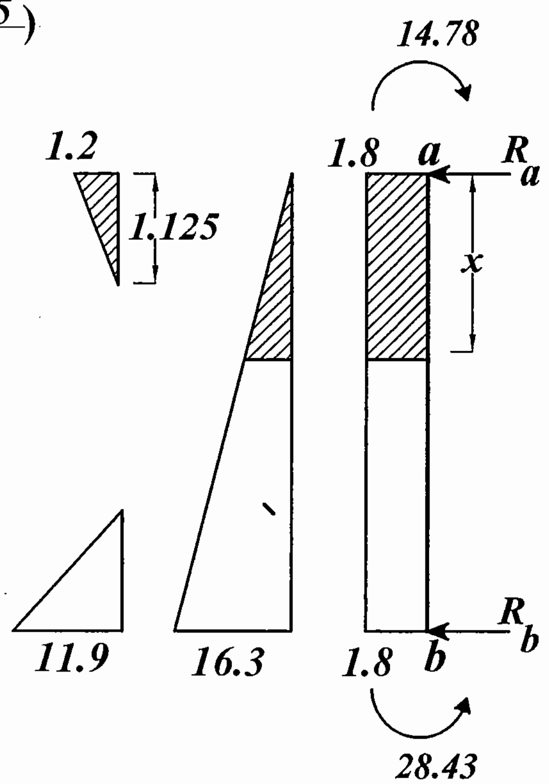
$$M_b = 1.8 \times 4.5 \left(\frac{4.5}{2}\right) + 0.5 \times 16.3 \times 4.5 \left(\frac{4.5}{3}\right)$$

$$+ 0.5 \times 1.2 \times 1.125 \left(4.5 - \frac{1.125}{3}\right)$$

$$+ 0.5 \times 11.9 \times 1.125 \left(\frac{1.125}{3}\right)$$

$$+ 14.78 - R_a \times (4.5) = 28.43$$

$$R_a = 14.4 \ kN \qquad R_b = 37.75 \ kN$$



Get Point of Zero Shear

$$R_a - 1.8 \ (x) - \frac{1}{2} \times (x) \times \left(\frac{16.3}{4.5} x\right)$$

$$- \frac{1}{2} \times 1.2 \times 1.125 = 0$$

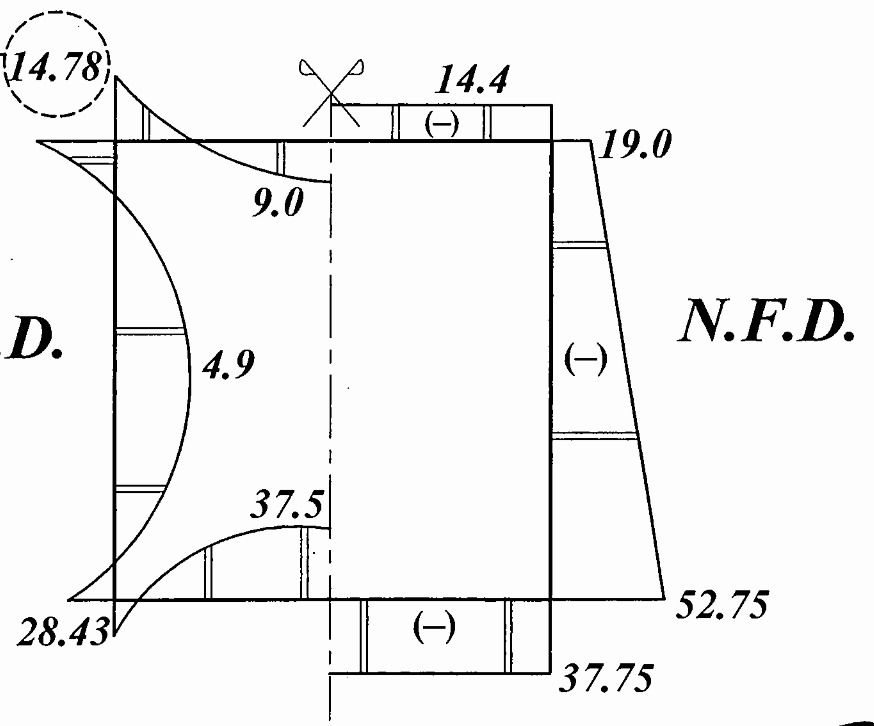
$$1.81 x^2 + 1.8 x - 13.725 = 0$$

$$\boxed{x = 2.30 \ m}$$

$$M_{\substack{max \\ +ve}} = 14.4 \times 2.3 - (0.5 \times 1.2 \times 1.125) \times \left(2.3 - \frac{1.125}{3}\right) - 1.8 \times (2.30) \times \left(\frac{2.30}{2}\right)$$

$$- 0.5 \times (2.30) \left(\frac{16.3}{4.5} \times 2.30\right) \times \left(\frac{2.30}{3}\right) - 14.78 = 4.9 \ kN.m$$

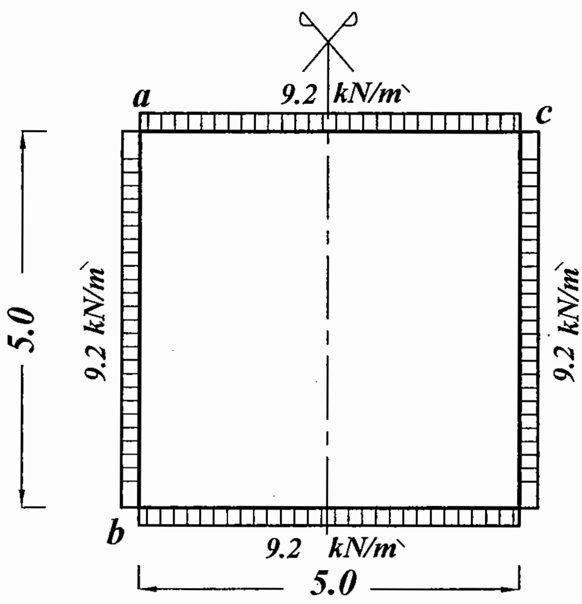
قيمة الـ *Moment* عالية لذلك
لا يمكن إهمال *Cover*
و ذلك لأن الـ *Cover* يؤثر علية
أحمال عالية

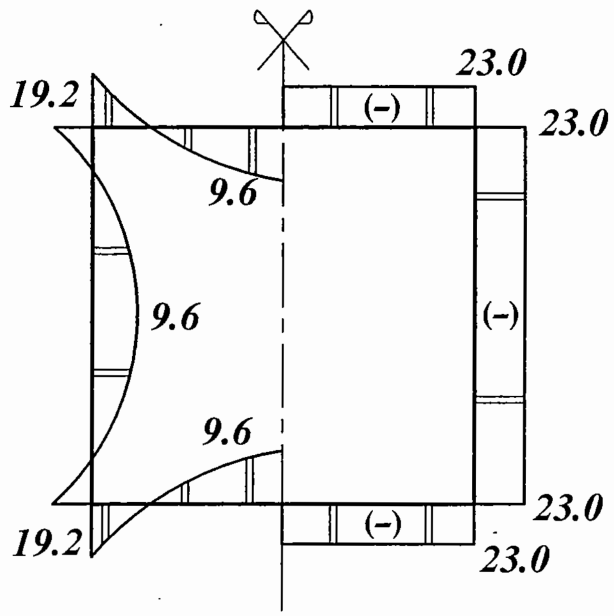


Hz strip at $\frac{h}{4}$

$$P_C = K_a \times \gamma_{soil} \times h_C = \frac{1}{3} \times 18 \times (5.0 - 1.125) = 23.25 \ kN/m^2$$

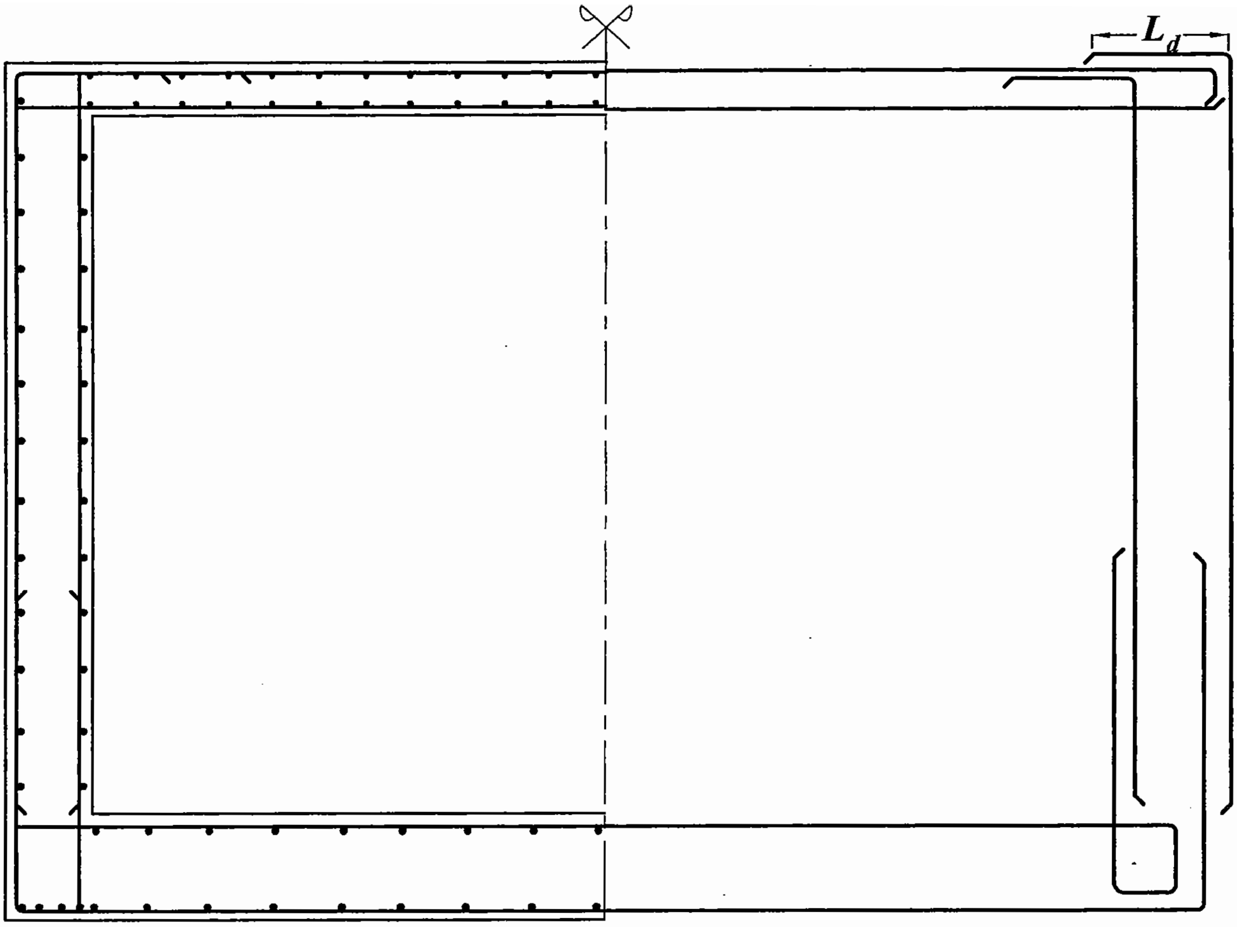
$$(\beta \ P_C) = 0.397 \times 23.25 = 9.2 \ kN/m^2$$



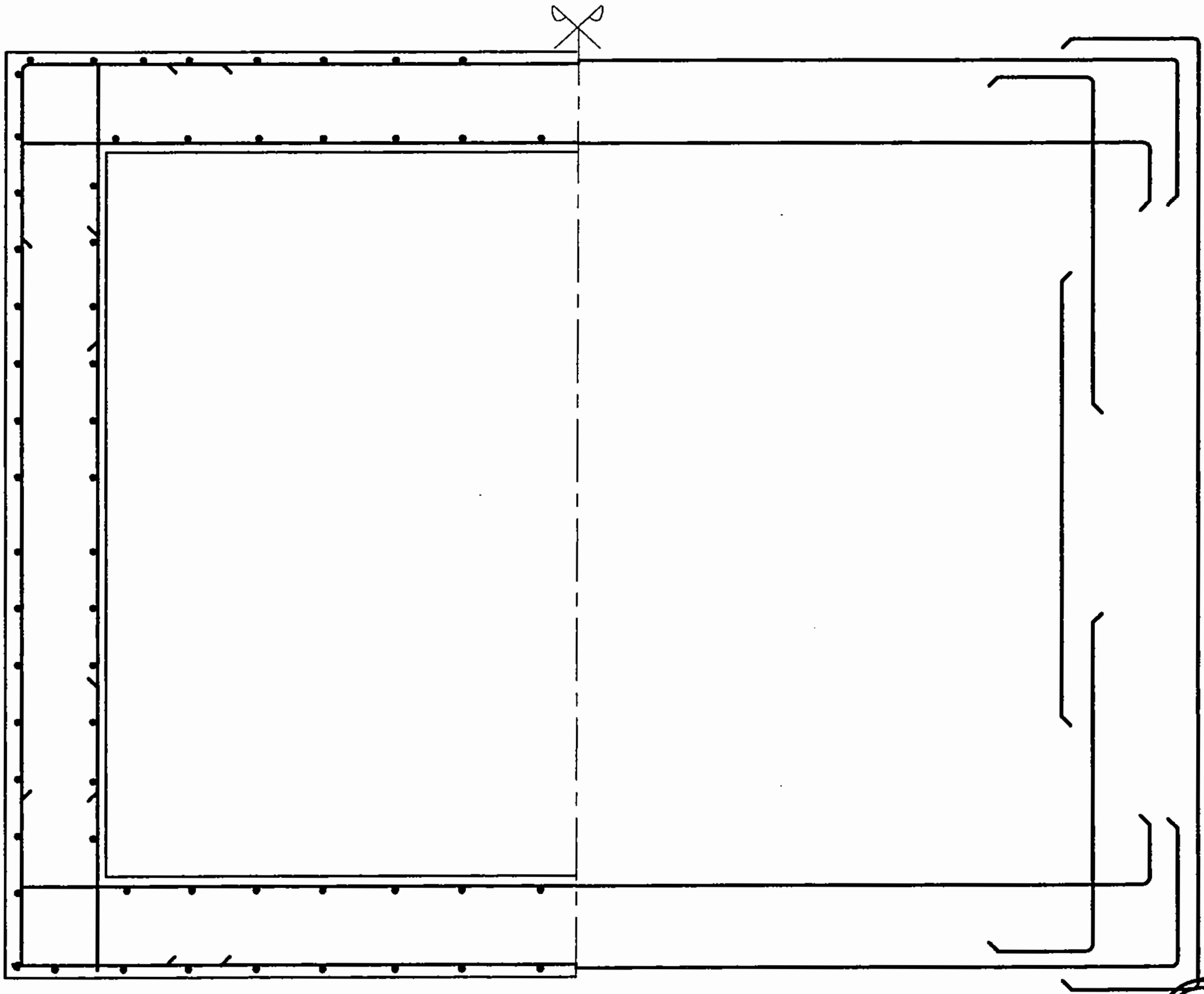


B.M.D. **N.F.D.**

> **Note**
>
> ***If The Tension Side At The Soil Side Or Water Side The Section Will be Designed as a Water Sections***



Vl Strip A - A



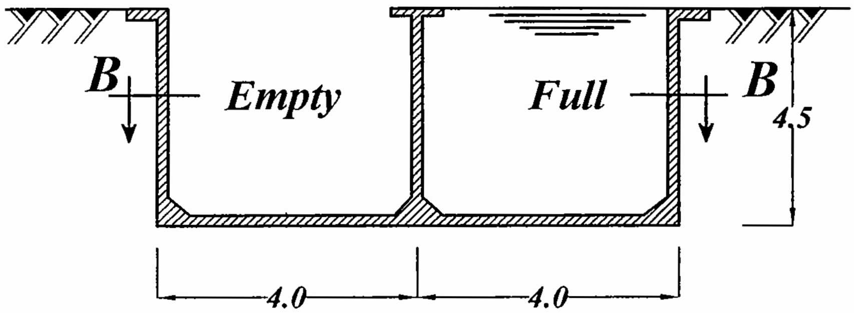
Hz Strip B - B

Example ②

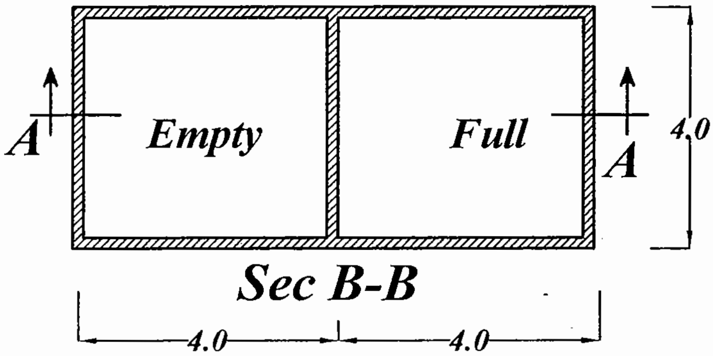
① Draw the load diagram for Vl. and Hz. sections

$\gamma_{soil} = 18 \;\; kN/m^3$

$K = \frac{1}{3}$



Sec A-A



Sec B-B

Concrete Dimension

$$t_w = \frac{h}{16} = \frac{4500}{16} = 281.3 = 300 \quad mm$$

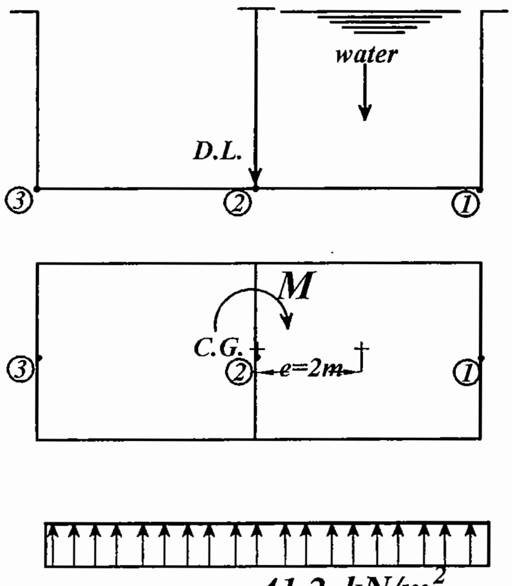
$$t_s = \frac{L}{12} = \frac{4000}{12} = 333.3 = 400 \;\; mm$$

$$(W_{D.L.}) = \underset{\text{Hz Beam}}{(0.25\times0.70\times25)(4\times7)}$$

$$+ \underset{\text{Walls}}{(0.3\times25)(4\times4.5\times7)}$$

$$+ \underset{\text{Lower Floor}}{(0.4\times25)\times(4\times8)} = 1317.5 \; kN$$

$$F_{gross_{D.L.}} = \frac{W_{D.L.}}{A} = \frac{1317.5}{4\times8} = 41.2 \; kN/m^2$$



Gross Stress due to D.L.

$$F_{gross_{water}} = \frac{W_{water}}{A} \pm \frac{M}{I} Y$$

$$(W_{water}) = (4\times4\times4.5)\times10 = 720 \quad kN$$

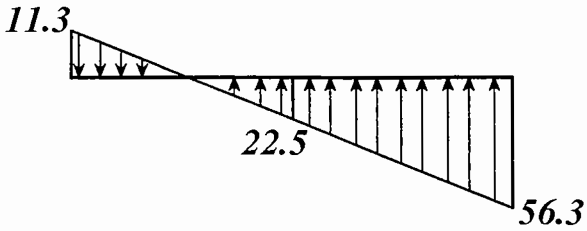
$$M = (720)\times2.0 = 1440 \;\; kN.m$$

$$I = \frac{4(8)^3}{12} = 170.7 \quad m^4$$

$$F_1 = +\frac{720}{32} + \frac{1440}{170.7}(4) = +56.3 \ kN/m^2$$

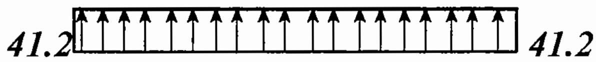
$$F_2 = +\frac{720}{32} + \frac{1440}{170.7}(0) = +22.5 \ kN/m^2$$

$$F_3 = +\frac{720}{32} - \frac{1440}{170.7}(4) = -11.3 \ kN/m^2$$



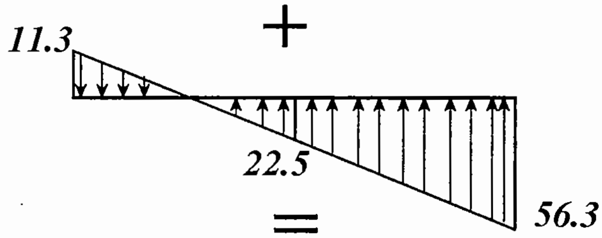
Gross Stress due to water

Total Gross Stress = Gross Stress due to D.L.



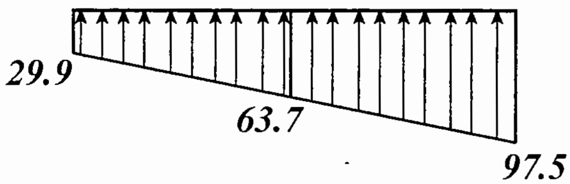
+

Gross Stress due to water



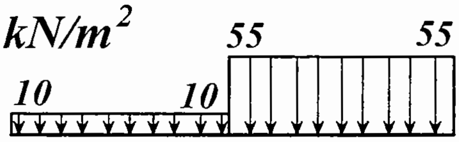
=

Total Gross Stress



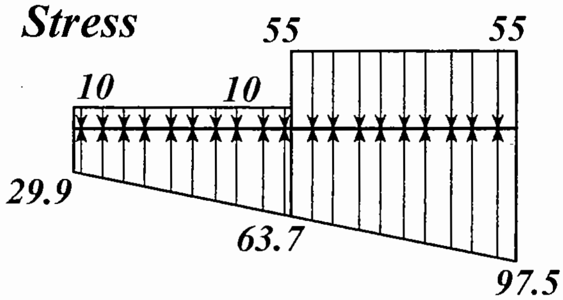
$$Direct\ Stress_{Empty} = (0.4 \times 25) = 10 \ kN/m^2$$

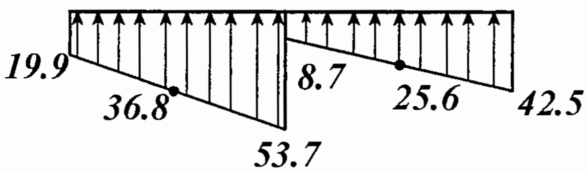
$$Direct\ Stress_{Full} = (0.4 \times 25 + 10 \times 4.5) = 55 \ kN/m^2$$



Direct Stress

Net Stress = Total Gross Stress − Direct Stress





Net Stress

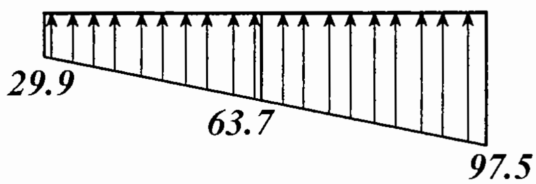
Note The net stresses must be distributed according to $(\alpha \ \& \ \beta)$

Note You can get total gross stress using (W_{total})

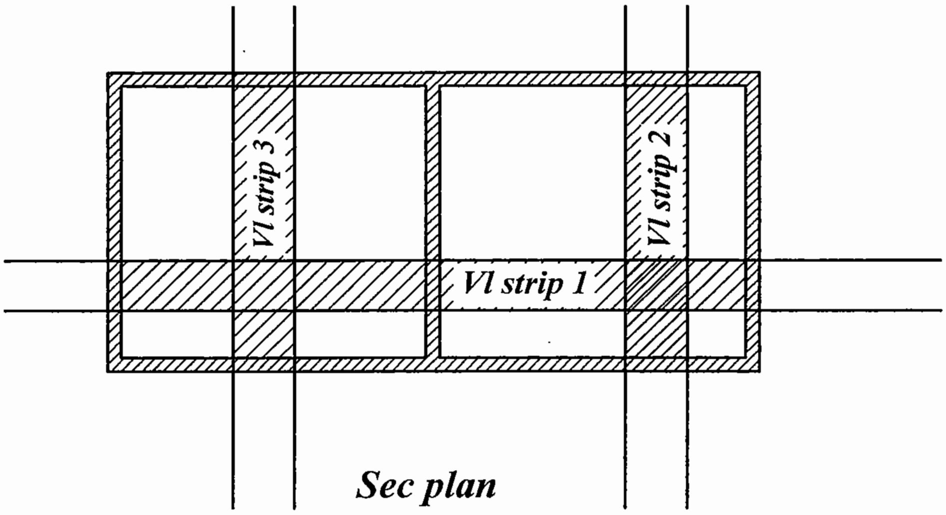
$$F_1 = +\frac{(1317.5+720)}{32} + \frac{1440}{170.7}(4) = +97.5 \ kN/m^2$$

$$F_2 = +\frac{(1317.5+720)}{32} + \frac{1440}{170.7}(0) = +36.7 \ kN/m^2$$

$$F_3 = +\frac{(1317.5+720)}{32} - \frac{1440}{170.7}(4) = -29.9 \ kN/m^2$$



Total Gross Stress



Sec plan

Walls *(4.0 & 4.5) Two way*

$$r = \frac{0.87 \times 4.5}{0.76 \times 4.0} = 1.288 \qquad \alpha = 0.73 \leftrightarrow \qquad \beta = 0.27 \updownarrow$$

$$(\alpha w) = 0.73 \times 45 = 32.8\ kN/m \leftrightarrow$$

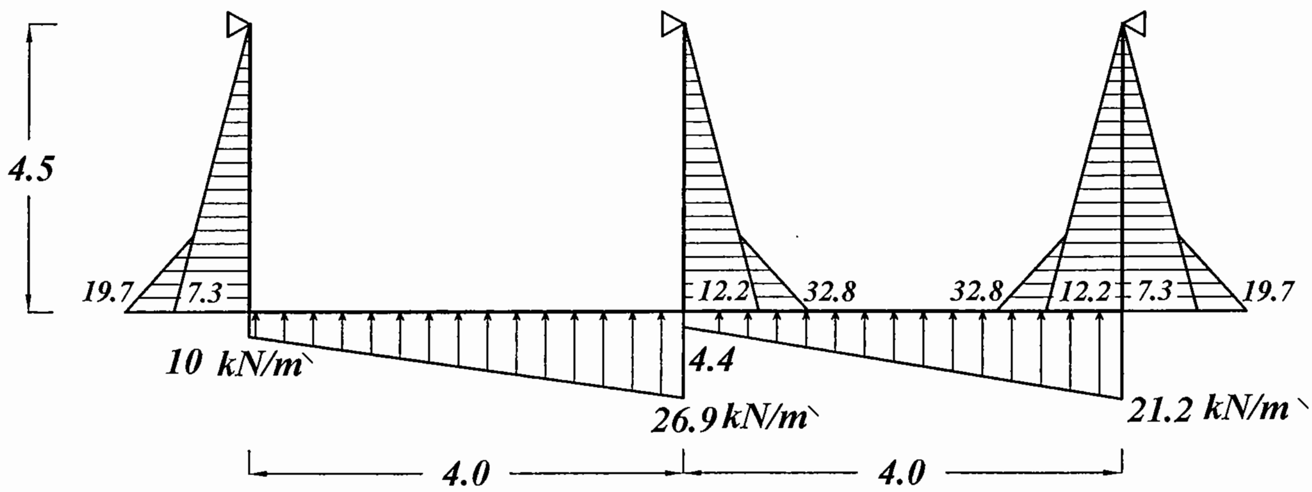
$$(\beta w) = 0.27 \times 45 = 12.2\ kN/m \updownarrow$$

For soil $= P = \frac{1}{3} \times 18 \times 4.5 = 27\ kN/m$

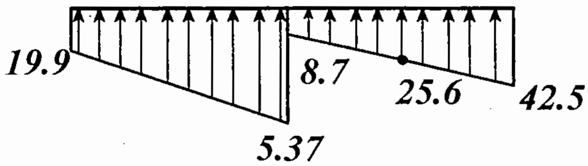
$(\alpha P) = 0.73 \times 27 = 19.7\ kN/m$ $\quad (\beta P) = 0.27 \times 27 = 7.3\ kN/m$

Slab *(4.0 & 4.0) Two way* $\alpha = \beta = 0.5$

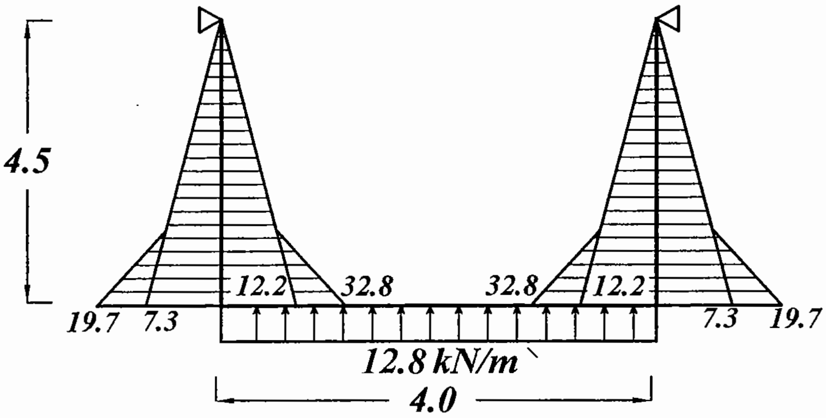
Vl Strip ①



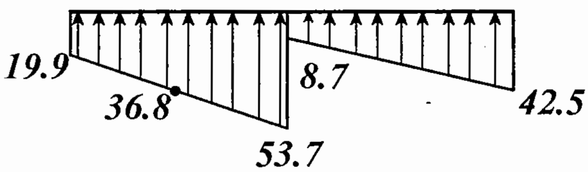
Vl Strip ②



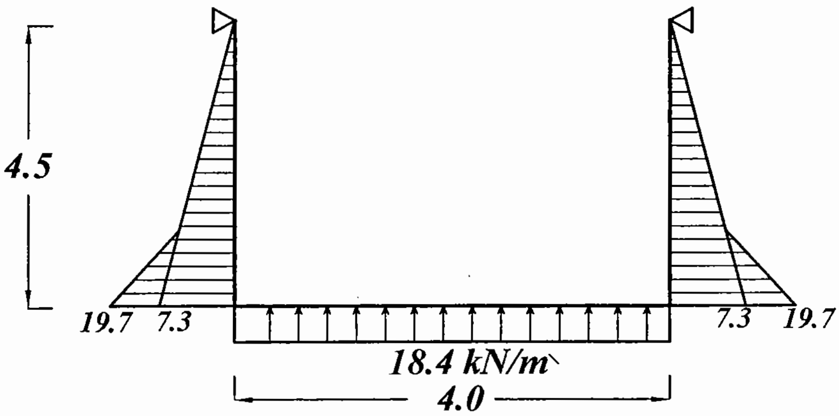
$(\alpha W) = 0.5 \times 25.6 = 12.8\ kN/m$



Vl Strip ③



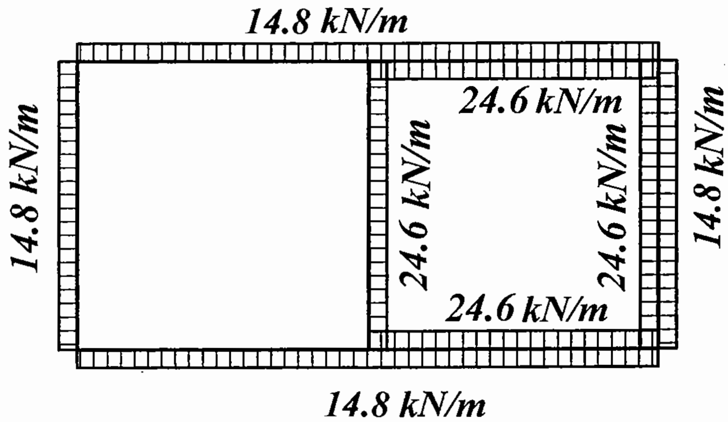
$(\alpha W) = 0.5 \times 36.8 = 18.4\ kN/m$



Hz Strip at H/4

$\frac{3}{4}(\alpha W) = \frac{3}{4} \times 32.8 = 24.6\ kN/m$

$\frac{3}{4}(\alpha P) = \frac{3}{4} \times 19.7 = 14.8\ kN/m$



Example ③

① Check uplift for the shown tank

② Draw the load diagram for Vl. and Hz. sections

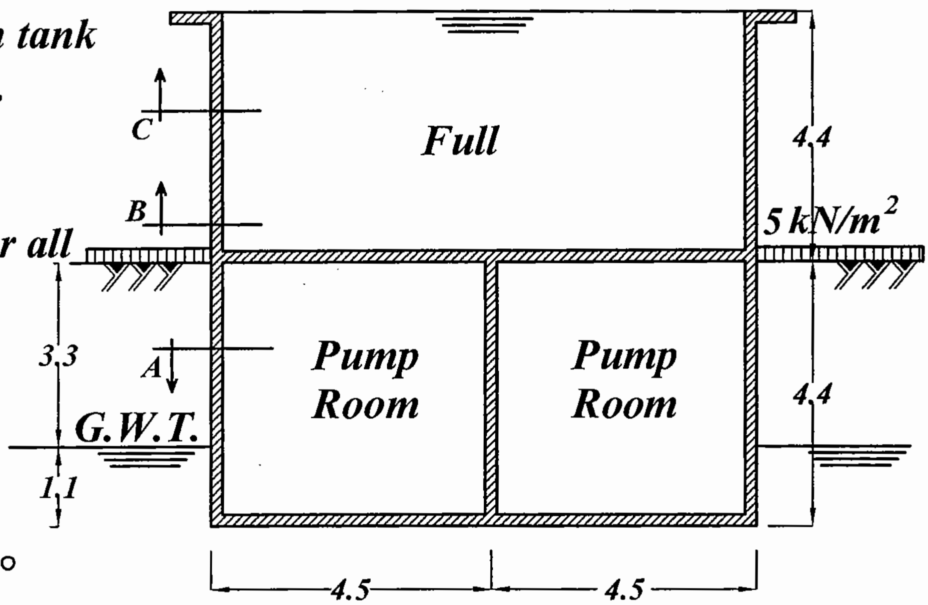
③ Draw B.M.D. & N.F.D. for all concrete elements

④ Draw Details of RFT in plan & cross sections

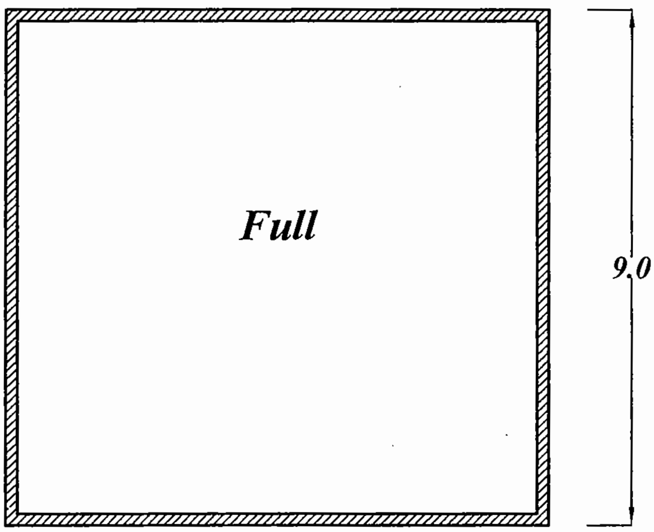
$\gamma_{soil} = 18\ kN/m^3$

$F_{cu} = 25\ N/mm^2 \qquad \phi = 30^\circ$

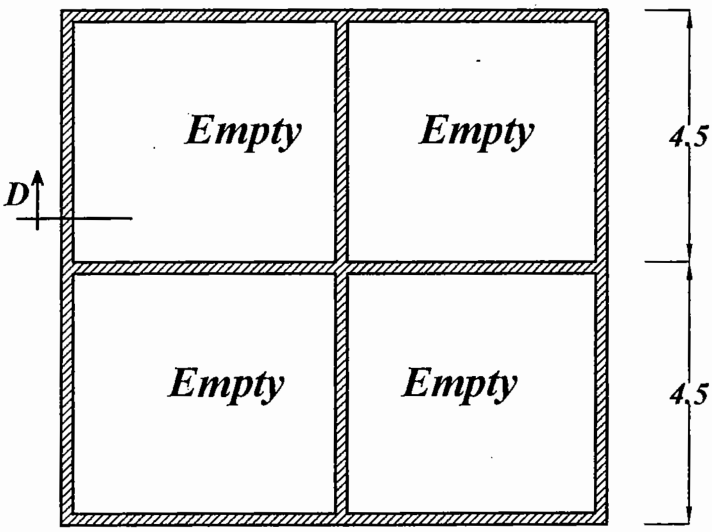
St. 360/520



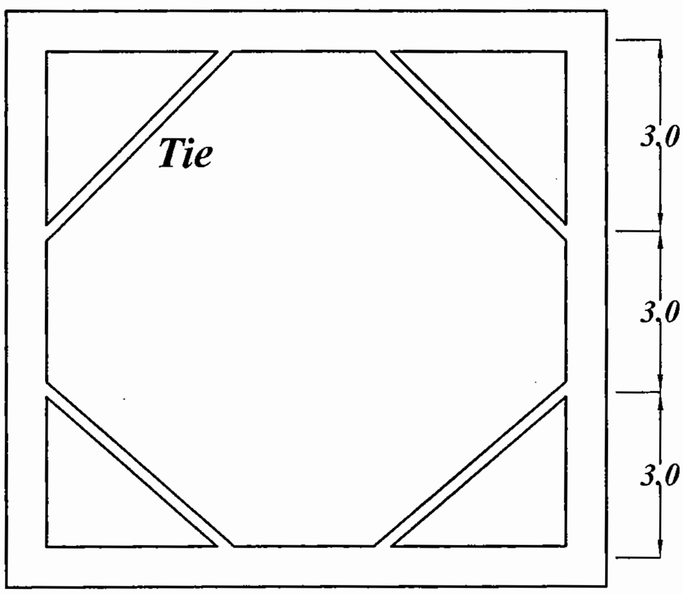
Sec D - D



Sec B - B

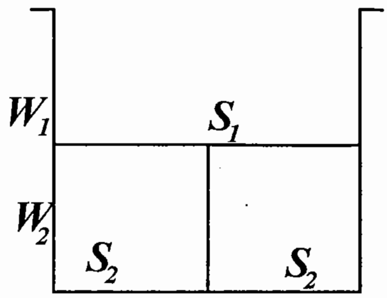


Sec A - A



Sec C - C

Concrete Dimension



$$t_w = \frac{h}{16} = \frac{4500}{16} = 281.3 = 300 \quad mm$$

$$t_{s1} = \frac{L}{16} = \frac{4500}{16} = 275 \quad = 300 \ mm$$

$$t_{s2} = \frac{L}{12} = \frac{4500}{12} = 375 \quad = 400 \ mm$$

$$(W_{Total}) = \underbrace{(0.25\times0.70\times25)(9\times4)}_{Hz\ Beam} + \underbrace{(0.25\times0.25\times25)(3\sqrt{2}\times4)}_{Tie}$$

$$+ \underbrace{(0.3\times25)(9\times4.4\times4)}_{Upper\ Walls} + \underbrace{(0.3\times25)(9\times4.4\times6)}_{Lower\ Walls} + \underbrace{4.4\times(9\times9)\times10}_{water}$$

$$+ \underbrace{(0.3\times25)\times(9\times9)}_{Upper\ Floor} + \underbrace{(0.4\times25)\times(9\times9)}_{Lower\ Floor} = 8135.5 \ kN$$

$$F_{gross} = \frac{W_{Total}}{A} = \frac{8135.5}{9\times9} = 100.4 \ kN/m^2$$

$$Direct\ Stress = (t_s \gamma_c) = (0.4\times25) = 10 \ kN/m^2$$

$$F_{net} = Total\ Stress - Direct\ Stress$$

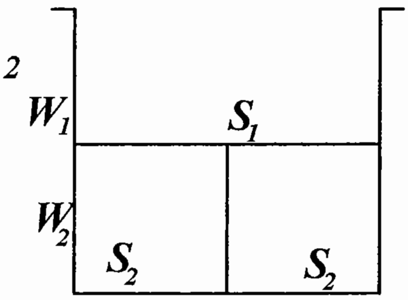
$$= 100.4 - 10 = 90.4 \quad kN/m^2$$

Check uplift

$$(W_{Empty}) = 8135.5 - 4.4\times(9\times9)\times10 = 4571.5 \ kN$$

$$(Uplift) = 1.1\times(9\times9)\times10 = 890 \quad kN$$

$$Factor\ of\ Safety = \frac{Minimum\ weight\ of\ the\ tank}{Up\ Lift\ Force} = \frac{4571.5}{891.0} = 5.13 > 1.5$$



S_1 $(4.5 \ \& \ 4.5) \quad \alpha = \beta = 0.5$

$$w = (t_s \gamma_c + \gamma_w h) = 0.3\times25 + 10\times4.4 = 51.5 \ kN/m^2$$

$$(\beta w) = (\alpha w) = 0.5\times 51.5 = 25.75 \ kN/m^2$$

S_2 $(4.5 \ \& \ 4.5) \quad \alpha = \beta = 0.5$

$$(\beta F_{net}) = (\alpha F_{net}) = 0.5\times 90.4 = 45.2 \quad kN/m^2$$

W_1 (4.4 & 9.0) One way

$$w = \gamma_w \, h = 10 \times 4.4 = 44.0 \; kN/m$$

W_2 (4.4 & 4.5) Two way $m' = 0.76$ $m = 0.76$

$$r = \frac{0.76 \times 4.5}{0.76 \times 4.4} = 1.023 \qquad \alpha = 0.52 \qquad \beta = 0.48$$

$$K_a = \frac{1 - \sin\phi}{1 + \sin\phi} = \frac{1 - 0.5}{1 + 0.5} = \frac{1}{3}$$

$$P_1 = K_a \times L.L = \frac{1}{3} \times 5.0 = 1.7 \; kN/m$$

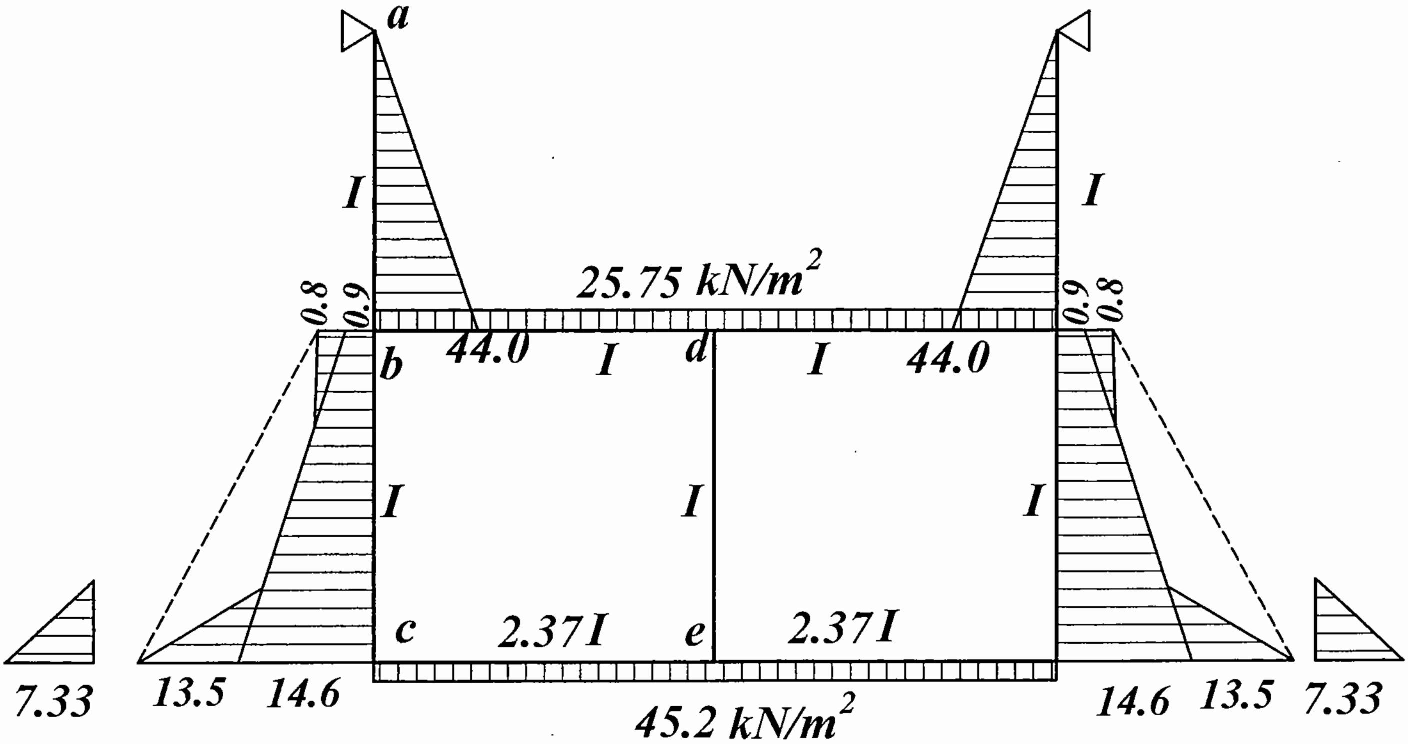
$$(\alpha P_1) = 0.52 \times 1.70 = 0.90 \; kN/m \qquad (\beta P_1) = 0.48 \times 1.70 = 0.80 \; kN/m$$

$$P_2 = K_a \times L.L + K_a \times \gamma_{soil} \times h_2$$

$$P_2 = \frac{1}{3} \times 5.0 + \frac{1}{3} \times 18 \times 4.4 = 28.1 \; kN/m$$

$$(\alpha P_2) = 0.52 \times 28.1 = 14.6 \; kN/m \qquad (\beta P_2) = 0.48 \times 28.1 = 13.5 \; kN/m$$

$$P_{2w} = (1 - K_a)\, \gamma_w h_w = (1 - \frac{1}{3}) \times 10 \times 1.1 = \frac{2}{3} \times 10 \times 1.1 = 7.33 \; kN/m$$



$$F.E.M_{b-a} = +\frac{wL^2}{15} = +\frac{44 \times (4.4)^2}{15} = +56.8 \ kN.m$$

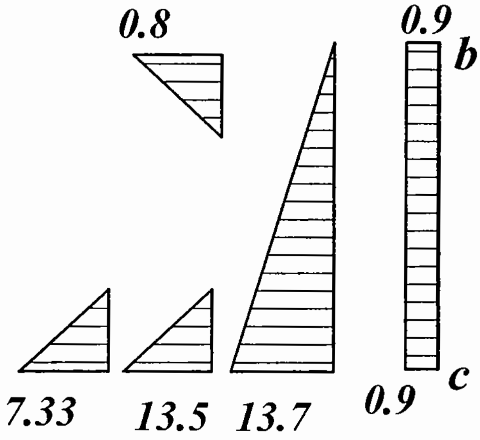
$$F.E.M_{b-c} = +\frac{0.9 \times (4.4)^2}{12} + \frac{13.7 \times (4.4)^2}{30} + \frac{20.8 \times (4.4)^2}{904} + \frac{0.8 \times (4.4)^2}{124} = + \ 10.9 \ kN.m$$

$$F.E.M_{c-b} = -\frac{0.9 \times (4.4)^2}{12} - \frac{13.7 \times (4.4)^2}{20} - \frac{20.8 \times (4.4)^2}{124} - \frac{0.8 \times (4.4)^2}{904} = -18.0 \ kN.m$$

$$F.E.M_{b-d} = -\frac{wL^2}{12} = -\frac{25.75 \times (4.5)^2}{12} = -43.5 \ kN.m$$

$$F.E.M_{c-e} = +\frac{wL^2}{12} = +\frac{45.2 \times (4.5)^2}{12} = +76.3 \ kN.m$$

$$\left(\frac{t_s}{t_w}\right)^3 = \left(\frac{40}{30}\right)^3 = 2.37$$



Distribution Factor For joint (b)

$$D.F._{b-a} = \frac{\frac{3}{4} \times \frac{I}{4.4}}{\frac{3}{4} \times \frac{I}{4.4} + \frac{I}{4.4} + \frac{I}{4.5}} = 0.275$$

$$D.F._{b-c} = \frac{\frac{I}{4.4}}{\frac{3}{4} \times \frac{I}{4.4} + \frac{I}{4.4} + \frac{I}{4.5}} = 0.367$$

$$D.F._{b-d} = 1 - 0.275 - 0.367 = 0.358$$

Distribution Factor For joint (c)

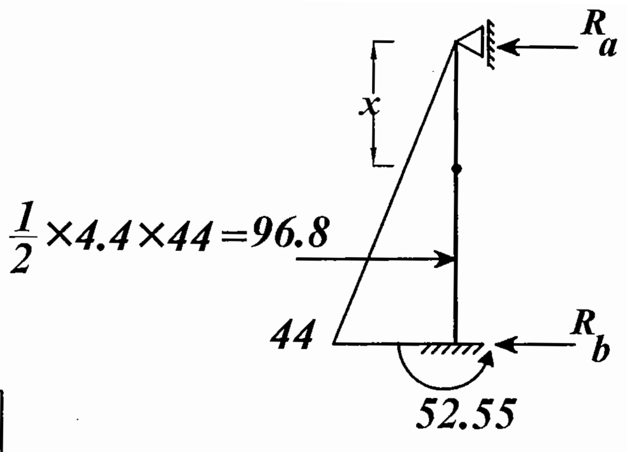
$$D.F._{c-b} = \frac{\frac{1}{4.4}}{\frac{1}{4.4} + \frac{2.37}{4.5}} = 0.30$$

$$D.F._{c-e} = 1 - 0.30 = 0.70$$

Joint	e	c		b			d
member	e - c	c - e	c - b	b - c	b - a	b - d	d - b
D.F.	——	0.70	0.30	0.367	0.275	0.358	——
F.E.M.	−76.3	76.3	−18.0	10.9	56.8	− 43.5	43.5
B.M.	——	− 40.81	−17.5	− 8.88	−6.66	− 8.66	——
C.O.M.	−20.4	——	−4.44	−8.75	——	——	− 4.33
B.M.	——	3.11	1.33	3.21	2.41	3.13	——
F.M.	− 96.7	38.6	−38.6	− 3.52	52.55	− 49.03	39.2

$$96.8\times\left(\frac{4.4}{3}\right) - R_a\times(4.4) = 52.55$$

$\boxed{R_a = 20.3\,kN}$ $\boxed{R_b = 76.5\,kN}$



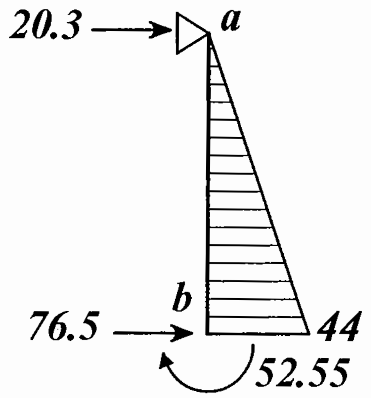
Get Point of Zero Shear (a-b)

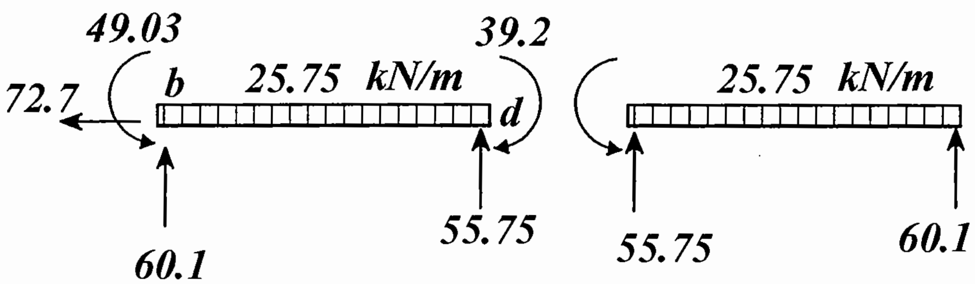
$$R_a - \frac{1}{2}\times(10x^2) = 0$$

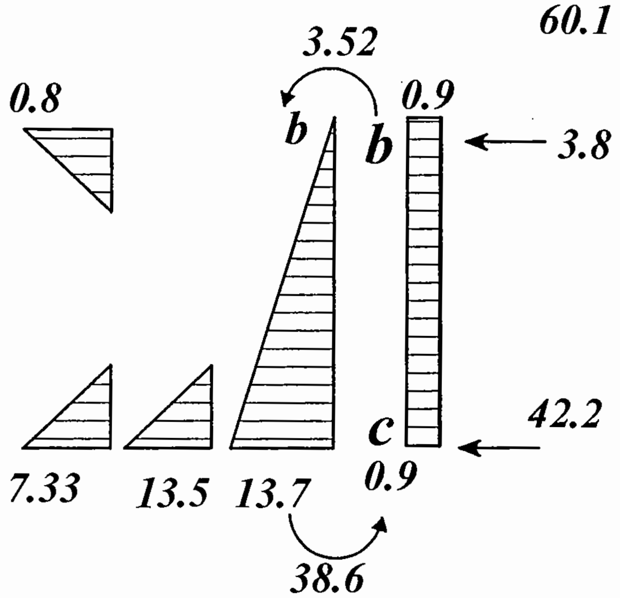
$$20.3 = \frac{1}{2}\times(10\times x^2) \qquad \boxed{x = 2.0 \quad m}$$

$$M_{\substack{max\\+ve}} = R_a\times(x) - \frac{1}{2}\times(10\times x^2)\times\left(\frac{x}{3}\right)$$

$$= 20.3 \times 2.0 - \frac{1}{2}\times 10\times 2.0^2\times\frac{2.0}{3} = 26.7 \ kN.m$$



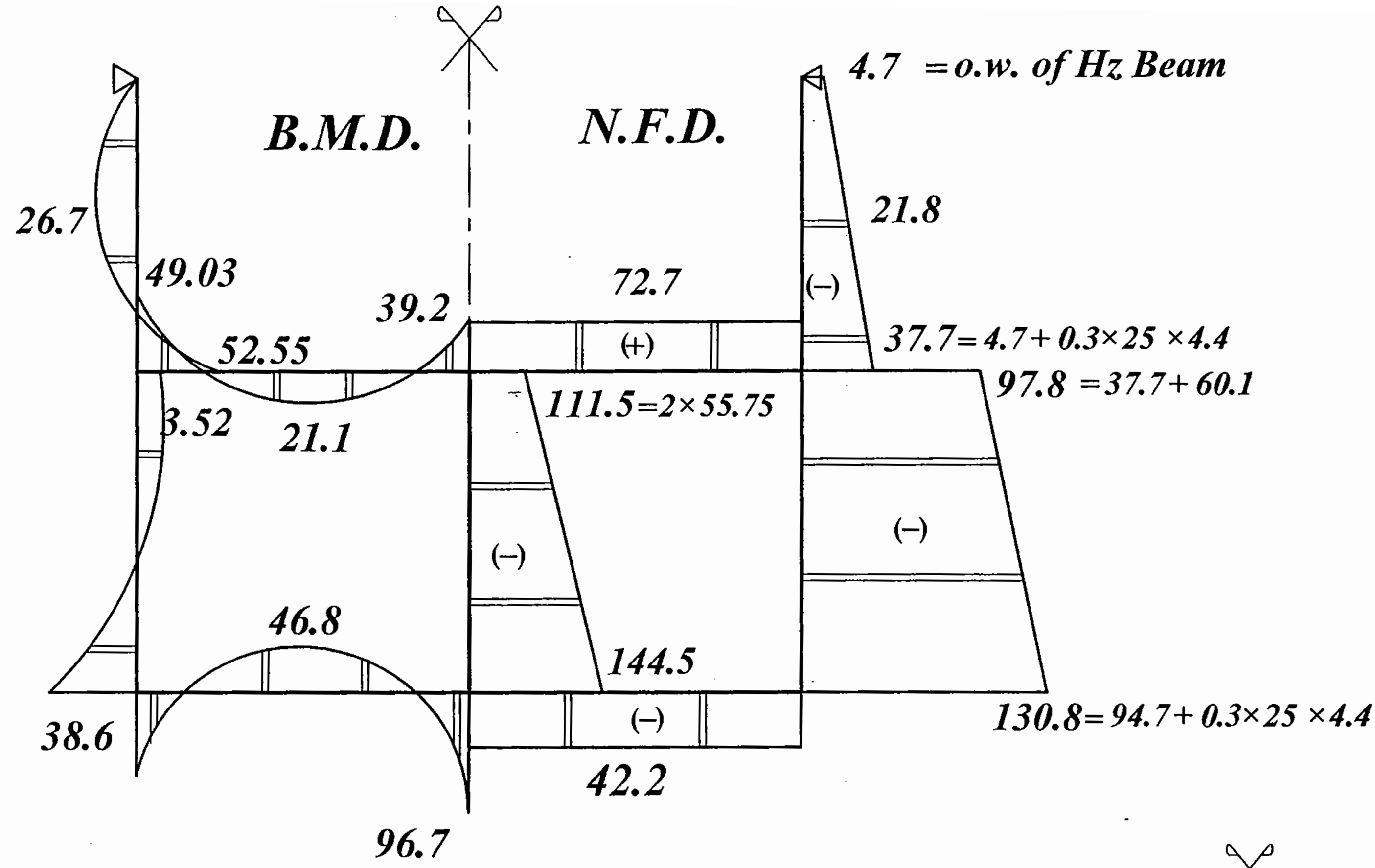




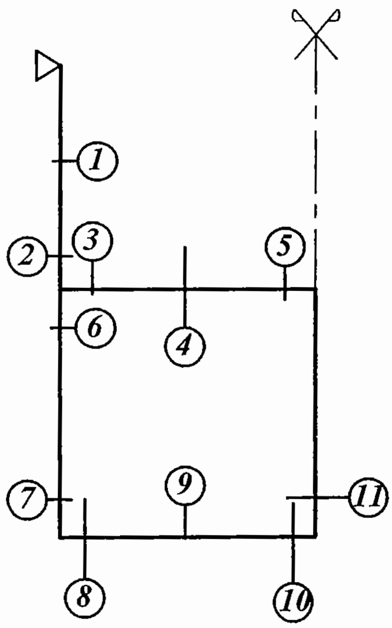
$$3.96\times2.2 + 30.14\times\left(\frac{4.4}{3}\right) + 7.4\times\left(\frac{1.1}{3}\right) + 4.03\times\left(\frac{1.1}{3}\right)$$

$$+0.44\times\left(4.4 - \frac{1.1}{3}\right) - 3.52 - R_b\times(4.4) = 38.6$$

$\boxed{R_b = 3.8}$ $\boxed{R_c = 42.2}$



Sec	Type	B.M.	N.F.
1	AirSec	26.7	- 21.8
2	Water Sec	52.55	- 37.7
3	Water Sec	49.903	+ 72.7
4	AirSec	21.1	+ 72.7
5	Water Sec	39.2	+ 72.7
6	AirSec	3.52	- 97.8
7	Water Sec	38.6	-130.8
8	Water Sec	38.6	- 42.2
9	AirSec	46.8	- 42.2
10	Water Sec	96.7	- 42.2
11	AirSec	0	- 144.5



Design of Sections

Sec② $M = 52.55\ kN.m$ $N = 37.7\ kN$ **Water Section**

Stage①

$$t = \sqrt{\frac{M \times 10^3}{Factor}} - 20\ mm = \sqrt{\frac{52.55 \times 10^3}{0.28}} - 20 = 420\ mm$$

Take $t = 450$ mm

$$(F_{ct})_{act} = -\frac{N}{A} + \frac{M}{Z} = -\frac{37.7 \times 10^3}{1000 \times 450} + \frac{6 \times 52.55 \times 10^6}{1000 \times (450)^2}$$

$$= -0.0838 + 1.557 = 1.473\ N/mm^2$$

$$t_v = t\,(1 - \frac{(F_{ct})_N}{(F_{ct})_M}) = 450(1 - \frac{0.0838}{1.557}) = 425.8\ mm$$

$(F_{ct})_{all} = 1.85\ N/mm^2$ $(F_{ct})_{act} < (F_{ct})_{all}$

Stage②

$M_u = 52.55 \times 1.5 = 78.8\ kN.m$ $N_u = 37.7 \times 1.5 = 56.6\ kN$

$$e = \frac{M_u}{N_u} = \frac{78.8}{56.6} = 1.39$$

$$e_s = e + \frac{t}{2} - c = 1.39 + \frac{0.45}{2} - 0.04 = 1.575\ m$$

$$M_s = N_u \times e_s = 56.6 \times 1.575 = 89.1\ kN.m$$

$$d = 410 = C_1 \sqrt{\frac{89.1 \times 10^6}{25 \times 1000}} \longrightarrow C_1 = 6.87 \longrightarrow J = 0.826$$

Use ϕ 12 $\longrightarrow \beta_{cr} = 0.83$

$$A_s = \frac{1}{\beta_{cr}}\left[\frac{M_s}{J\ F_y\ d} - \frac{N_u}{F_y/\gamma_s}\right] = \frac{1}{0.83}\left[\frac{89.1 \times 10^6}{0.826 \times 360 \times 410} - \frac{56.6 \times 10^3}{360/1.15}\right] = 647\ mm^2$$

$6\phi12/m'$

Sec③ $M = 49.03 kN.m$ $T = 72.7\ kN$ Water Section

Stage①

$$t = \sqrt{\frac{M \times 10^3}{Factor}} + 20\ mm$$

$$t = \sqrt{\frac{49.03 \times 10^3}{0.3}} + 20 = 438.5\ mm$$

Take $t = 450 mm$

$$(F_{ct})_{act} = + \frac{T}{A} + \frac{M}{Z}$$

$$= \frac{72.7 \times 10^3}{1000 \times 450} + \frac{6 \times 49.03 \times 10^6}{1000 \times (450)^2}$$

$$= 0.162 + 1.453 = 1.615\ N/mm^2$$

$$t_v = t\left(1 + \frac{(F_{ct})_N}{(F_{ct})_M}\right) = 450\left(1 + \frac{0.162}{1.453}\right) = 500\ mm$$

$(F_{ct})_{all} = 1.81\ 1.615\ N/mm^2$ $(F_{ct})_{act} < (F_{ct})_{all}$

Stage②

$M_u = 49.03 \times 1.5 = 73.5\ kN.m$ $T_u = 72.7 \times 1.5 = 109.1\ kN$

$$e = \frac{M_u}{T_u} = \frac{73.5}{109.1} = 0.67 > \frac{t}{2}$$

$\therefore$ Big Eccentricity

$$e_s = e - \frac{t}{2} + c = 0.67 - \frac{0.45}{2} + 0.04 = 0.485\ m$$

$$M_s = T_u \times e_s = 109.1 \times 0.485 = 52.9\ kN.m$$

$$d = C_1 \sqrt{\frac{M_S}{F_{cu}\ b}} \longrightarrow 410 = C_1 \sqrt{\frac{52.9 \times 10^6}{25 \times 1000}} \longrightarrow C_1 = 8.91 \longrightarrow J = 0.826$$

Use ϕ 16 $\longrightarrow \beta_{cr} = 0.75$

$$A_s = \frac{1}{\beta_{cr}}\left[\frac{M_S}{J\ F_y\ d} + \frac{T_u}{F_y/\gamma_s}\right] = \frac{1}{0.75}\left[\frac{52.9 \times 10^6}{0.826 \times 360 \times 410} + \frac{109.1 \times 10^3}{360\ /1.15}\right] = 1043 mm^2$$

6 ϕ16/m`

Sec (10) $M = 96.7\ kN.m$ $N = 42.2\ kN$ **Water Section**

Stage (1)

$$t = \sqrt{\frac{M \times 10^3}{Factor}} - 20\ mm$$

$$t = \sqrt{\frac{96.7 \times 10^3}{0.28}} - 20 = 567\ mm$$

Take $t = 600$ mm

$$(F_{ct})_{act} = -\frac{N}{A} + \frac{M}{Z}$$

$$= -\frac{42.2 \times 10^3}{1000 \times 600} + \frac{6 \times 96.7 \times 10^6}{1000 \times (600)^2}$$

$$= -0.0703 + 1.611 = 1.541\ N/mm^2$$

$$t_v = t\left(1 - \frac{(F_{ct})_N}{(F_{ct})_M}\right) = 600\left(1 - \frac{0.0703}{1.611}\right) = 574 mm$$

$(F_{ct})_{all} = 1.79\ N/mm^2$ $(F_{ct})_{act} < (F_{ct})_{all}$

Stage (2)

$M_u = 96.7 \times 1.5 = 145.1 kN.m$ $N_u = 4.22 \times 1.5 = 63.3\ kN$

$$e = \frac{M_u}{N_u} = \frac{145.1}{63.3} = 2.29 > \frac{t}{2}$$ $\therefore$ Big Eccentricity

$$e_s = e + \frac{t}{2} - c = 2.29 + \frac{0.60}{2} - 0.04 = 2.55\ m$$

$$M_s = N_u \times e_s = 63.3 \times 2.55 = 161.4\ m.t$$

$$d = C_1 \sqrt{\frac{M_S}{F_{cu}\ b}} \longrightarrow 560 = C_1 \sqrt{\frac{161.4 \times 10^6}{25 \times 1000}} \longrightarrow C_1 = 6.97 \longrightarrow J = 0.826$$

Use ϕ 16 $\longrightarrow \beta_{cr} = 0.75$

$$A_s = \frac{1}{\beta_{cr}}\left[\frac{M_S}{J\ F_y\ d} - \frac{N_u}{F_y/\gamma_s}\right] = \frac{1}{0.75}\left[\frac{161.4 \times 10^6}{0.826 \times 360 \times 560} - \frac{63.3 \times 10^3}{360/1.15}\right] = 1020\ mm^2$$

$6\ \phi 16/m$

Sec ④ $M = 21.1\ kN.m$ $T = 72.7\ kN$ **Air Section**

Stage②

Take $t = 300mm$

$M_u = 21.1 \times 1.5 = 31.65\ kN.m$ $N_u = 72.7 \times 1.5 = 109.05\ kN$

$e = \frac{M_u}{N_u} = \frac{31.65}{109.05} = 0.29 > \frac{t}{2}$ $\therefore$ Big Eccentricity

$e_s = e + \frac{t}{2} - c = 0.29 - \frac{0.30}{2} + 0.04 = 0.18\ m$

$M_s = T_u \times e_s = 109.05 \times 0.18 = 19.63\ kN.m$

$d = C_1 \sqrt{\frac{M_S}{F_{cu}\ b}} \longrightarrow 260 = C_1 \sqrt{\frac{19.6 \times 10^6}{25 \times 1000}} \longrightarrow C_1 = 9.27 \longrightarrow J = 0.826$

Use $\phi 12$ —— $\beta_{cr} = 0.93$ Cat II

$$A_s = \frac{1}{\beta_{cr}} \left[\frac{M_s}{J\ F_y\ d} - \frac{T_u}{F_y/\delta_s} \right] = \frac{1}{0.93} \left[\frac{19.6 \times 10^6}{0.826 \times 360 \times 260} - \frac{109.05 \times 10^3}{360/1.15} \right] = 648\ mm^2$$

$6 \phi 12/m'$

Sec ⑨ $M = 46.8\ kN.m$ $N = 42.2\ kN$ **Air Section**

Stage②

Take $t = 400mm$

$M_u = 46.8 \times 1.5 = 70.2\ kN.m$ $N_u = 42.2 \times 1.5 = 63.3\ kN$

$e = \frac{M_u}{N_u} = \frac{70.2}{63.3} = 1.11 > \frac{t}{2}$ $\therefore$ Big Eccentricity

$e_s = e + \frac{t}{2} - c = 1.11 + \frac{0.40}{2} - 0.04 = 1.27\ m$

$M_s = N_u \times e_s = 63.3 \times 1.27 = 80.4\ kN.m$

$d = C_1 \sqrt{\frac{M_S}{F_{cu}\ b}} \longrightarrow 360 = C_1 \sqrt{\frac{80.4 \times 10^6}{25 \times 1000}} \longrightarrow C_1 = 6.35 \longrightarrow J = 0.826$

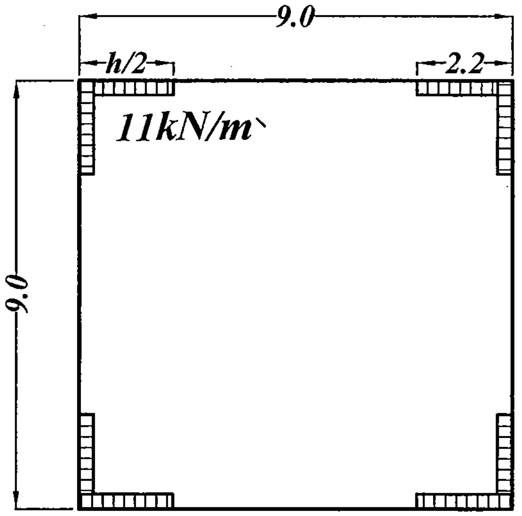
Use $\phi 12$ —— $\beta_{cr} = 0.93$ Cat II

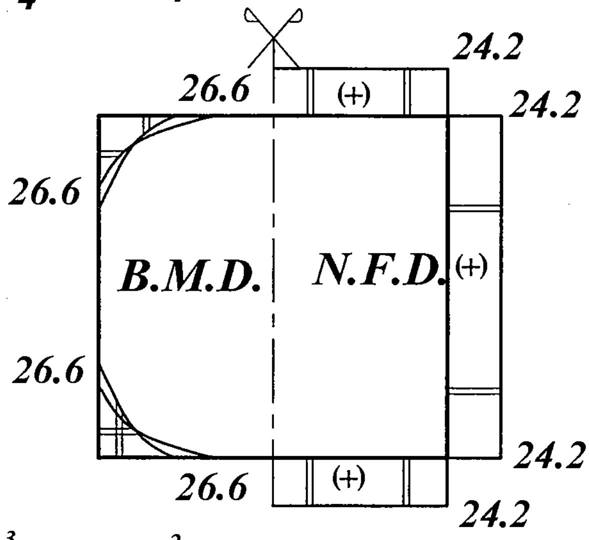
$$A_s = \frac{1}{\beta_{cr}} \left[\frac{M_s}{J\ F_y\ d} - \frac{T_u}{F_y/\delta_s} \right] = \frac{1}{0.93} \left[\frac{80.4 \times 10^6}{0.826 \times 360 \times 360} - \frac{63.3 \times 10^3}{360/1.15} \right] = 590\ mm^2$$

$6 \phi 12/m'$

Hz Strip at h/2 in Upper Tank

$$w = \frac{\gamma_w h}{4} = \frac{10 \times 4.4}{4} = 11 \ kN/m'$$





$$M = \frac{\gamma_w h^3}{32} = \frac{10 \times 4.4^3}{32} = 26.6 \ kN.m \qquad T = \frac{\gamma_w h^3}{8} = \frac{10 \times 4.4^2}{8} = 24.2 \ kN$$

Sec 1 $M = 26.6 \ kN.m$ $\quad T = 24.2 \ kN$ **Water Section**

Stage ① $t = 300 \ mm$

$$(F_{ct})_{act} = +\frac{T}{A} + \frac{M}{Z} = \frac{24.2 \times 10^3}{1000 \times 300} + \frac{6 \times 26.6 \times 10^6}{1000 \times (300)^2} = 0.081 + 1.773 = 1.854$$

$$t_v = t\left(1 + \frac{(F_{ct})_N}{(F_{ct})_M}\right) = 300\left(1 + \frac{0.081}{1.773}\right) = 314 \ mm \qquad (F_{ct})_{all} = 2.0 \ N/mm^2$$

Stage ②

$$M_u = 26.6 \times 1.5 = 40 \ kN.m \qquad T_u = 24.2 \times 1.5 = 36.3 \ kN$$

$$e = \frac{M_u}{T_u} = \frac{40}{36.3} = 1.1 > \frac{t}{2} \qquad \therefore \text{Big Eccentricity}$$

$$e_s = e - \frac{t}{2} + c = 1.1 - \frac{0.30}{2} + 0.04 = 0.99 \ m$$

$$M_s = T_u \times e_s = 36.3 \times 0.99 = 35.9 \ kN.m$$

$$d = C_1 \sqrt{\frac{M_S}{F_{cu} \ b}} \longrightarrow 260 = C_1 \sqrt{\frac{35.9 \times 10^6}{25 \times 1000}} \longrightarrow C_1 = 6.86 \longrightarrow J = 0.826$$

Use ϕ 12 $\longrightarrow \beta_{cr} = 0.83$

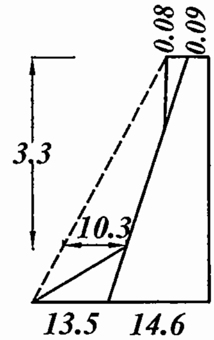
$$A_s = \frac{1}{\beta_{cr}}\left[\frac{M_S}{J \ F_y \ d} + \frac{T_u}{F_y/\gamma_s}\right] = \frac{1}{0.83}\left[\frac{35.9 \times 10^6}{0.826 \times 360 \times 260} + \frac{36.3 \times 10^3}{360/1.15}\right] = 700 \ mm^2$$

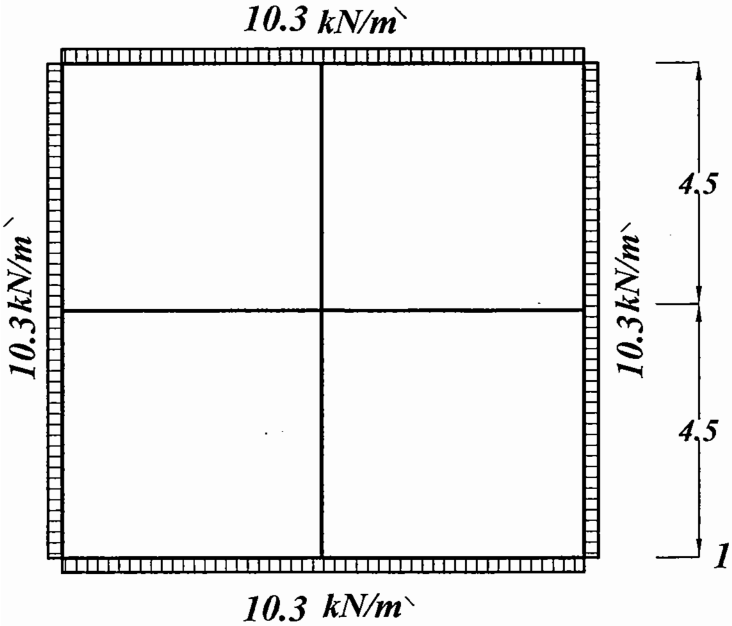
7 ϕ 12 /m`

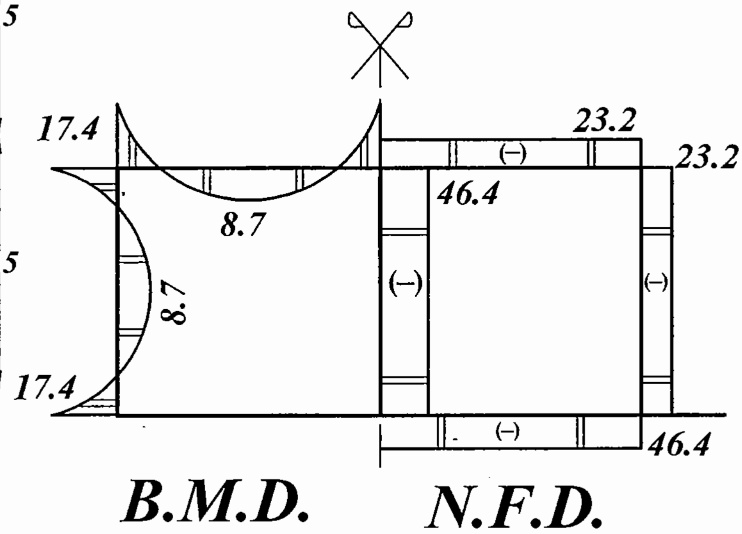
Hz Strip at h/4 in Lower Tank

$$P = 1.7 + \frac{1}{3} \times 18 \times 3.3 = 21.5 \ kN/m$$

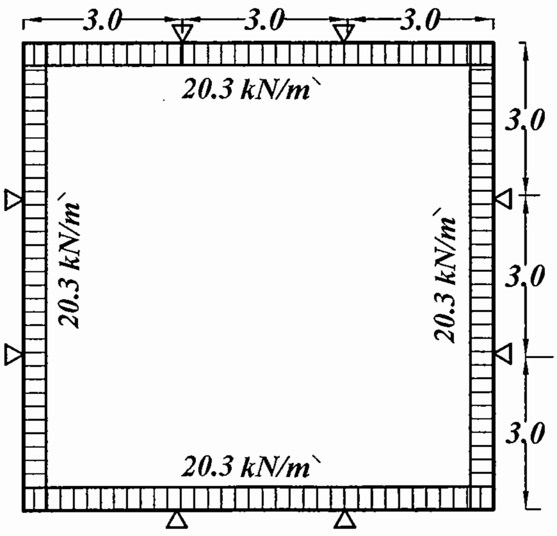
$$(\beta P) = 0.48 \times 21.5 = 10.3 \ kN/m$$

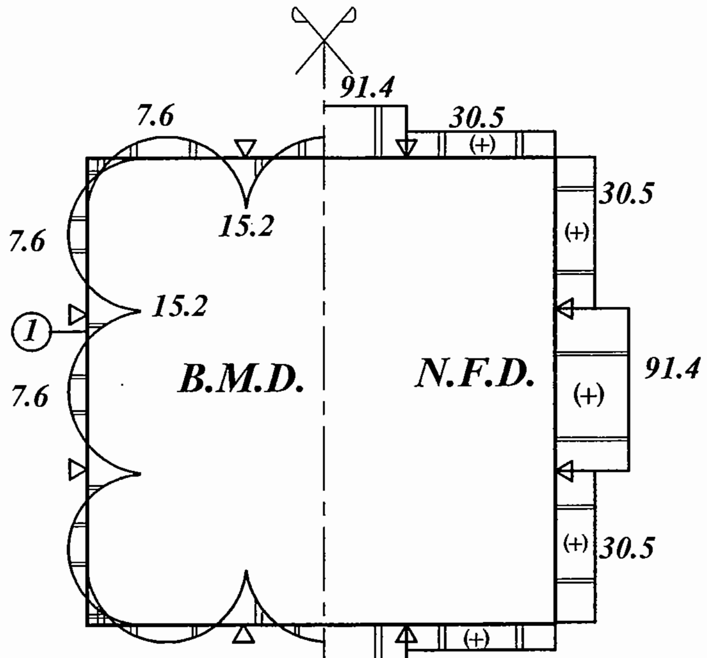






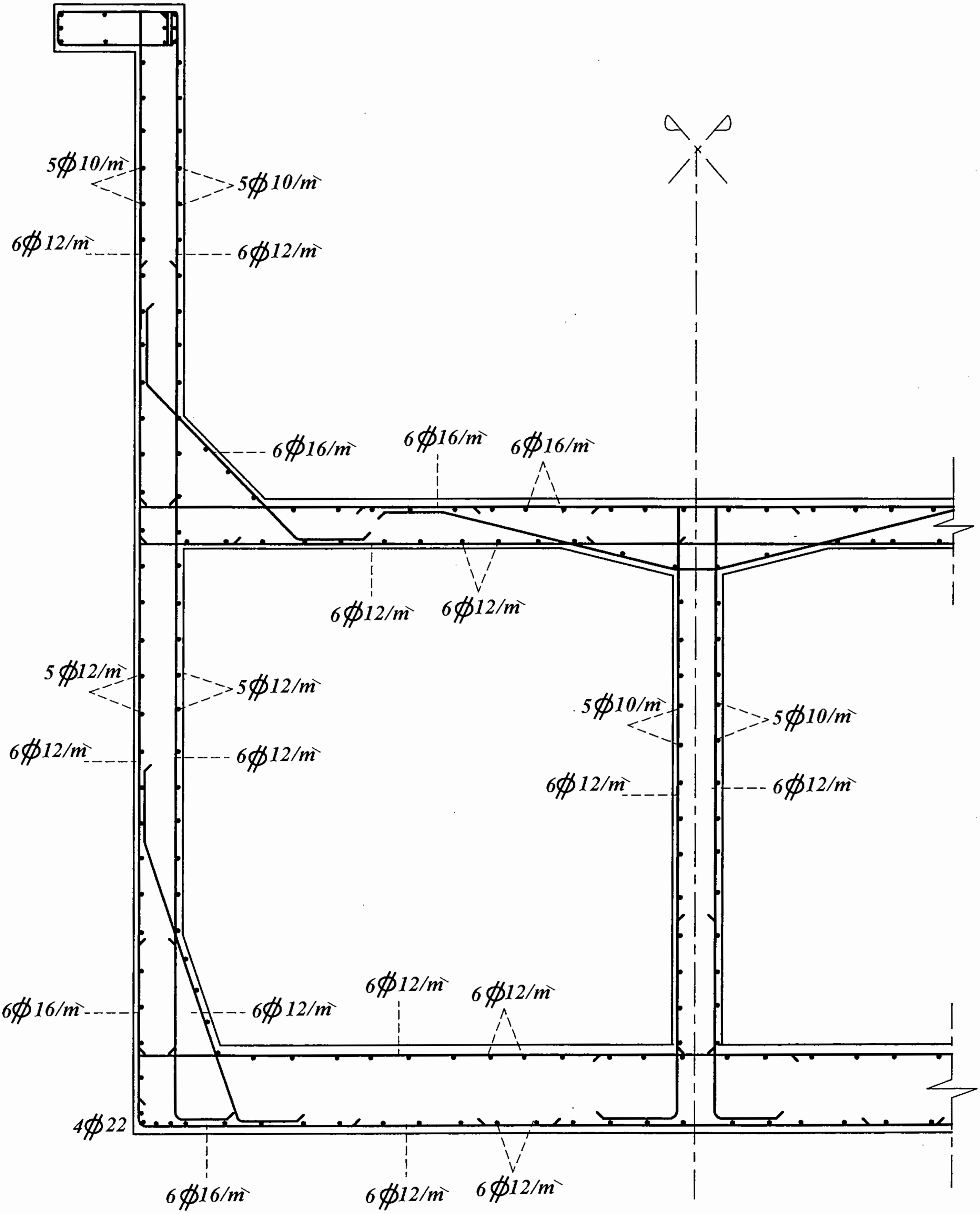
HL Beam





$$\frac{wL^2}{12} = \frac{20.3 \times 3.0^2}{12} = 15.2 kN.m \quad \frac{1}{2} wL = \frac{20.3 \times 3.0}{2} = 30.5 \ kN$$

$$\frac{wL^2}{24} = \frac{20.3 \times 3.0^2}{24} = 7.6 \ kN.m \quad \frac{3}{2} wL = \frac{3 \times 20.3 \times 3.0}{2} = 91.4 \ kN$$



5φ10/m'
5φ10/m'
6φ12/m'
6φ12/m'
6φ16/m'
6φ16/m'
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4φ22
6φ16/m'
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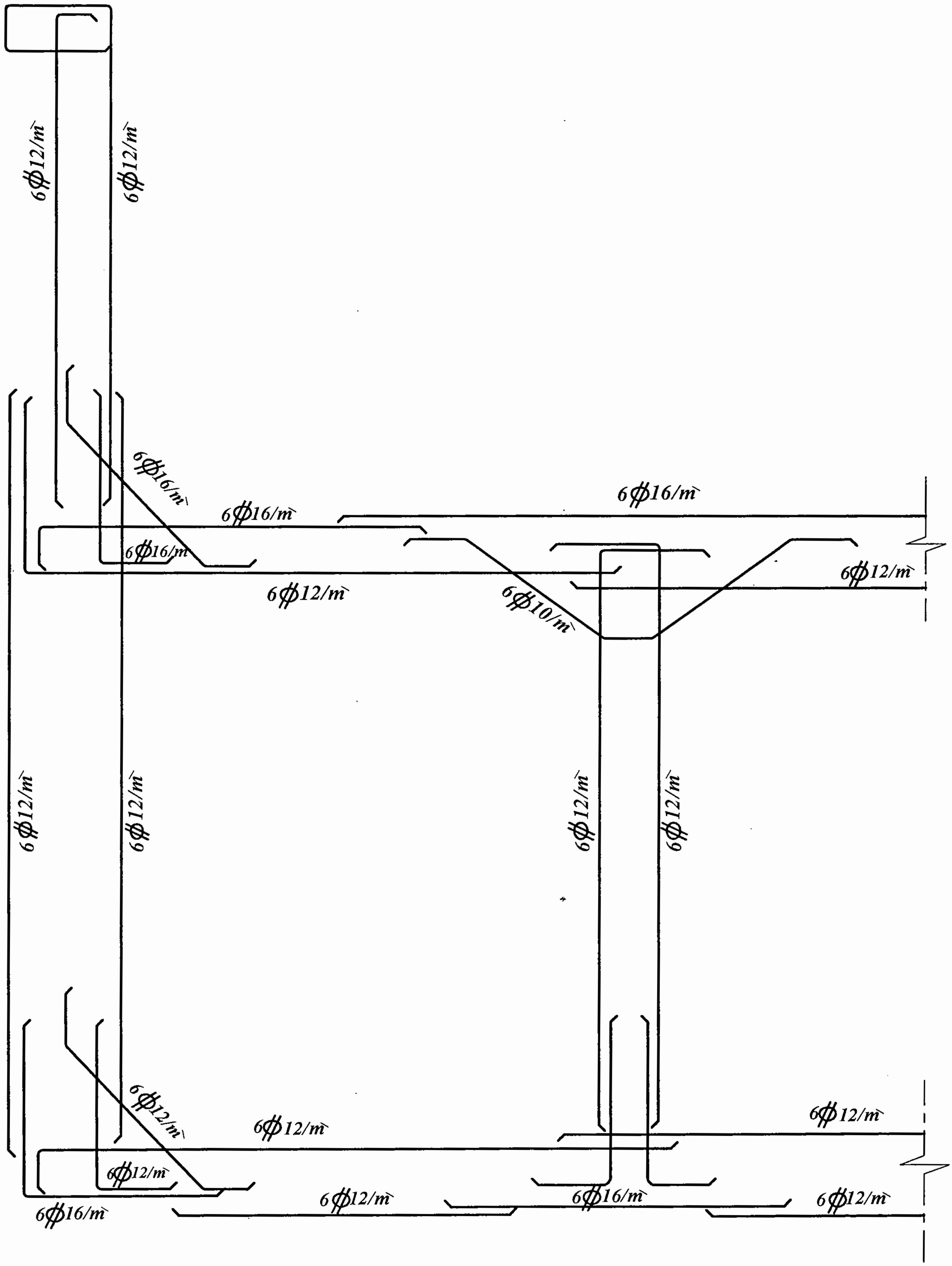
6φ12/m'


6ϕ12/m'
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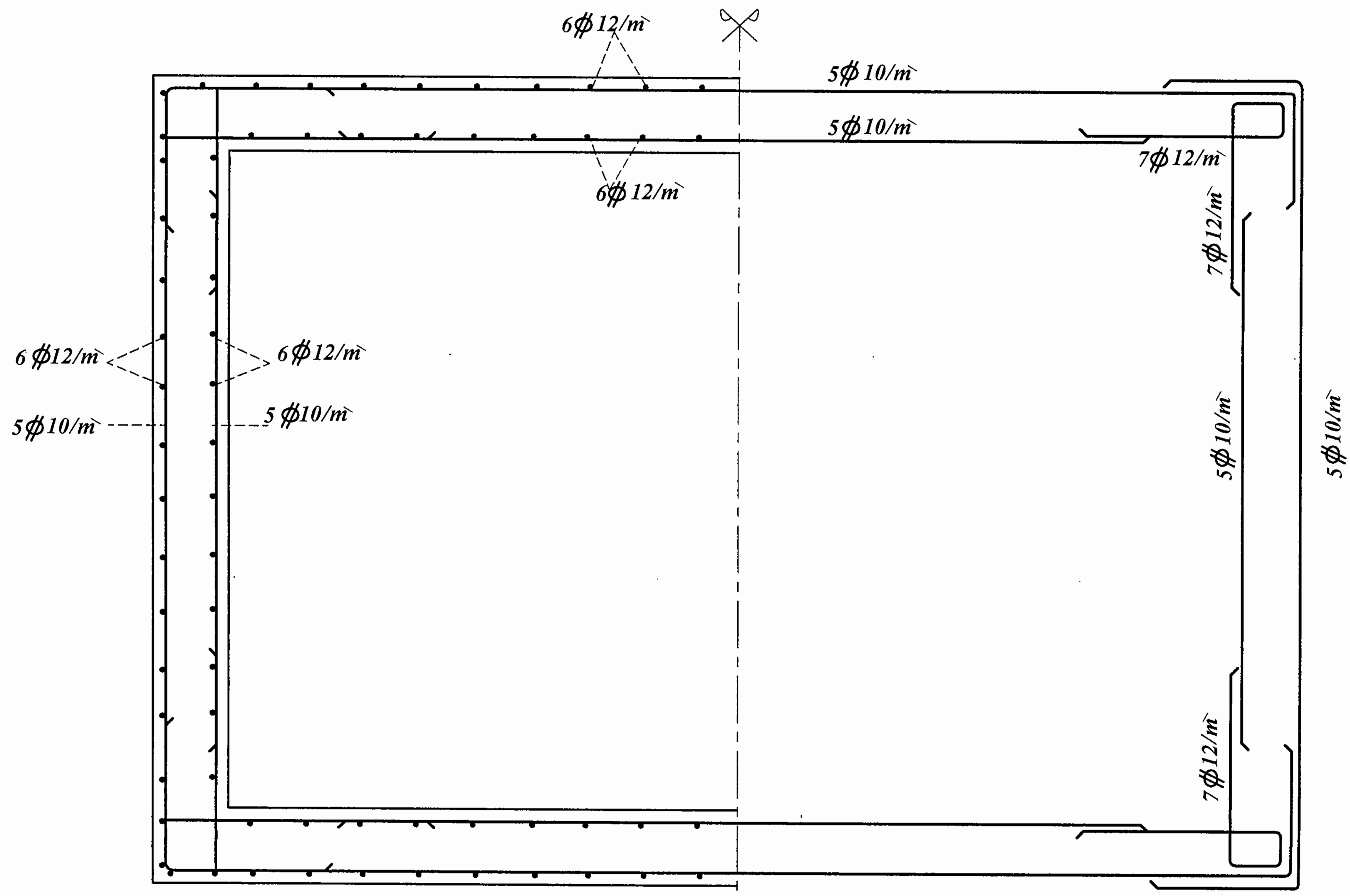
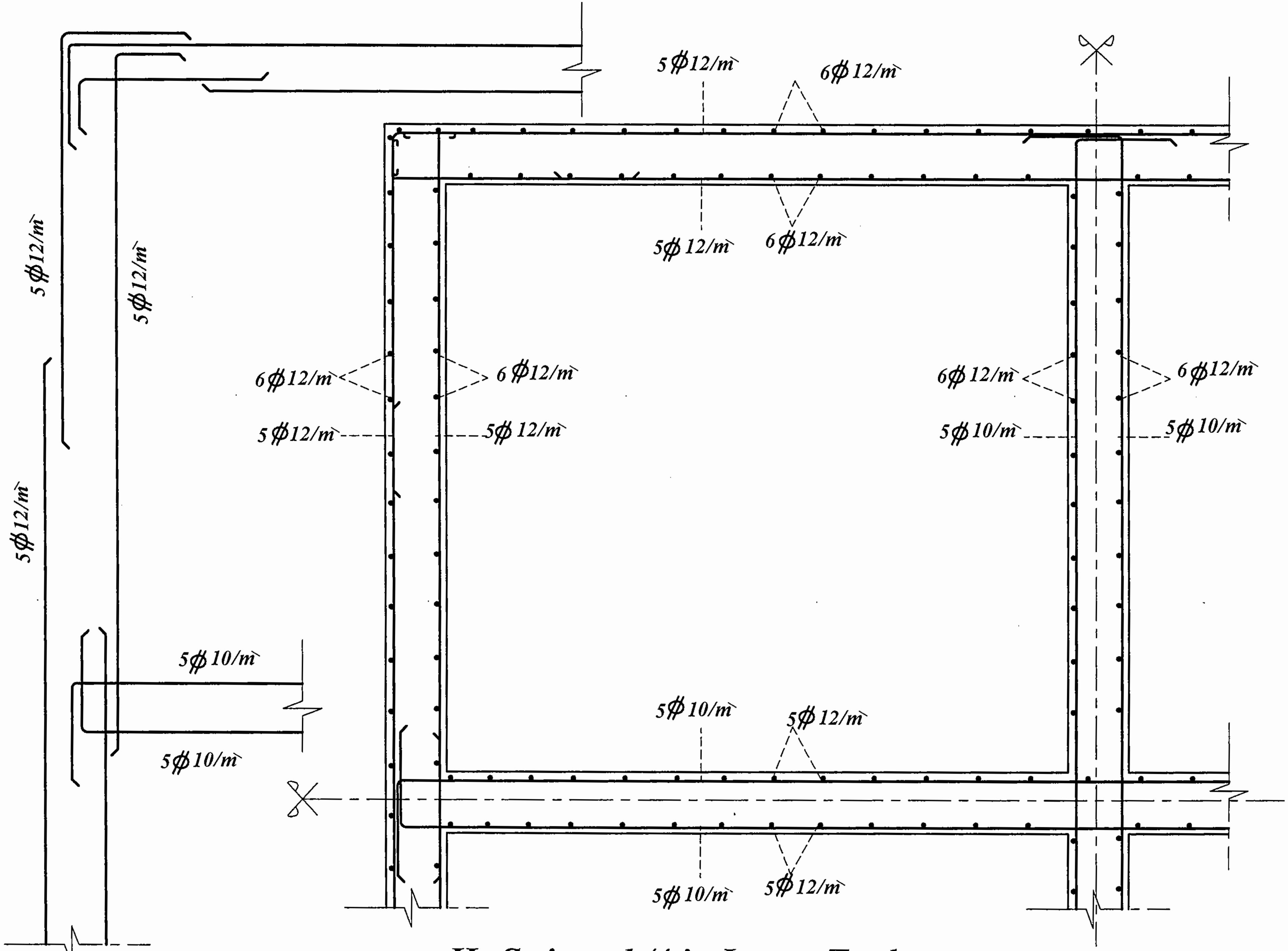


Hz Strip at h/2 in Upper Tank

Corner Effect



Hz Strip at h/4 in Lower Tank

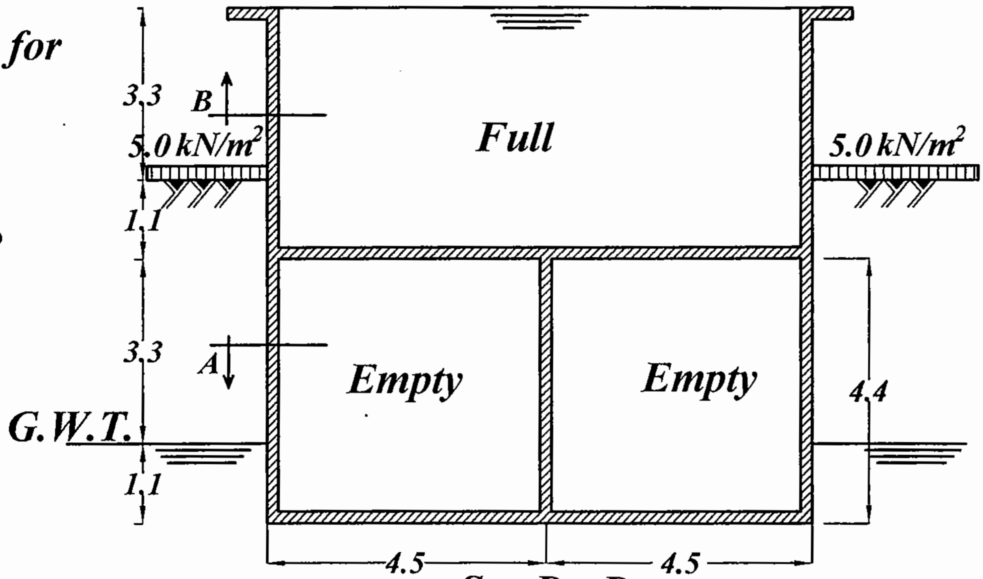
Example ④

① **Draw the load diagram for Vl. sections**

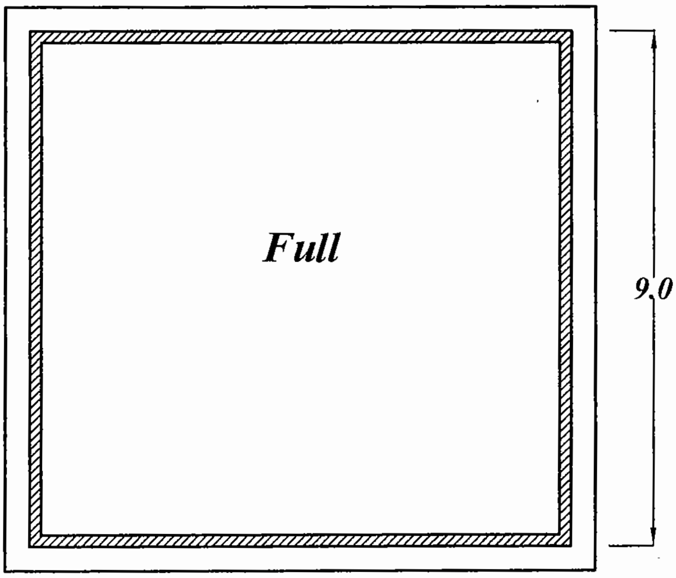
$\gamma_{soil} = 18\ kN/m^3$

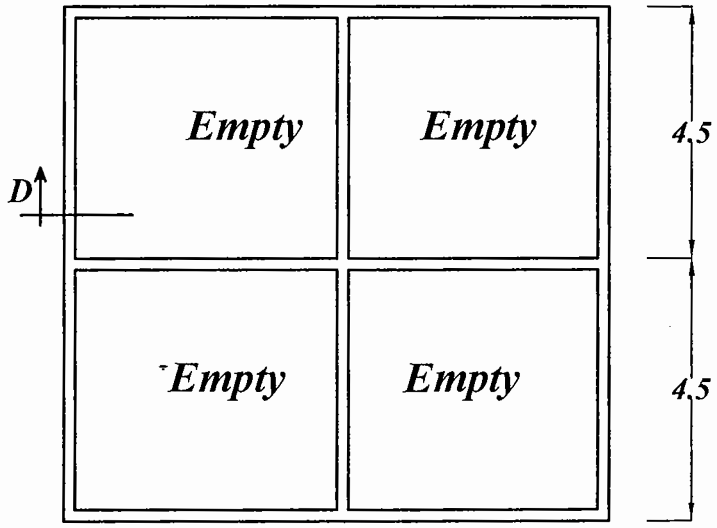
$F_{cu} = 25\ N/mm^2 \qquad \phi = 30°$

St 36/52



Sec D - D





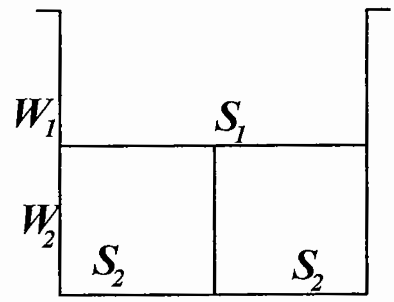
Sec B - B **Sec A - A**

Concrete Dimension

$$t_w = \frac{h}{16} = \frac{4500}{16} = 281.3 = 300 \quad mm$$

$$t_{s1} = \frac{L}{16} = \frac{4500}{16} = 275 \quad = 300\ mm$$

$$t_{s2} = \frac{L}{12} = \frac{4500}{12} = 375 \quad = 400\ mm$$



$$(W_{Total}) = \underbrace{(0.25\times0.70\times25)(9\times4)}_{\text{Hz Beam}} + \underbrace{(0.25\times0.25\times25)(3\sqrt{2}\times4)}_{\text{Tie}}$$

$$+ \underbrace{(0.3\times25)(9\times4.4\times4)}_{\text{Upper Walls}} + \underbrace{(0.3\times25)(9\times4.4\times6)}_{\text{Lower Walls}} + \underbrace{4.4\times(9\times9)\times10}_{\text{water}}$$

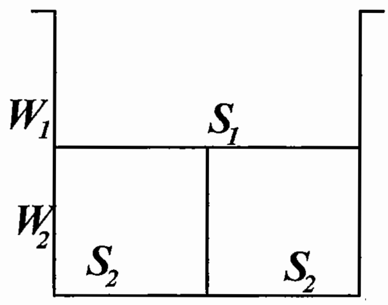
$$+ \underbrace{(0.3\times25)\times(9\times9)}_{\text{Upper Floor}} + \underbrace{(0.4\times25)\times(9\times9)}_{\text{Lower Floor}} = 8135.5\ kN$$

$$F_{gross} = \frac{W_{Total}}{A} = \frac{8135.5}{9\times 9} = 100.4 \ kN/m^2$$

$$Direct\ Stress = (t_s\gamma_c) = (0.4\times 25) = 10 \ kN/m^2$$

$$F_{net} = Total\ Stress - Direct\ Stress$$

$$= 100.4 - 10 = 90.4 \ kN/m^2$$



S_1 $(4.5 \ \& \ 4.5) \quad \alpha = \beta = 0.5$

$$w = (t_s\gamma_c + \gamma_w h) = 0.3\times 25 + 10\times 4.4 = 51.5 \ kN/m^2$$

$$(\beta w) = (\alpha w) = 0.5\times 51.5 = 25.75 \ kN/m^2$$

S_2 $(4.5 \ \& \ 4.5) \quad \alpha = \beta = 0.5$

$$(\beta f_{net}) = (\alpha f_{net}) = 0.5\times 90.4 = 45.2 \ kN/m^2$$

W_1 $(4.4 \ \& \ 9.0)$ One way

$$w = \gamma_w h = 10\times 4.4 = 44.0 \ kN/m$$

W_2 $(4.4 \ \& \ 4.5)$ Two way $\quad m` = 0.76 \quad m = 0.76$

$\alpha = 0.52 \qquad \beta = 0.48$

$$P_1 = K_a\times L.L = \frac{1}{3}\times 5.0 = 1.70 \ kN/m$$

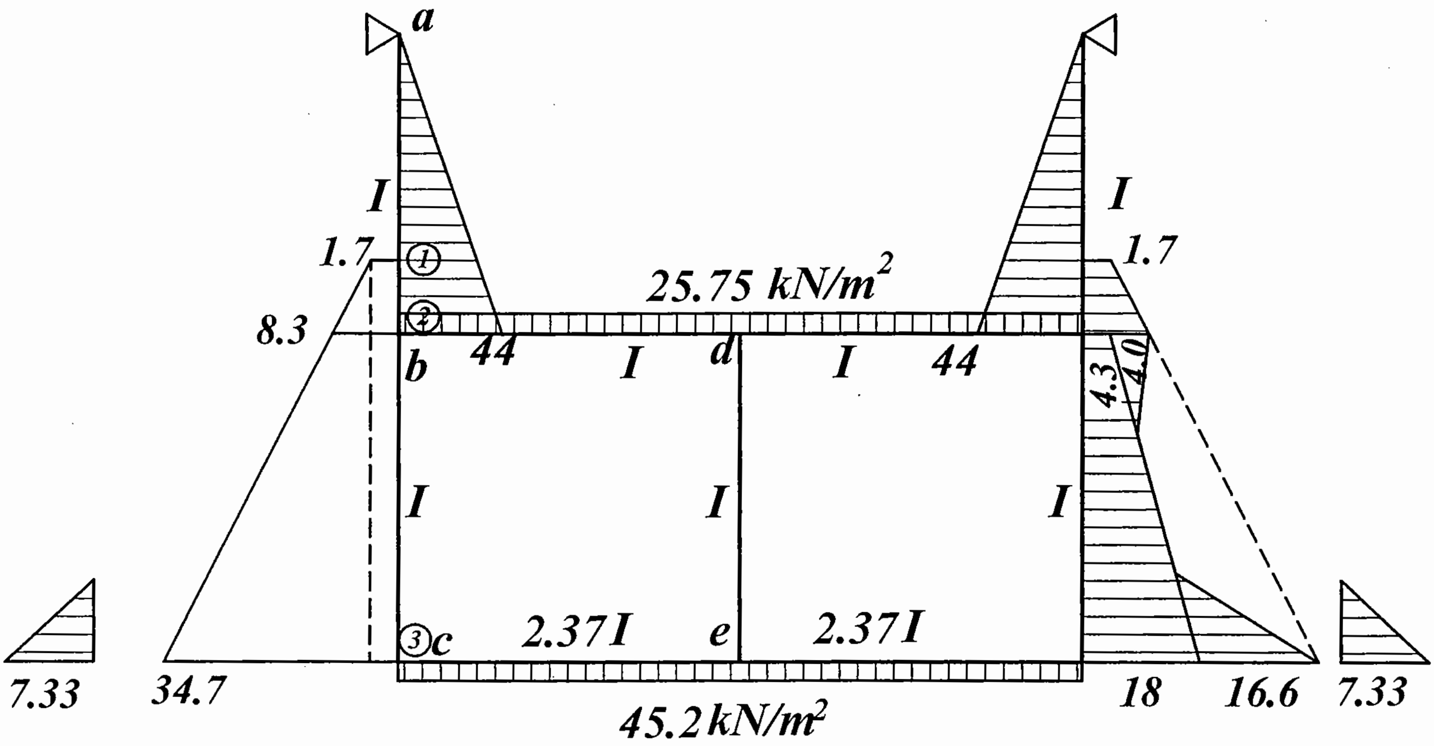
$$P_2 = 1.70 + \frac{1}{3}\times 18\times 1.1 = 8.30 \ kN/m$$

$$(\alpha P_2) = 0.52\times 8.30 = 4.30 \ kN/m \qquad (\beta P_2) = 0.48\times 8.30 = 4.0 \ kN/m$$

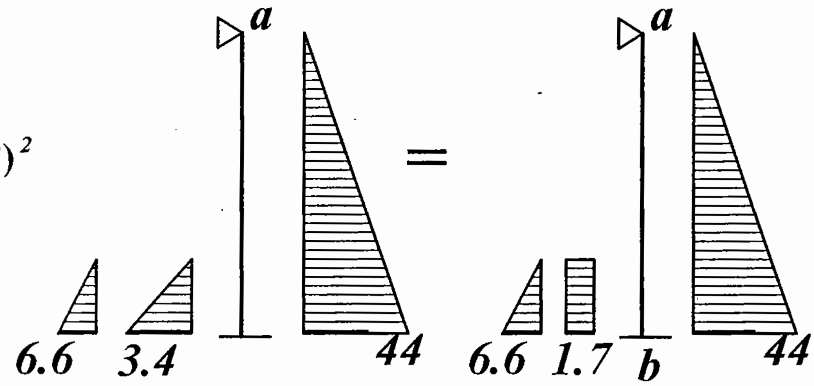
$$P_3 = 1.70 + \frac{1}{3}\times 18\times 5.5 = 34.7 \ kN/m$$

$$(\alpha P_3) = 0.52\times 34.7 = 18 \ kN/m \qquad (\beta P_3) = 0.48\times 34.7 = 16.6 \ kN/m$$

$$P_{3w} = (1-K_a)\gamma_w h_w = (1-\frac{1}{3})\times 10\times 1.1 = \frac{2}{3}\times 10\times 1.1 = 7.33 \ kN/m$$

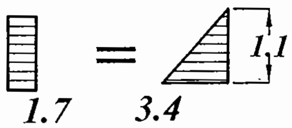


$$F.E.M_{b-a} = +\frac{44\times(4.4)^2}{15} - \frac{6.6\times(4.4)^2}{117} - \frac{3.4\times(4.4)^2}{117} = +55.13\ kN.m$$



$$1.7\times 1.1 = \frac{1}{2}\times x\times 1.1$$

$$x = 3.4$$



$$F.E.M_{b-c} = +\frac{4.3\times(4.4)^2}{12} + \frac{13.7\times(4.4)^2}{30} + \frac{23.9\times(4.4)^2}{904} + \frac{4.0\times(4.4)^2}{124} = +\ 16.9\ kN.m$$

$$F.E.M_{c-b} = -\frac{4.3\times(4.4)^2}{12} - \frac{13.7\times(4.4)^2}{20} - \frac{23.9\times(4.4)^2}{124} - \frac{4.0\times(4.4)^2}{904} = -24.0\ kN.m$$

$$F.E.M_{b-d} = -\frac{wL^2}{12} = -\frac{25.75\times(4.5)^2}{12} = -\ 43.5\ kN.m$$

$$F.E.M_{c-e} = +\frac{wL^2}{12} = +\frac{45.2\times(4.5)^2}{12} = +76.3\ kN.m$$