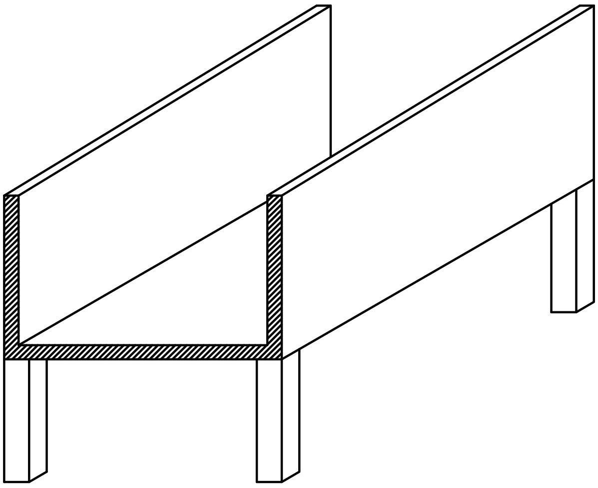
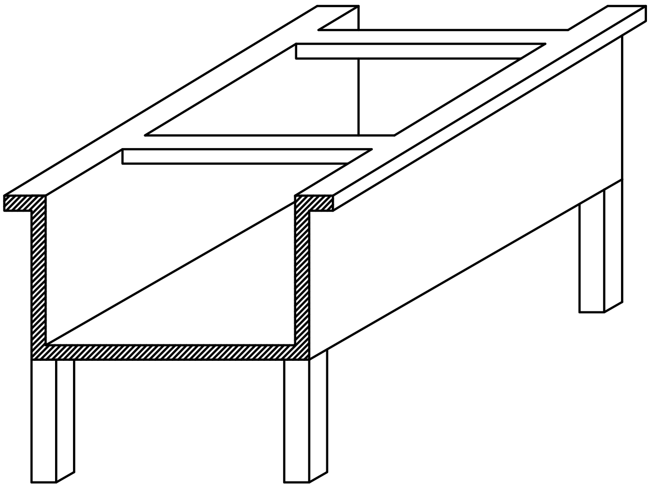
Elevated tanks

– Types of elevated tanks

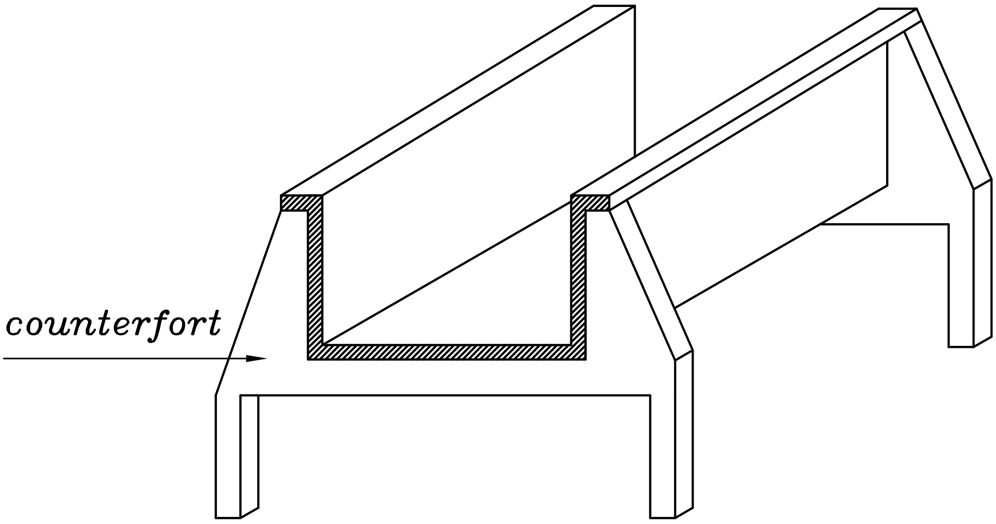
a– Open channel



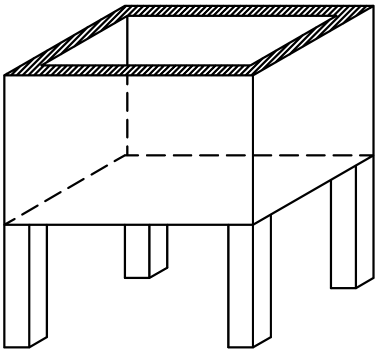
b– Open channel with top horizontal beam and ties



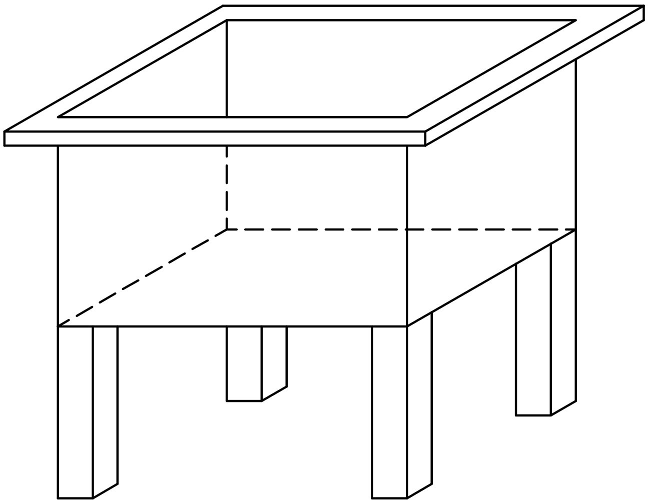
c– Open channel with counterfort



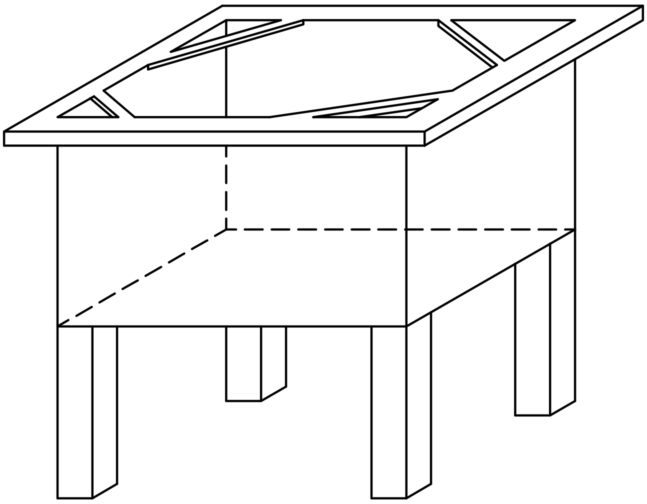
d- Rectangular tanks



e- Rectangular tanks with horizontal beam (with or without ties)

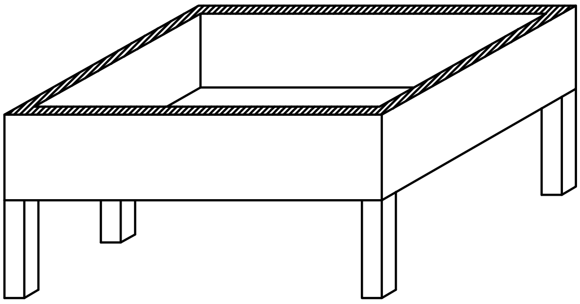


HZ. beam without ties

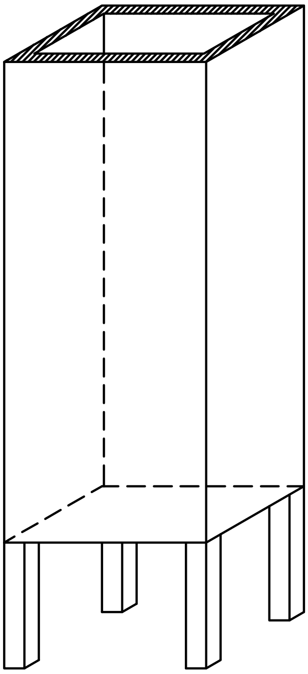


HZ. beam with ties

f- Shallow tanks



g- Deep tanks



من الانواع السابقة يتضح ان *(elevated tank)* يتكون من العناصر الاتية

1– *Floor slabs* ارضية الخزان

2– *Side walls* حوائط الخزان

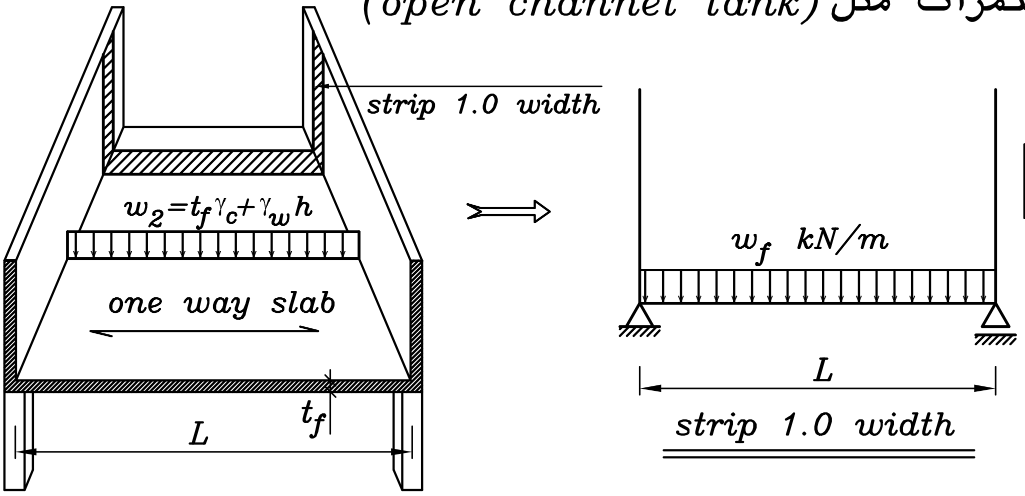
3– *Supporting elements (such as beams, ties, columns,..)*

1– Floor slabs ارضية الخزان

– Types of floor slabs

a– One way slabs $(t_f = \frac{L_s}{16} \nless 250mm)$

حيث تكون ارضية الخزان عبارة عن بلاطات *(one way)* مرتكزة على حوائط الخزان التى تعمل ككمرات مثل *(open channel tank)*

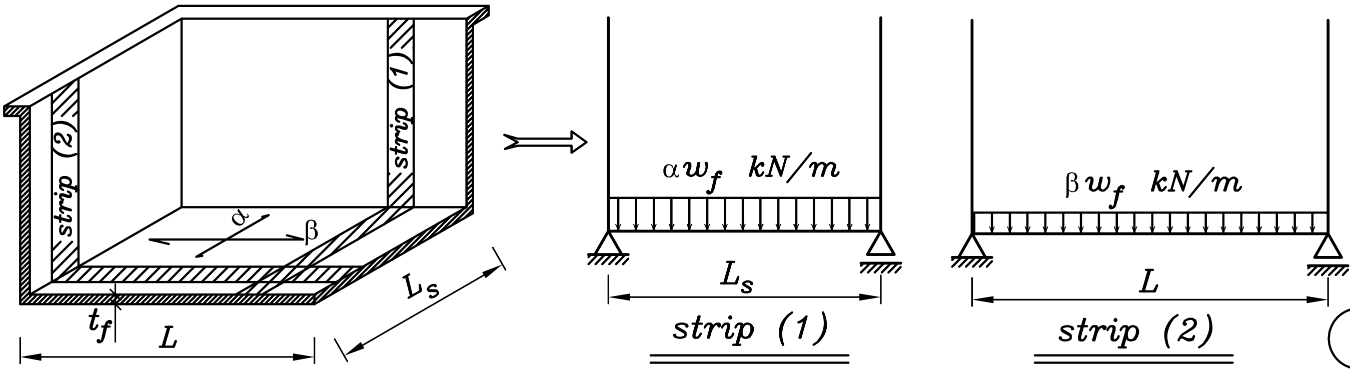


$$\boxed{w_f = t_f \gamma_c + \gamma_w h}$$

kN/m^2

a– Two way slabs $(t_f = \frac{L_s}{16} \nless 250mm)$ $\boxed{\frac{L}{L_s} < 2}$

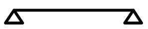
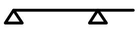
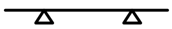
حيث تكون ارضية الخزان عبارة عن بلاطات *(two way)* مرتكزة على حوائط الخزان التى تعمل ككمرات مثل *(rectangular tank)*



How to get α &β

Calculate $\boxed{r = \frac{m\ L}{m'\ L_s} \geq 1.00}$

حيث (m,m') معاملات تتوقف على حالة اتصال اطوال البلاطة (L,L_s)

Strip			
m or m'	1.00	0.87	0.76

$$\boxed{\alpha = \frac{r^4}{1+r^4}\ ,\ \beta = \frac{1}{1+r^4}}$$

(Grashoff equations)

ـ ملحوظات هامة

(α) هى نسبة الحمل فى الاتجاه القصير و (β) هى نسبة الحمل فى الاتجاه الطويل

-فى حالة ان $(r<1)$ فاننا نحسب $(r^* = \frac{1}{r})$

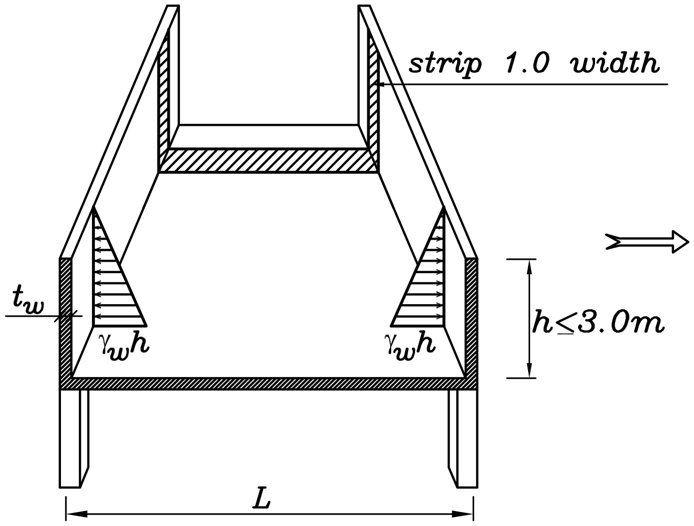
$$\Longrightarrow \boxed{\alpha = \frac{(r^*)^4}{1+(r^*)^4}\ ,\ \beta = \frac{1}{1+(r^*)^4}}$$

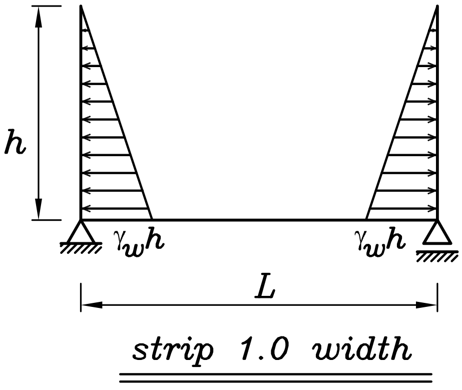
و فى هذه الحالة تكون (α) هى نسبة الحمل فى الاتجاه الطويل

و (β) هى نسبة الحمل فى الاتجاه القصير

2- Side walls حوائط الخزان

a- Cantilever walls $(t_w = \frac{H}{10} \not< 250mm)$



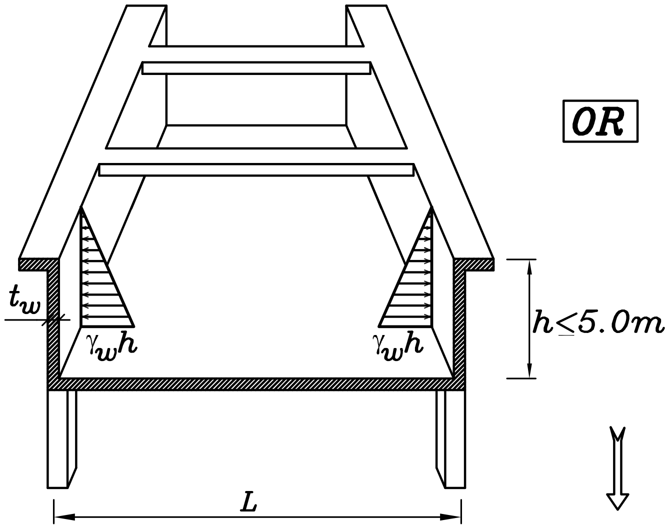


ـ ملحوظات هامة

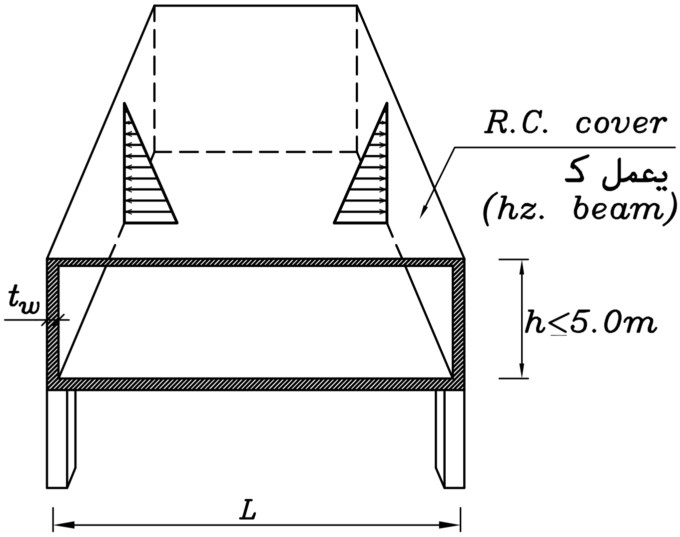
١-لا يتم وضع كمرة افقية طالما ان ارتفاع الحائط $(h \leq 3.0m)$

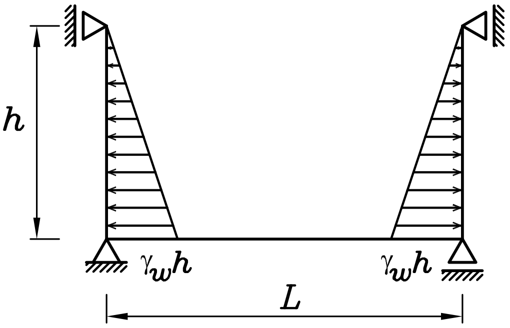
٢-لا يفضل زيادة ارتفاع الحائط الكابولى (cantilever wall) عن (3.0m) حتى لا تكون العزوم كبيرة و بالتالى نحتاج قطاع خرسانى كبير عند اتصال الحائط بالارضية ٠

b-One way in vertical direction $(t_w = \frac{H}{16} \not< 250mm)$



OR

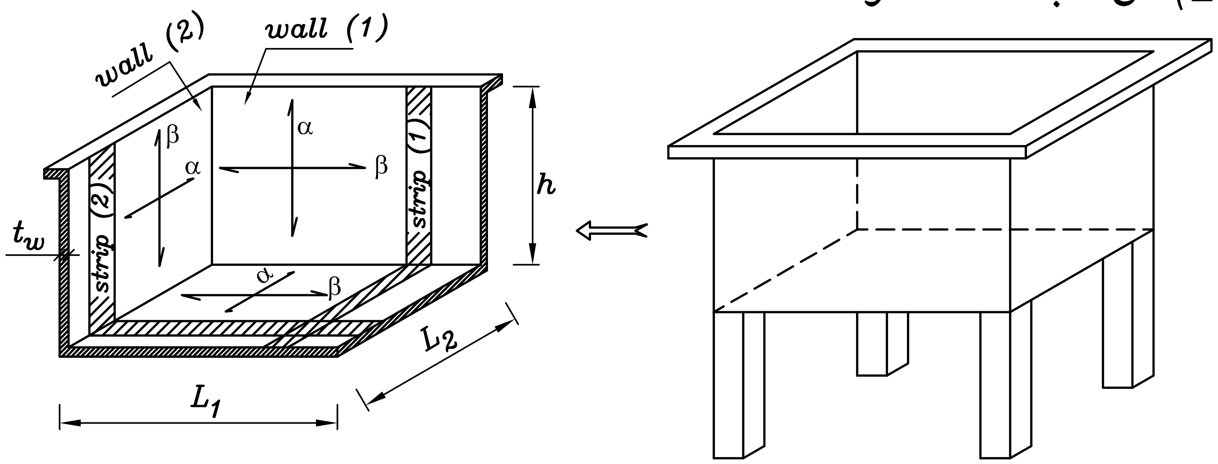




c-Two way slabs

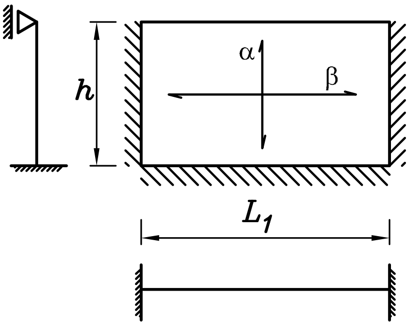
$(t_w=\frac{L_s}{16} \nless 250mm)$ $\boxed{\frac{L}{L_s} < 2}$

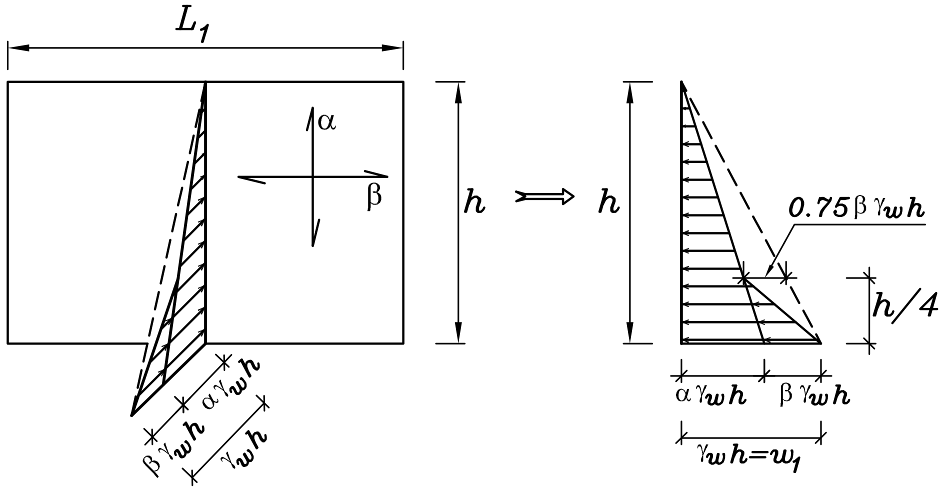
حيث (L_s) هى البعد الاصغر للحائط

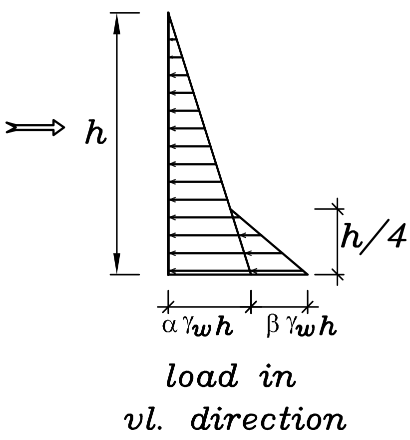


For wall (w_1) :

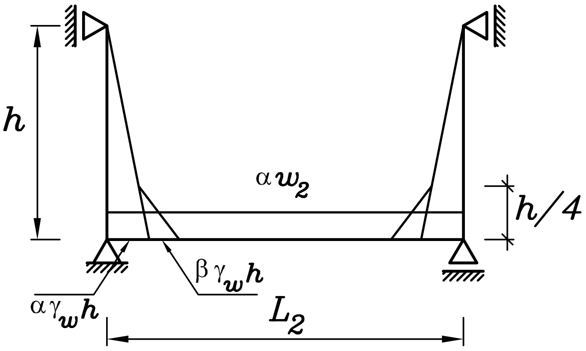
$$r=\frac{m\ L_1}{m\ h}=\frac{0.76L_1}{0.87h}$$ (assuming $L_1 > h$)







- VL. strip (1)

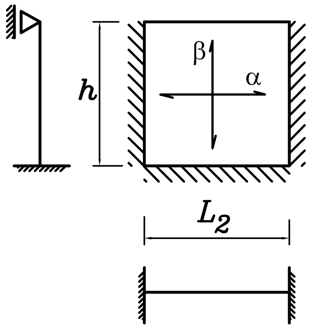


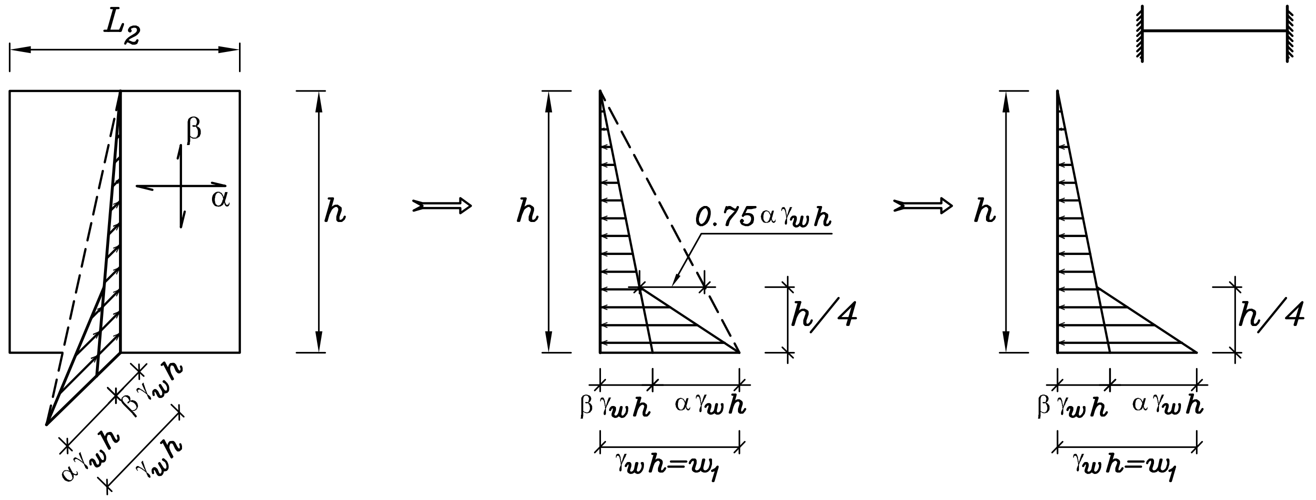
strip 1.0 width

For wall (w_2) :

$$r = \frac{m\ \ h}{m^{`}\ L_2} = \frac{0.87h}{0.76L_2}$$

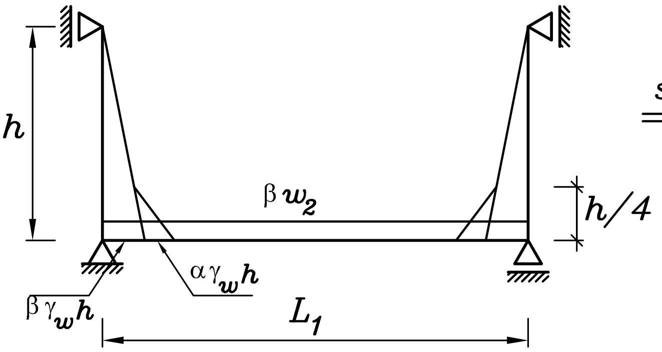
(assuming $h > L_2$)





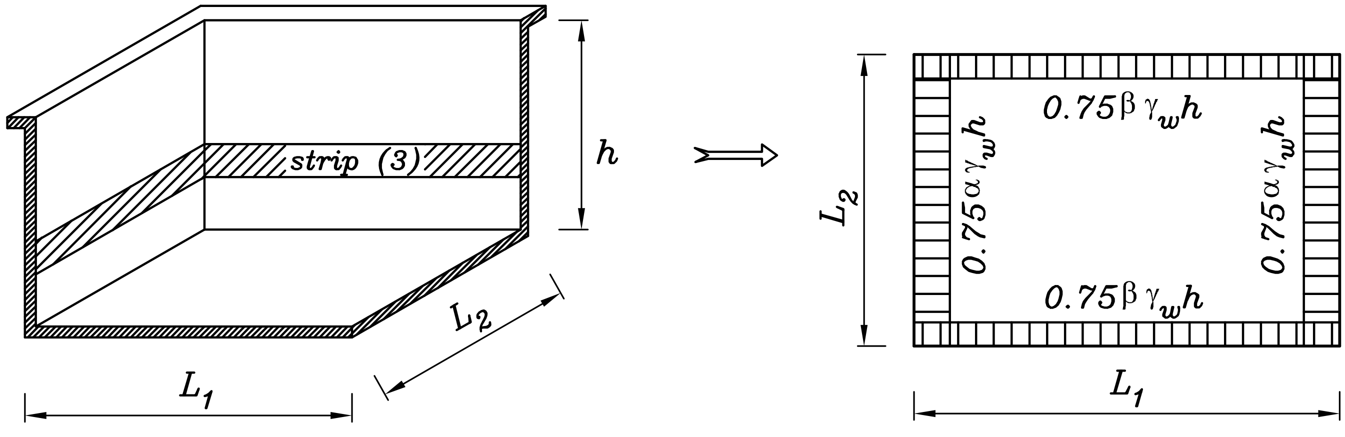
load in
vl. direction

– VL. strip (2)



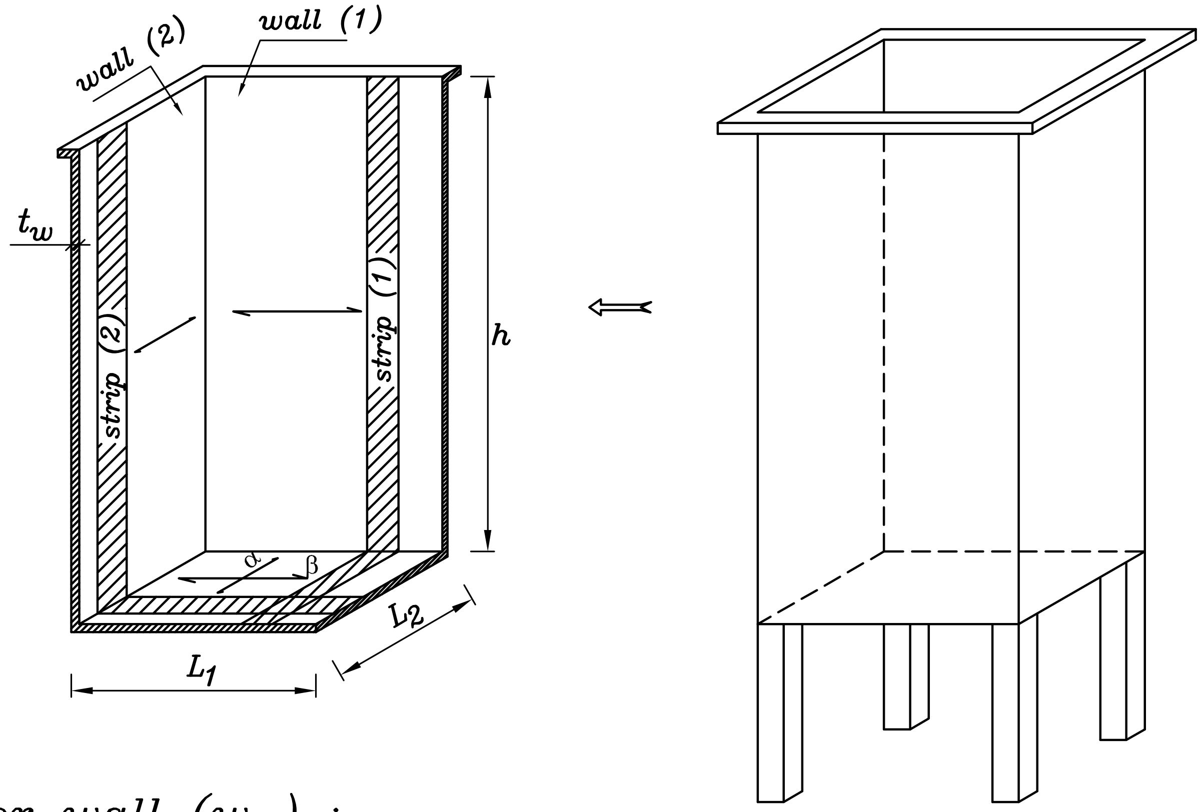
strip 1.0 width

– HZ. strip (3) at (h/4) from floor

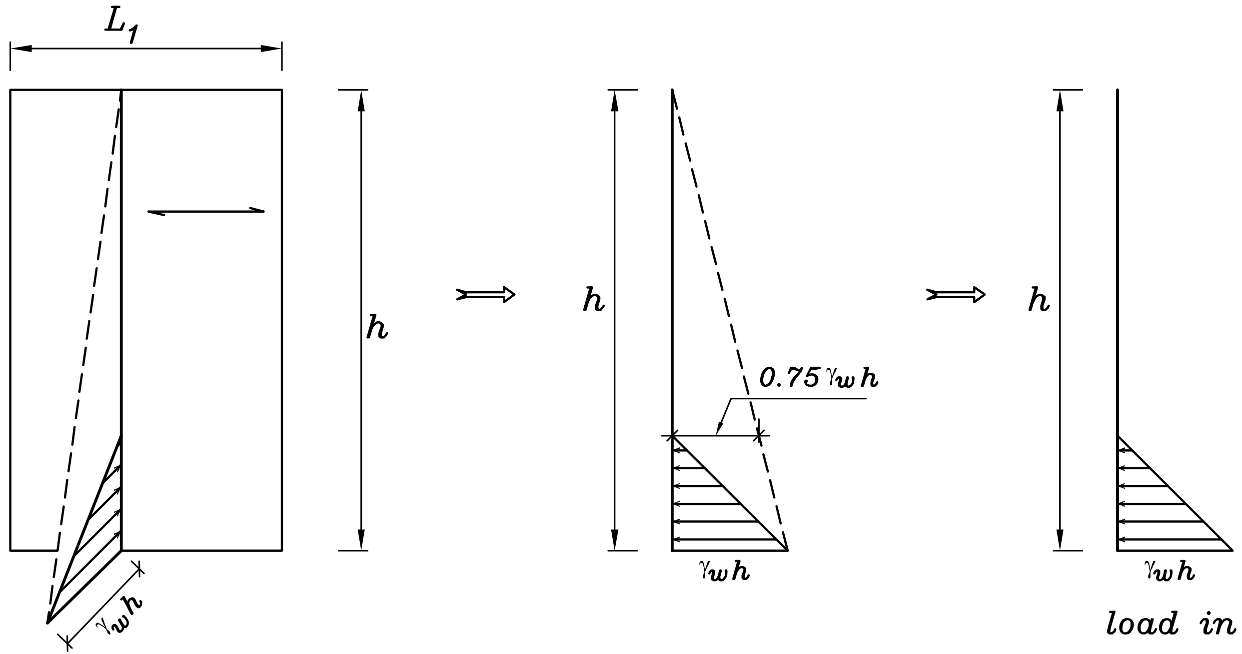


d-One way in horizontal direction (deep tank) $\boxed{\frac{h}{L} \geq 2}$

$$(t_w = \frac{L_s}{16} \not< 250mm)$$

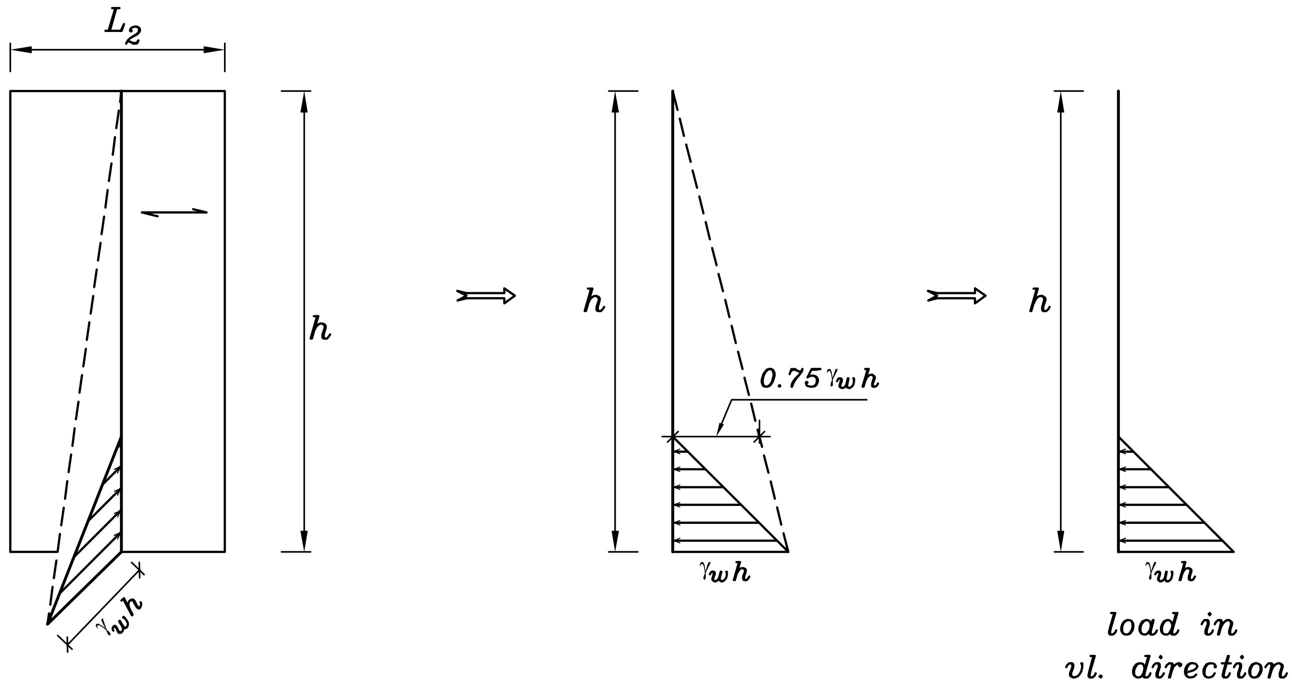


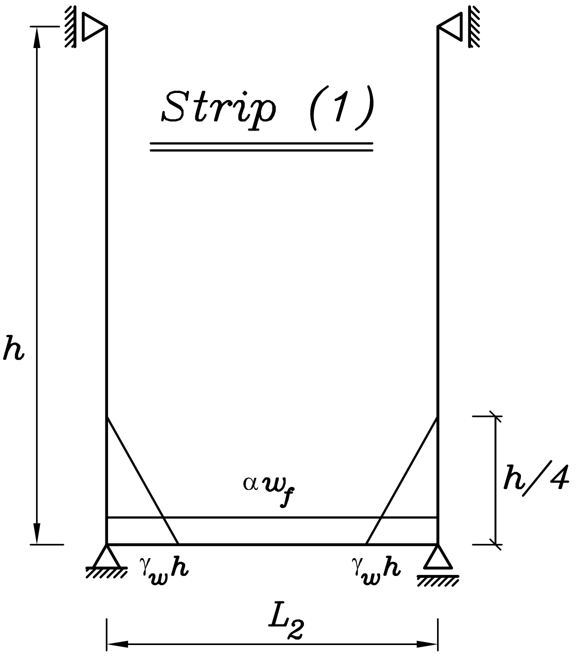
For wall (w_1) :

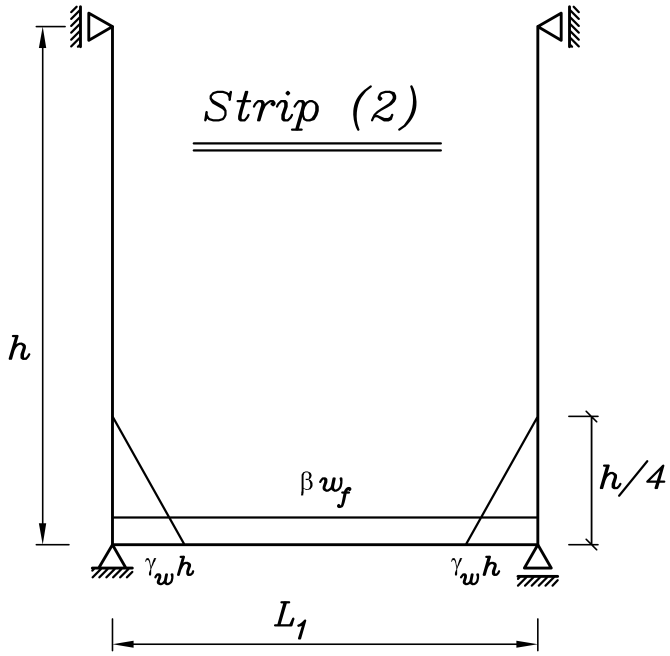


load in
vl. direction

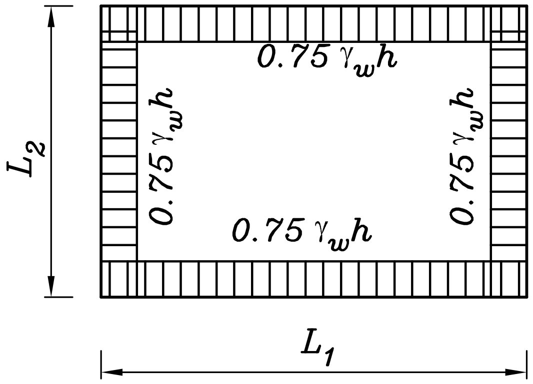
For wall (w_2) :







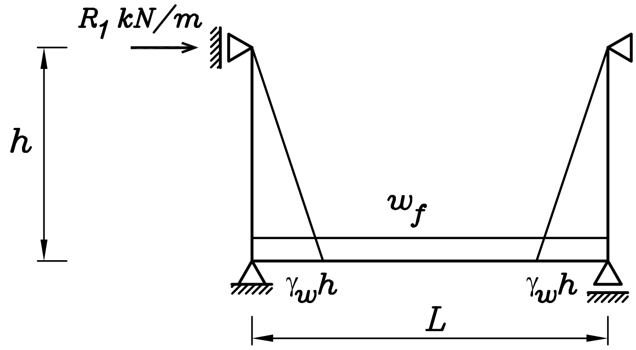
Strip (3) : horizontal strip at($\frac{h}{4}$)

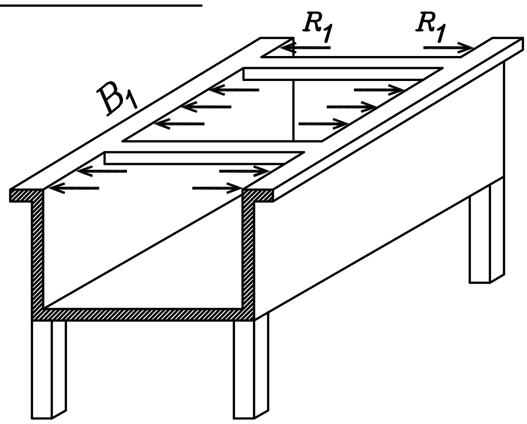


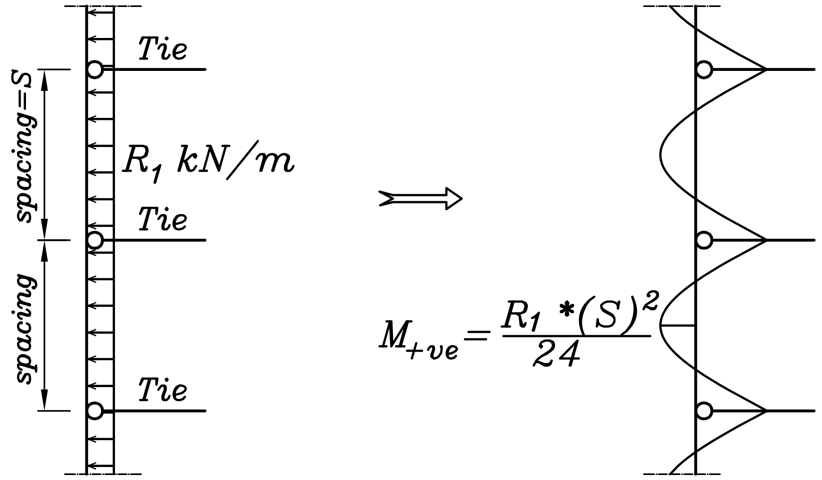
3- Supporting elements

1- Top horizontal beams

a- Horizontal beam of open channel tank





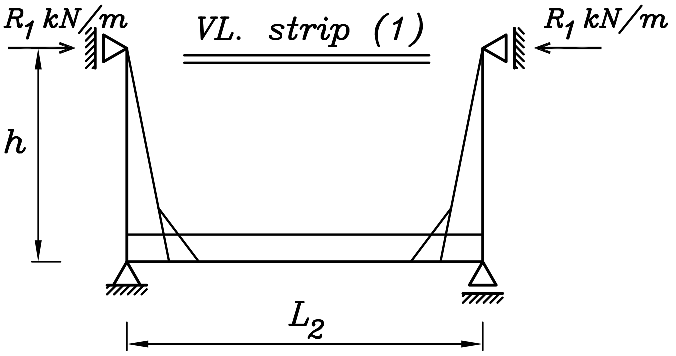


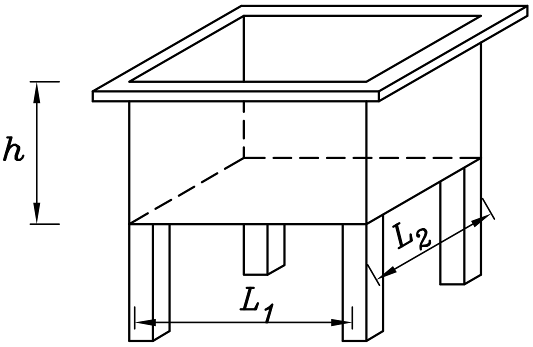
$$M_{-ve}=\frac{R_1*(S)^2}{12}$$

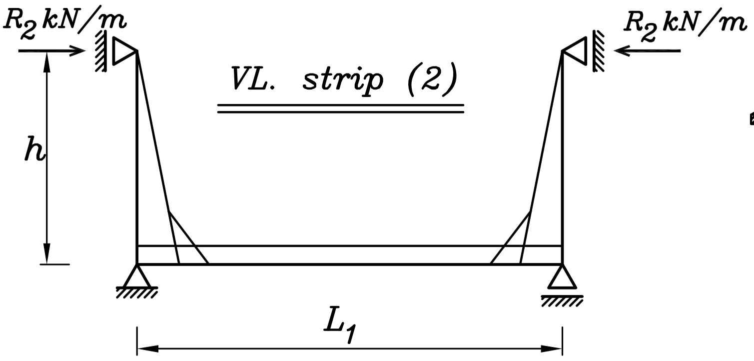
$$M_{+ve}=\frac{R_1*(S)^2}{24}$$

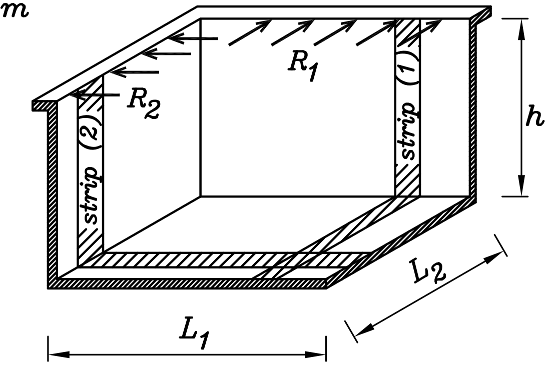
$\longrightarrow$ Tension in tie$=R_1*S$

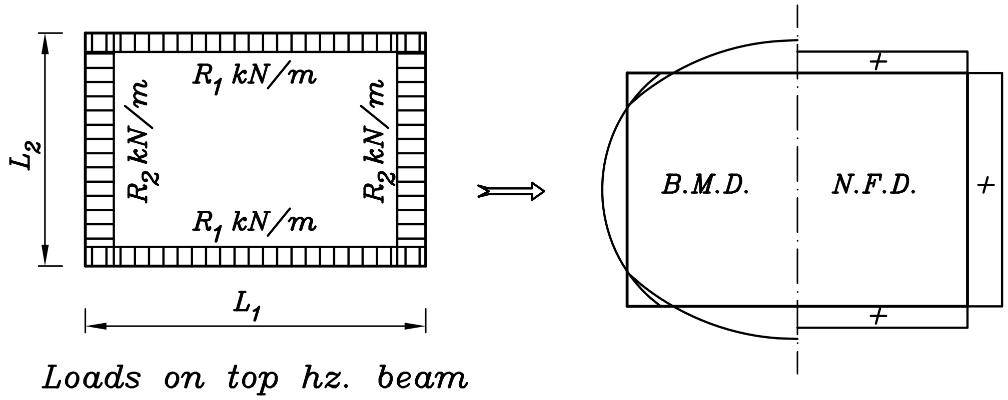
b- Closed frame without ties $(L\leq 7.0m)$





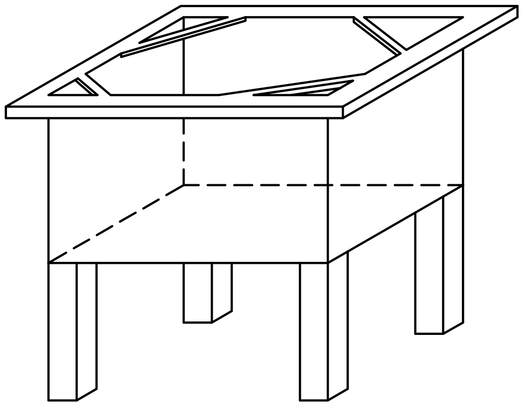


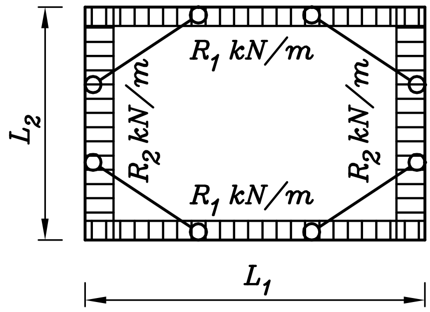




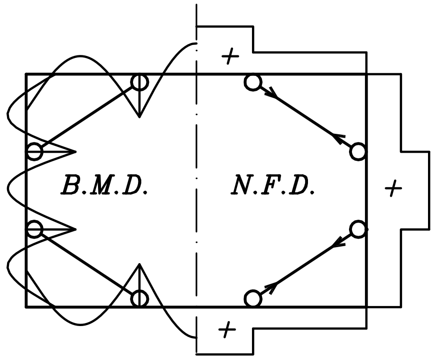
Loads on top hz. beam

d- Closed frame with ties (L>7.0m)





Loads on top hz. beam



ـ ملحوظة

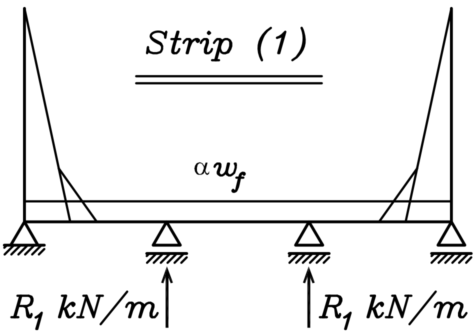
فى حالة ان طول الكمرة اكبر من (7.0m) يفضل وضع (tie) ليقلل (lateral displacement) للكمرة و بالتالى تكون (rigid) بحيث تعمل كركيزة بالنسبة الى (vertical wall)

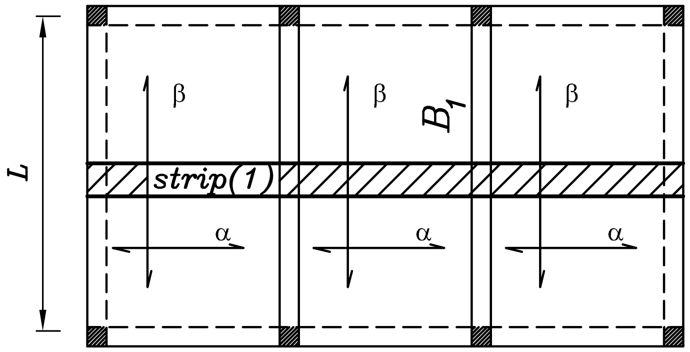
2- Floor beams

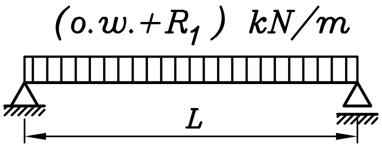
يوجد طريقتان لحساب الاحمال على الكمرة

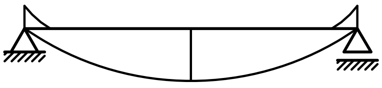
- Method (1)

حيث نعكس ردود افعال الشرائح العمودية على الكمرة $(R_1 \ kN/m)$

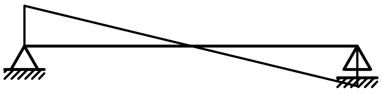








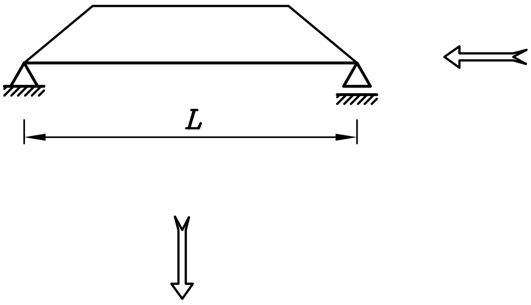
B.M.D.

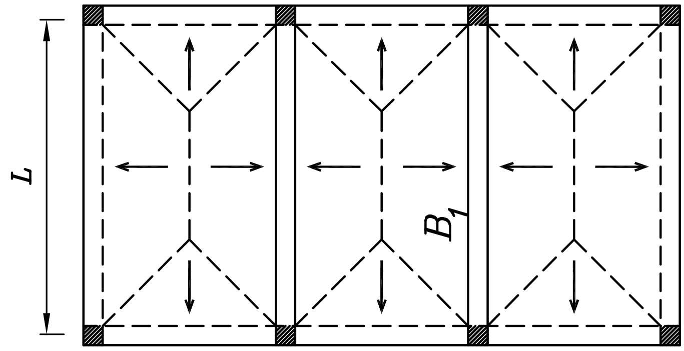


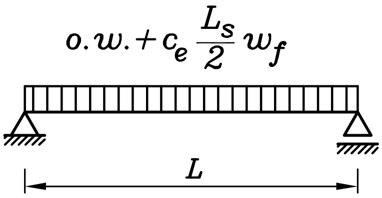
S.F.D.

- Method (2)

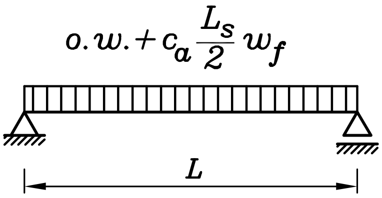
و هو عمل *(load distribution)* و حساب الاحمال الواقعة على الكمرة







load for moment



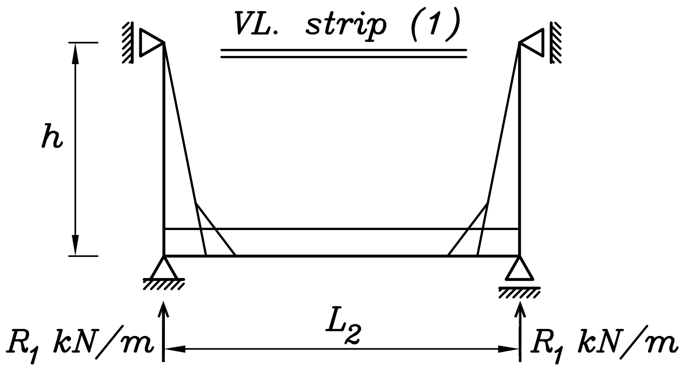
load for shear

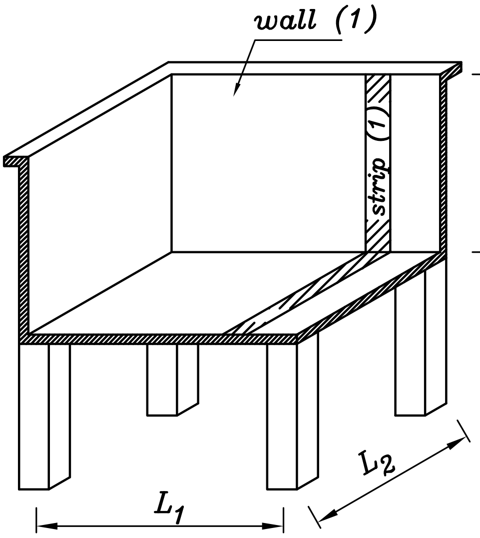
3- Wall acts as a beam

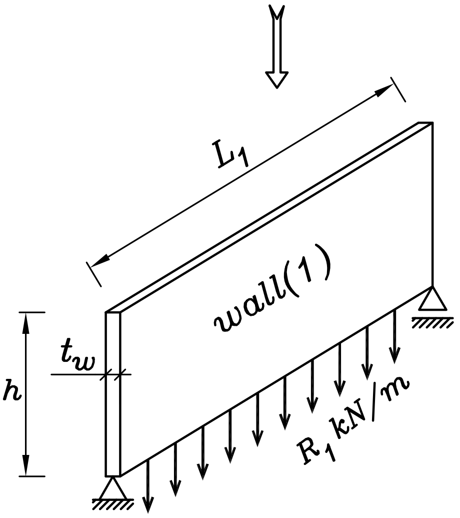
- كما سبق و راينا ان الحائط يعمل ككمرة مقلوبة بالنسبة للبلاطة لذلك يجب حساب الاحمال الواقعة عليها باعتبارها كمرة .

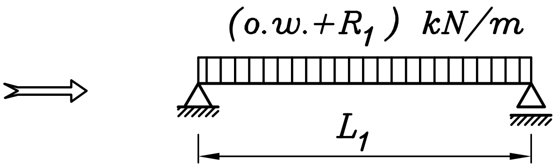
- يوجد طريقتان لحساب الاحمال على الكمرة

- Method (1)



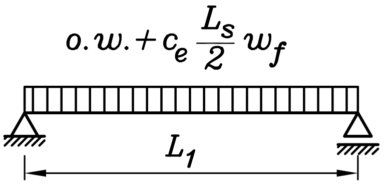




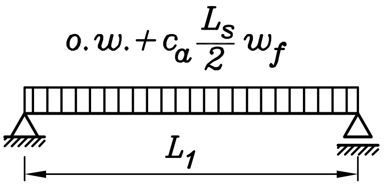


$o.w.$ of wall$=t_w.h\gamma_c$

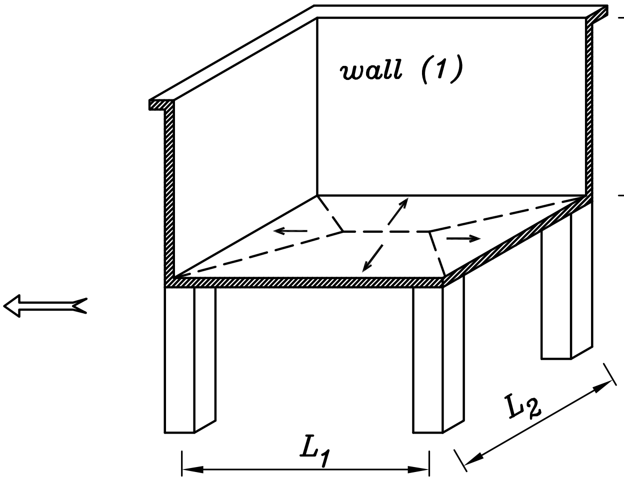
- Method (2)



load for moment



load for shear



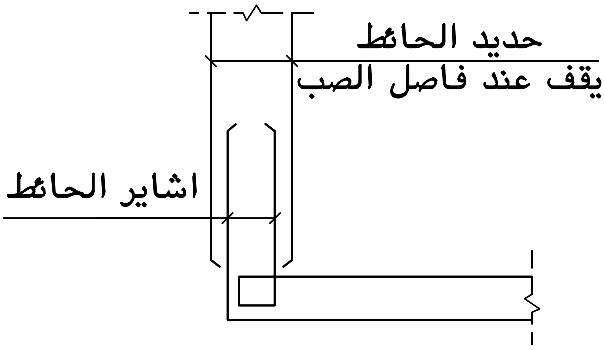
– Details of RFT.

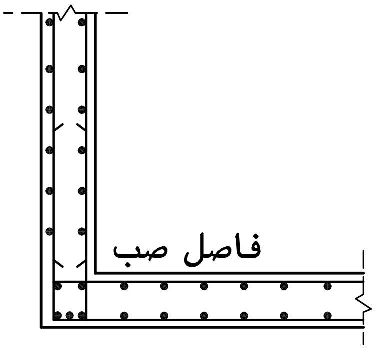
١-عدد الاسياخ يتراوح من (٥-١٠) اسياخ فى المتر .

٢-اقل كمية من الحديد توضع فى بلاطات الخزانات هى

$$A_{s_{min}} = \left[\begin{array}{l} 5\phi 12/m \text{ for main steel (at tension side)} \\ \\ 5\phi 10/m \text{ for secondary steel (at compression side)} \end{array}\right.$$

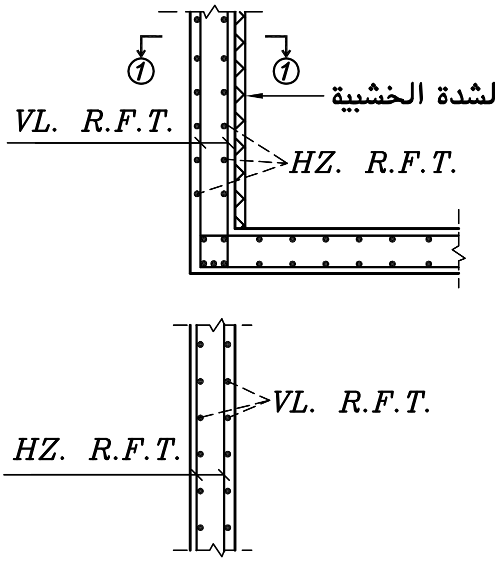
٣-يجب مراعاة مراحل صب الخزان بمعنى انه نتيجة صب ارضية الخزان اولا ثم صب الحائط بعد ذلك فان اشاير الحائط تخرج من ارضية الخزان و لا يدخل تسليح الحائط فى ارضية الخزان





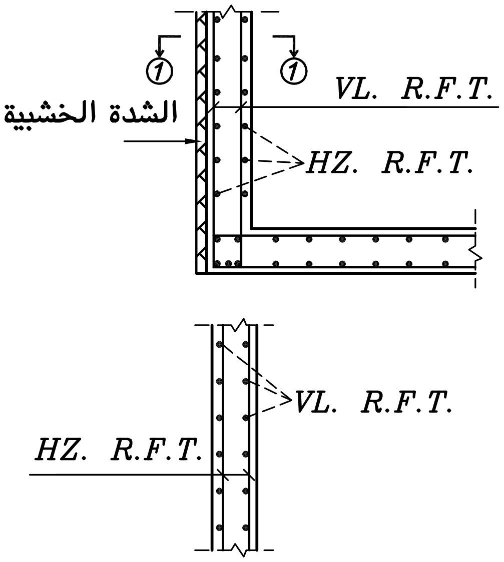
٤-يتم رص الحديد الافقى للحائط كما يلى لسهولة التنفيذ

يتم وضع الشدة ثم وضع الحديد الراسى للحائط يليه الحديد الافقى ثم يوضع الحديد الراسى فى الجهة المقابلة يليه الحديد الافقى كما يتضح من الرسم



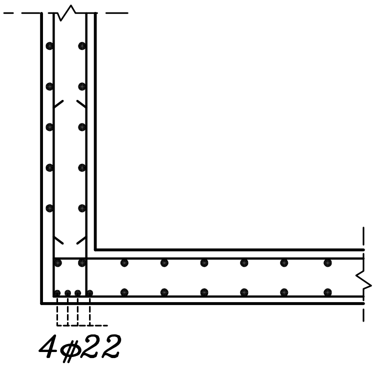
HZ. sec. (1–1)

OR



HZ. sec. (1–1)

٤-يتم تركيز حديد اسفل و اعلى الحائط لان الحائط يعمل ككمرة بالنسبة للارضية .



كيفية رسم (concrete dimensions) للخزان

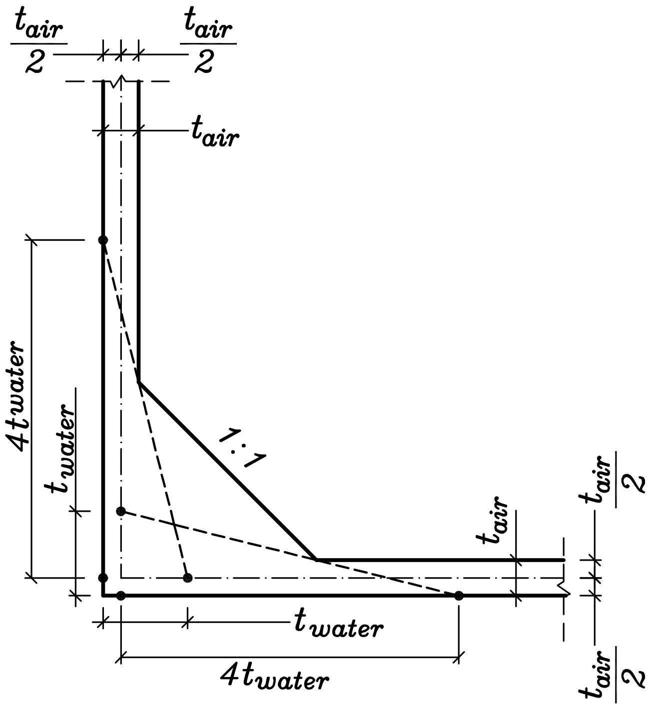
١ - نرسم (C.L.) للخزان و نوقع عليه تخانة (air sections) بحيث تكون التخانة فى منتصف ال (C.L.)

ملحوظة -

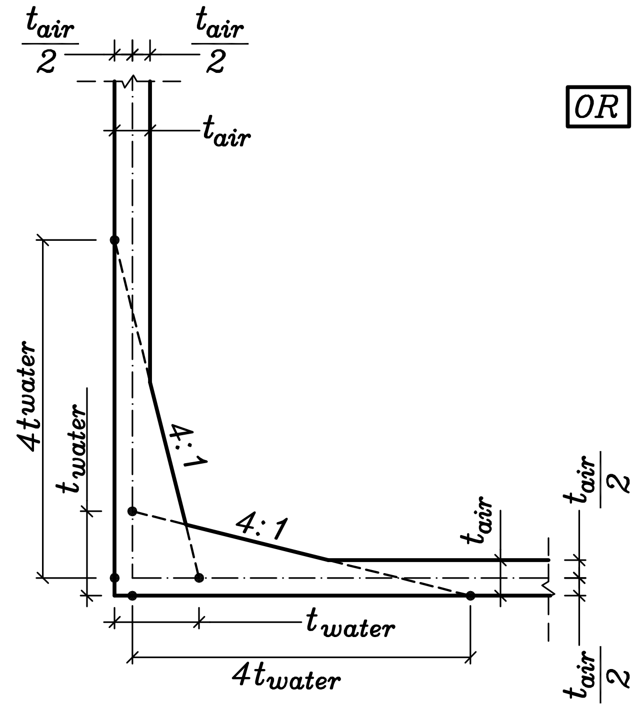
يقصد بتخانة (air sections) هى $\left(\frac{L_s}{16} \text{ or } \frac{H}{10} \nless 250mm\right)$

٢ - نوقع تخانة (water sections) كما بالرسم و منها نرسم الخزان .

How to draw the haunch



اسهل فى التنفيذ و لكن تاخذ حجم اكبر من الخزان

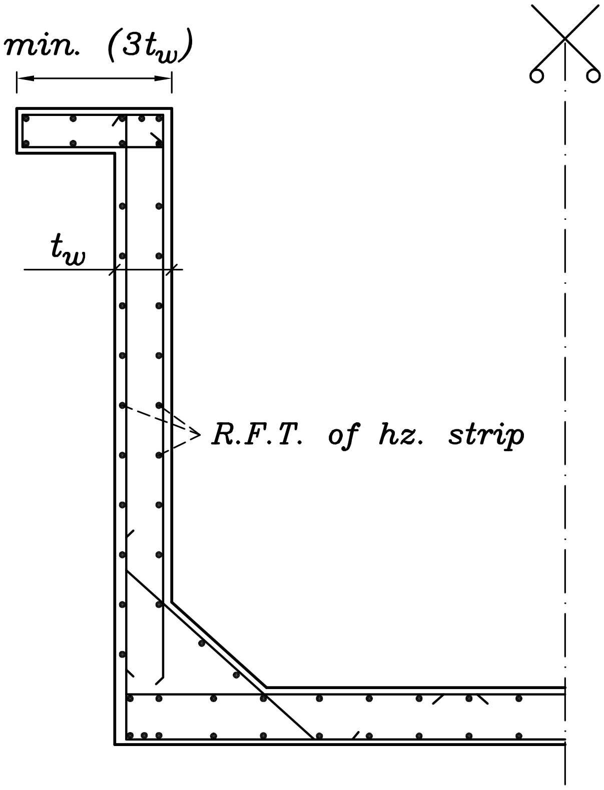


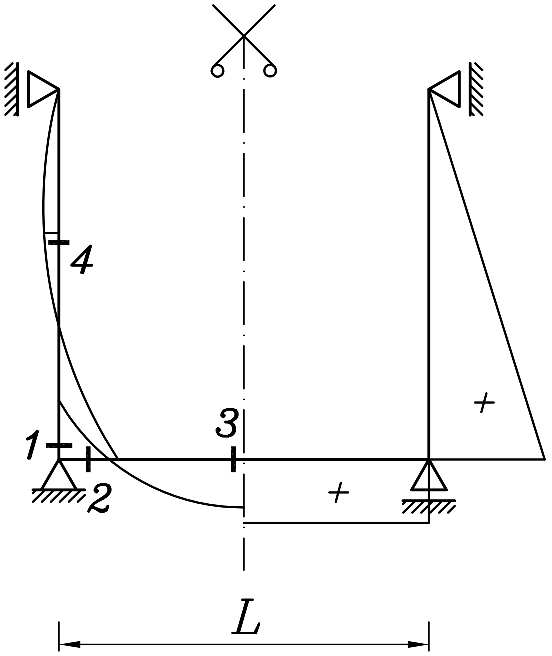
اصعب فى التنفيذ و لكن تاخذ حجم اقل من الخزان

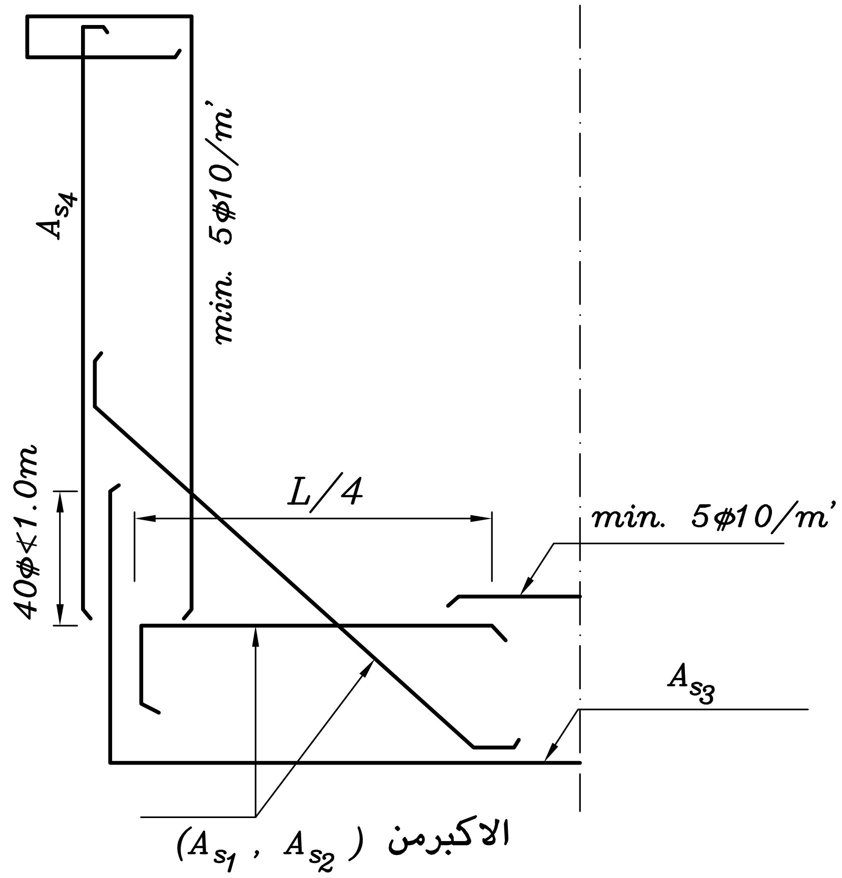
RFT. of elements of the tank

1– Walls

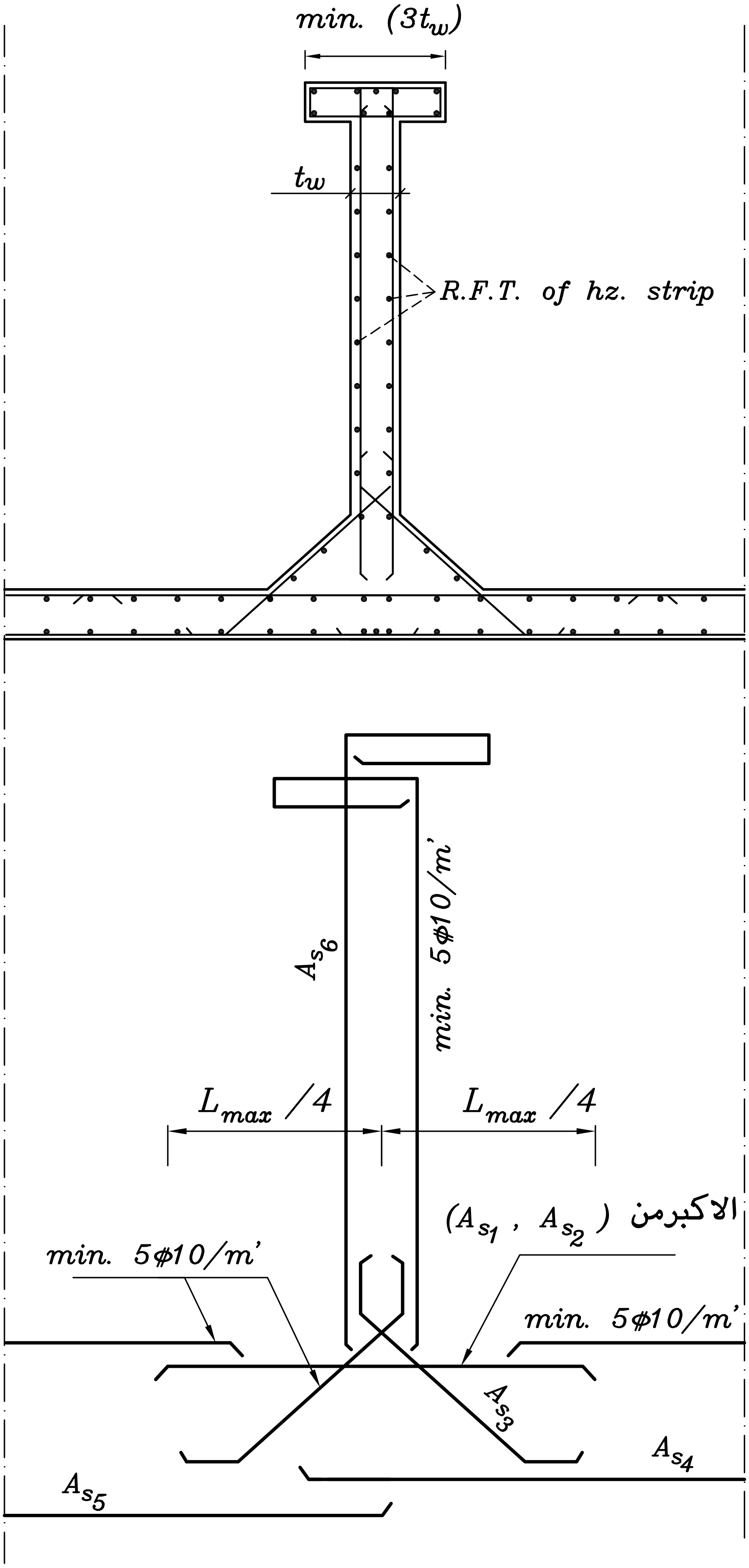
a– external walls

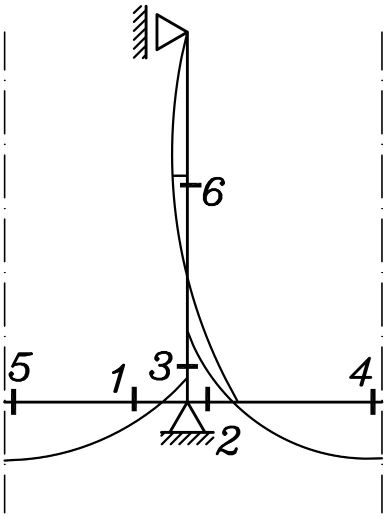






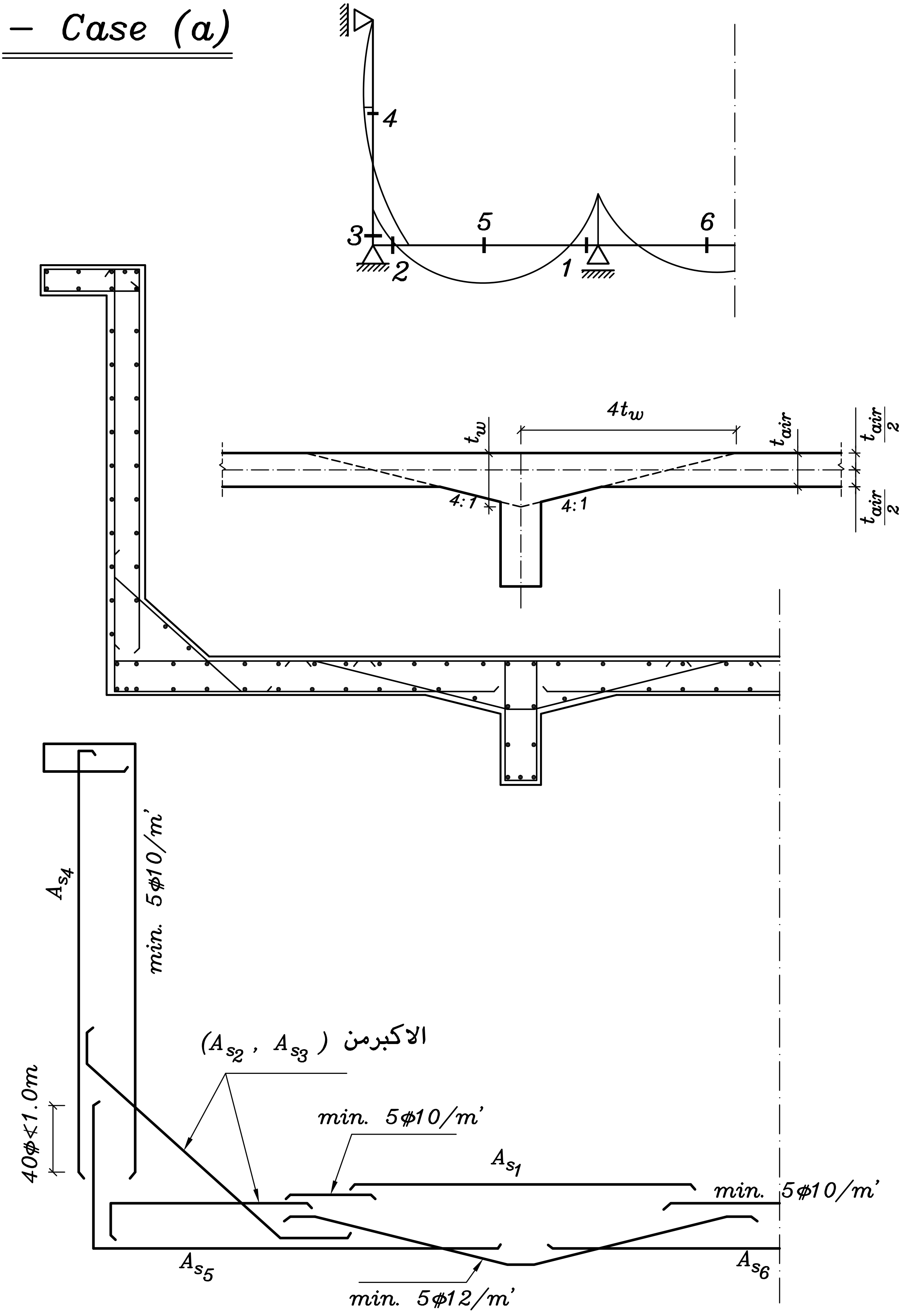
b- internal walls



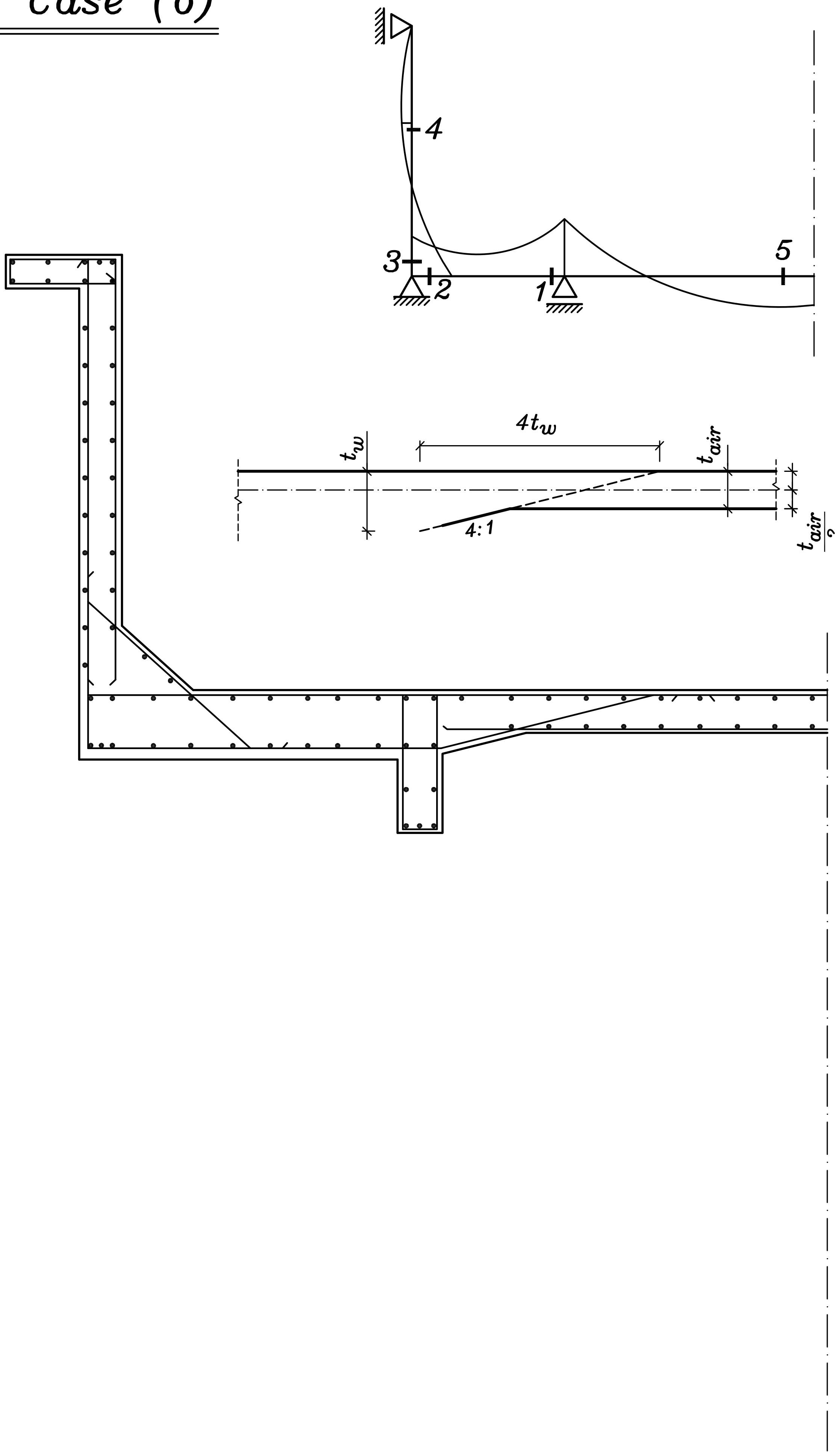


2- Floors

- Case (a)

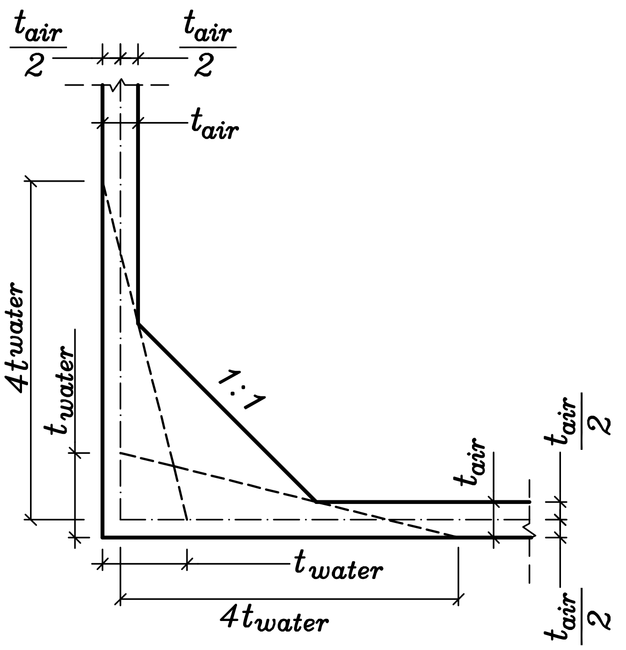


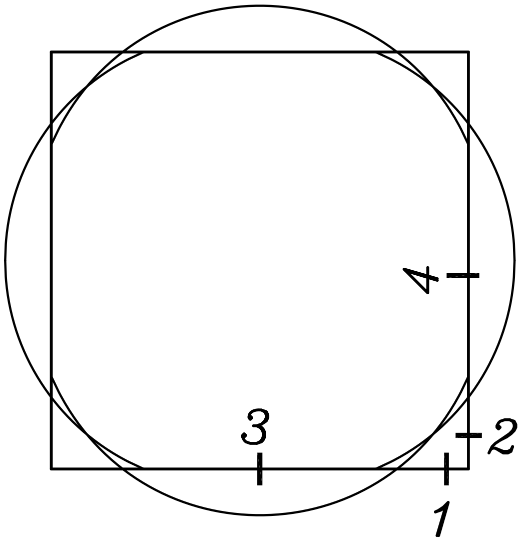
– Case (b)

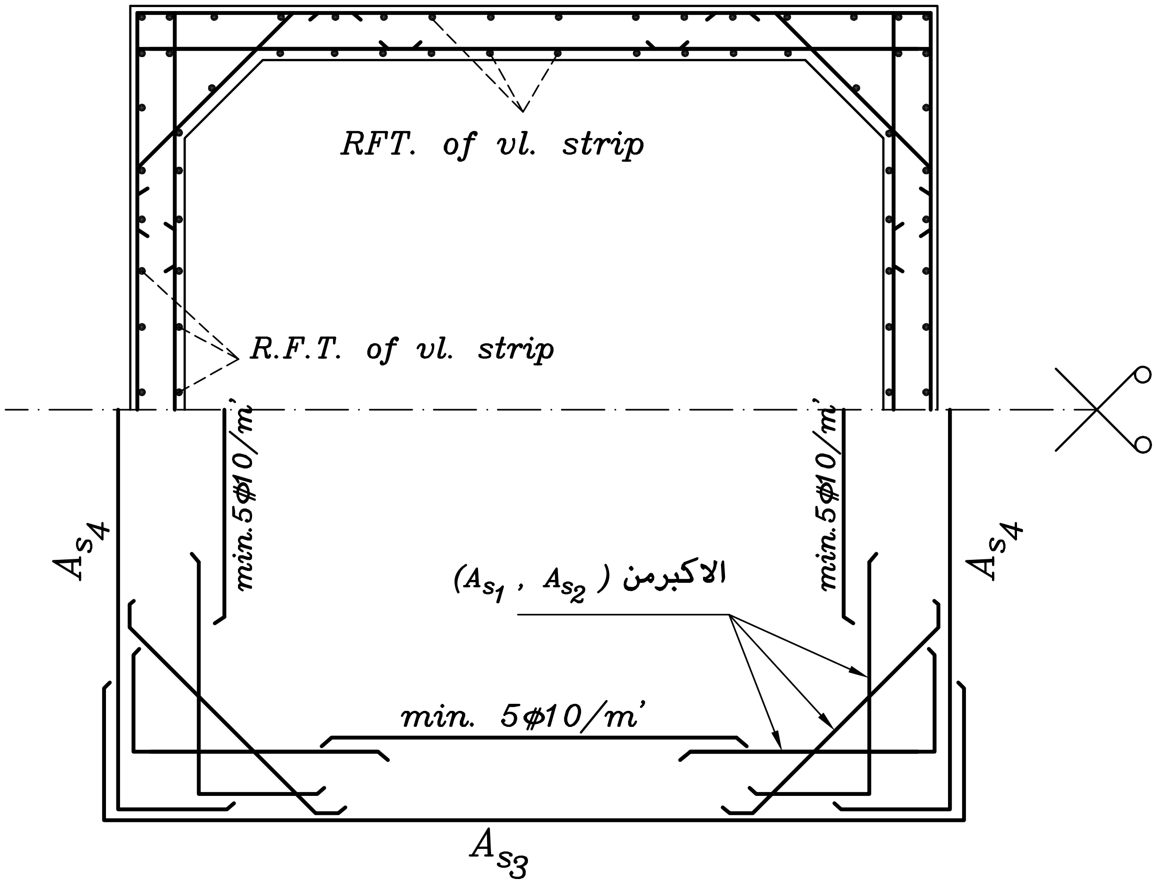


3- Hz. strip

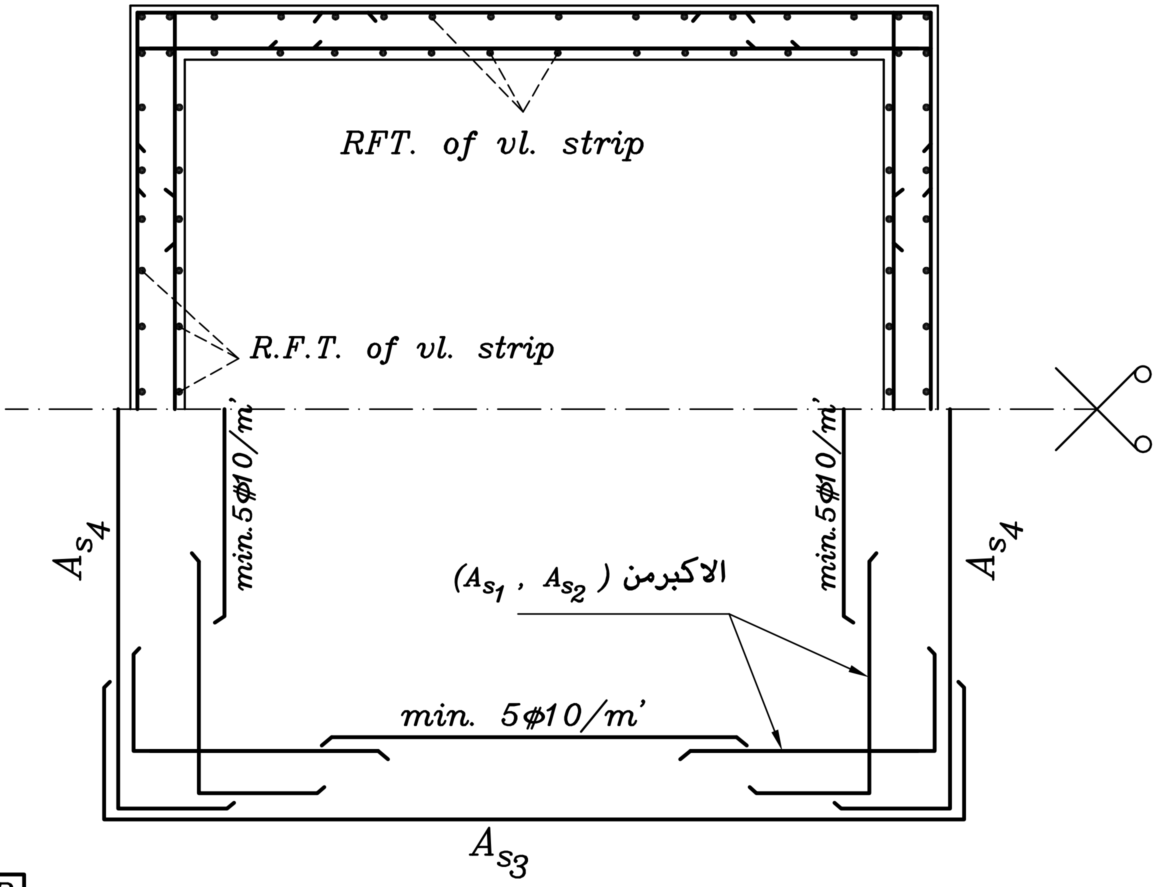
Case (a): haunch at hz. strip



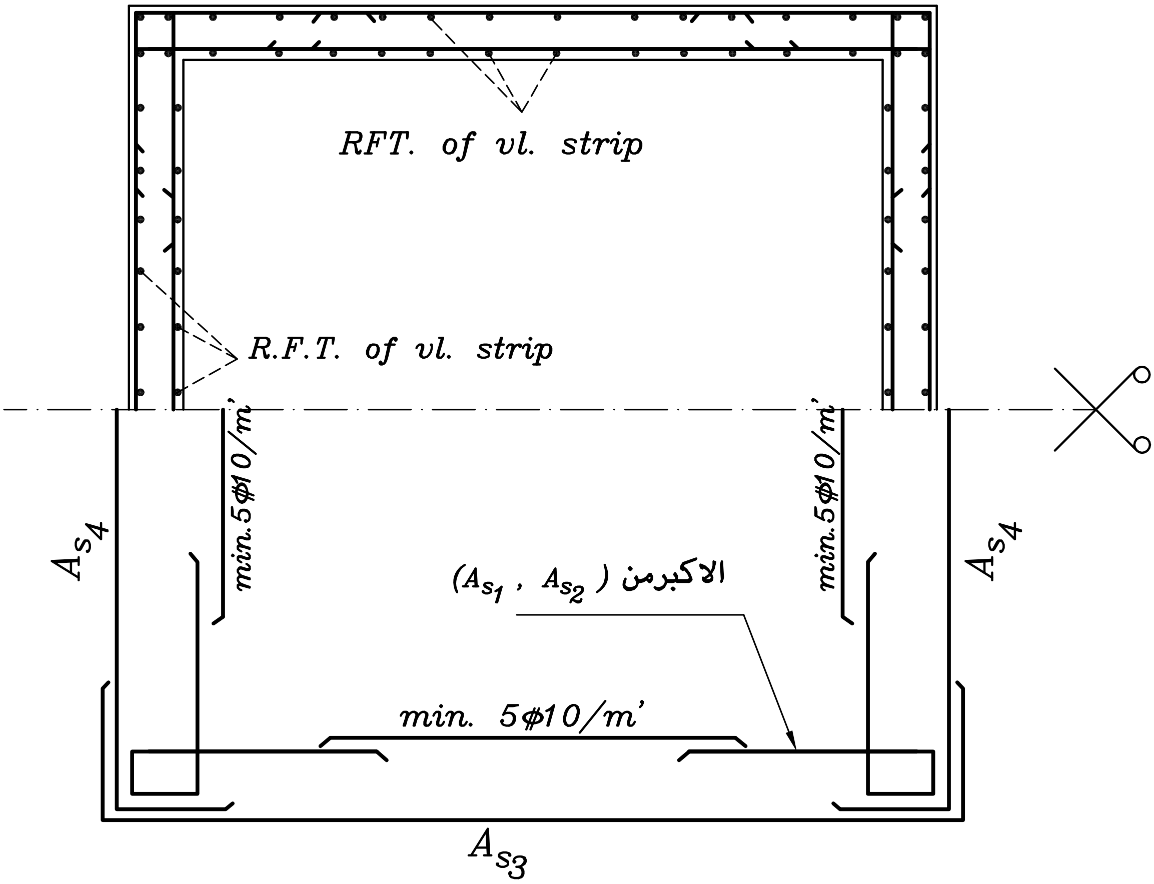




Case (b): no haunch at hz. strip



OR



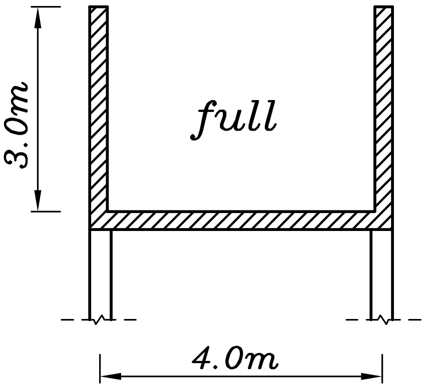
Example(1)

Given:

$f_{cu}=25\ N/mm^2$ & steel used is 360/520

Required

Design the given open channel tank.

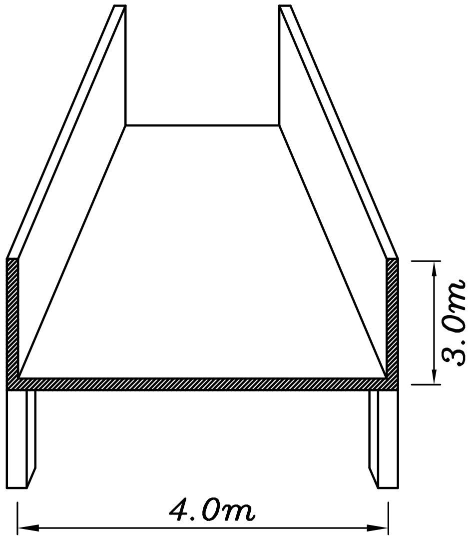


Solution

1- Concrete dimensions

$$t_w=\frac{h}{10}=\frac{300}{10}=30cm$$

$$t_f=\frac{L}{16}=\frac{400}{16}=25cm$$

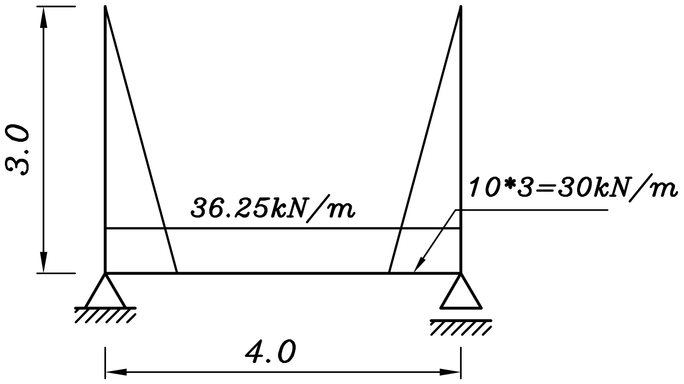


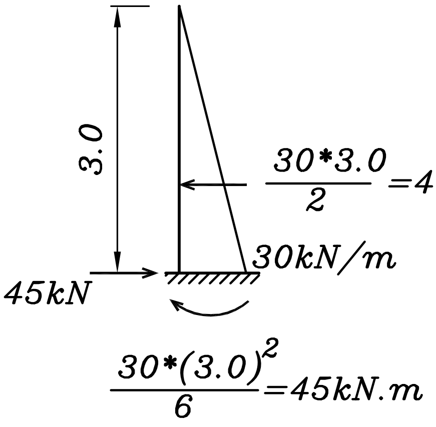
2- Loads on floor

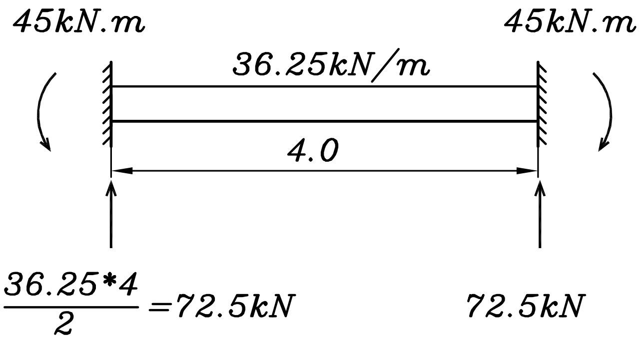
$$w_f=t_f\gamma_c+\gamma_w h=0.25*25+10*3$$

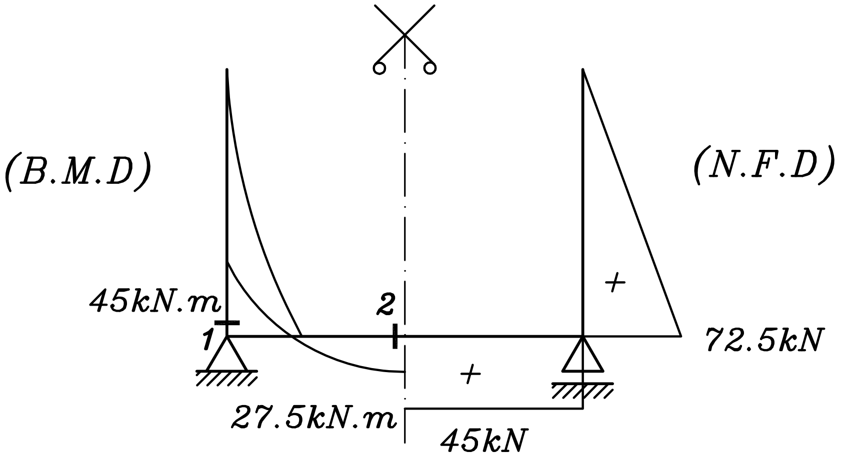
$$w_f=36.25\ kN/m^2$$

3- Analysis of strip









4- Design of sections

Sec (1-1) water section

$M_{working}=45.00\ kN.m$, $T_{working}=72.50\ kN$, $b=1000mm$

Stage (I)

$$t_{(mm)}=\sqrt{\frac{M*10^3}{factor}}+40mm=\sqrt{\frac{45.00*10^3}{0.30}}+40mm=427.30mm$$

$\Longrightarrow$ Take $t=450mm$

Check stresses

$$f_t=+\frac{T}{A}+\frac{M}{Z}=+\frac{72.50*10^3}{1000*450}+\frac{45.00*10^6}{1000*(450)^2/6}$$

$$=0.16+1.33=1.49\ N/mm^2$$

$$\Longrightarrow f_{ct}=\frac{0.6\sqrt{25}}{1.7}=1.76N/mm^2$$

$$\Longrightarrow f_t < f_{ct} \quad (safe)$$

Stage (II)

$$M_{u.l.}=1.5*45.00=67.50 \ kN.m \quad , \quad T_{u.l.}=1.5*72.50=108.75 \ kN$$

$$e=\frac{M_{u.l.}}{T_{u.l.}}=\frac{67.50}{108.75}=0.62m > \frac{t}{2} \ -cover$$

$$e_s=e-\frac{t}{2}+c=0.62-\frac{0.45}{2}+0.04=0.44m$$

$$M_{us}=108.75*0.44=47.31kN.m$$

$$410=C_1\sqrt{\frac{47.31*10^6}{1000*25}} \qquad C_1=9.42 \quad \& \quad J=0.826$$

$$A_s=\frac{1}{\beta_{cr}}*[\frac{M_{us}}{J*d*f_y}+\frac{T_{u.l.}}{f_y/\gamma_s}]$$

assume $\phi 16$ used $\Longrightarrow \beta_{cr}=0.75$

$$A_s=\frac{1}{0.75}[\frac{47.31*10^6}{0.826*410*360}+\frac{108.75*10^3}{360/1.15}]$$

$$A_s=980.59mm^2/m' \Longrightarrow 5\phi 16/m'$$

Sec (2-2) air section

$$M_{working}=27.50 \ kN.m \ , \quad T_{working}=45.00 \ kN \quad , \quad b=1000mm$$

Stage (II) , $t=250mm$

$$M_{u.l.}=1.5*27.50=41.25 \ kN.m \quad , \quad T_{u.l.}=1.5*45.00=67.50 \ kN$$

$$e=\frac{M_{u.l.}}{T_{u.l.}}=\frac{41.25}{67.50}=0.61m > \frac{t}{2} \ -cover$$

$$e_s=e-\frac{t}{2}+c=0.61-\frac{0.25}{2}+0.04=0.53m$$

$M_{us}=67.50*0.53=35.78kN.m$

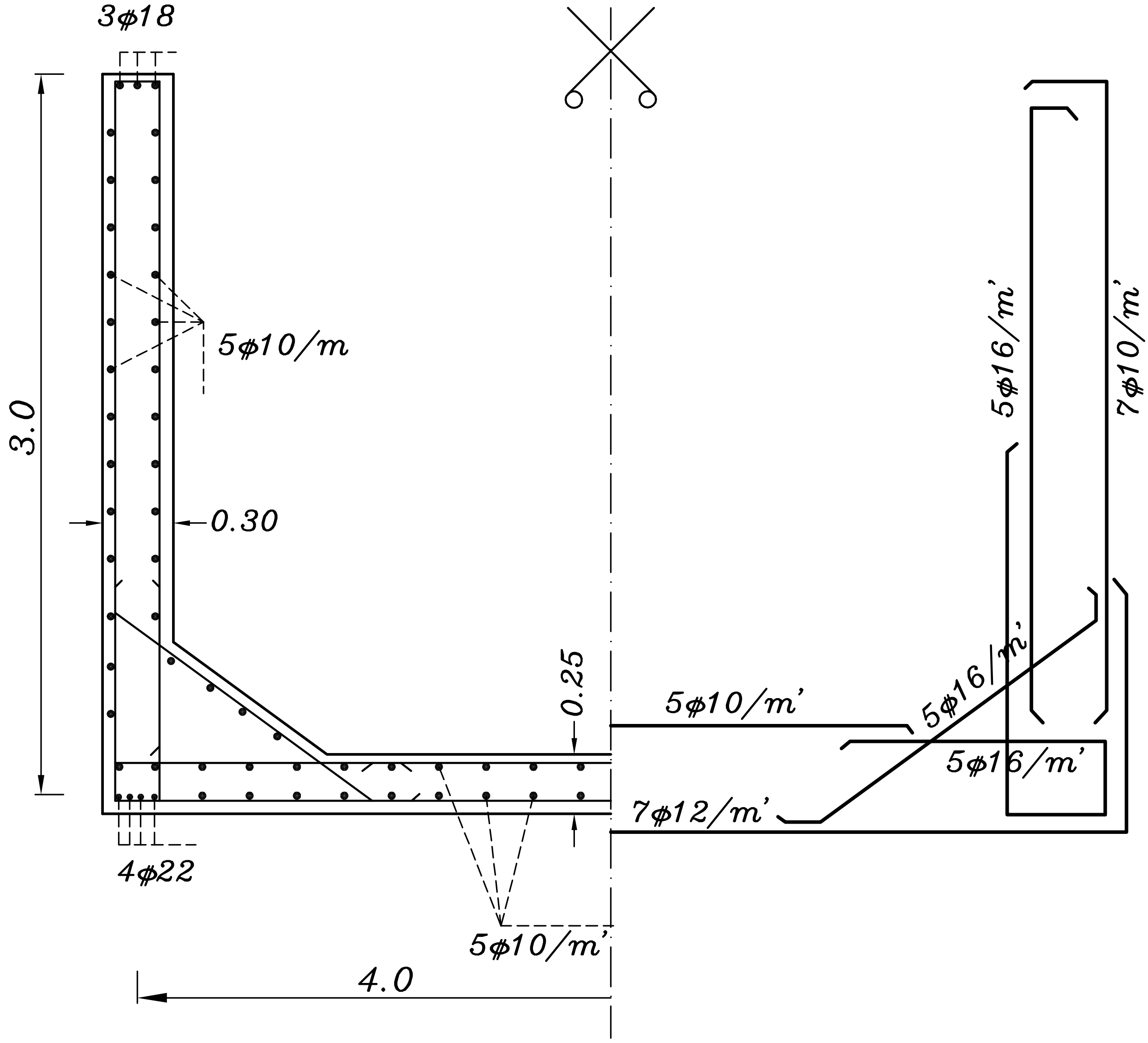
$210=C_1\sqrt{\frac{35.78*10^6}{1000*25}}$ $C_1=5.55$ & $J=0.826$

$A_s=\frac{1}{\beta_{cr}}*[\frac{M_{us}}{J*d*f_y}+\frac{T_{u.l.}}{f_y/\gamma_s}]$ assume $\phi 12$ used $\Longrightarrow$ $\beta_{cr}=1.00$

$A_s=\frac{1}{1.00}[\frac{35.78*10^6}{0.826*210*360}+\frac{67.50*10^3}{360/1.15}]$

$A_s=788.60mm^2/m' \Longrightarrow 7\phi12/m'$

Details of RFT.



Example(2)

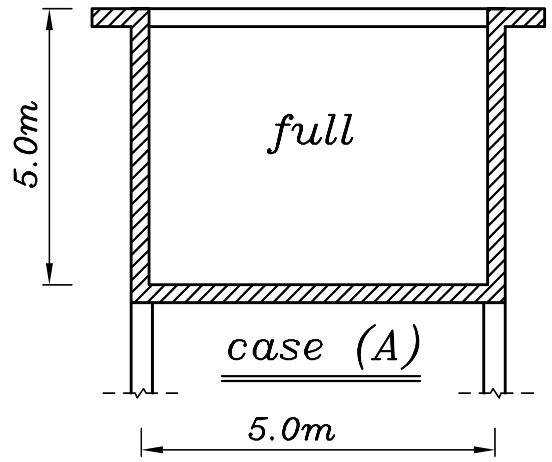
Given:

$f_{cu}=25\ N/mm^2$ & steel used is 360/520

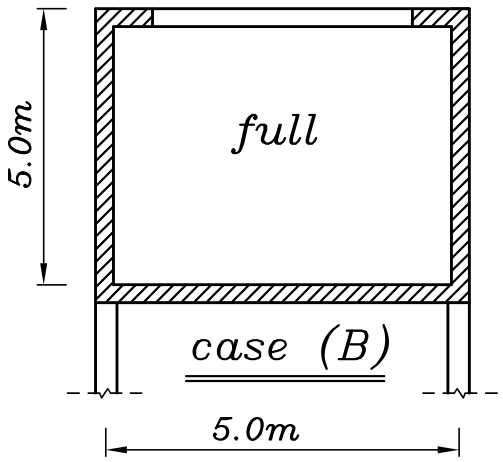
Required

1 – Design the given open channel tank.

2 – Design the top hz. beam & tie (spacing between ties =5.0m)



case (A)



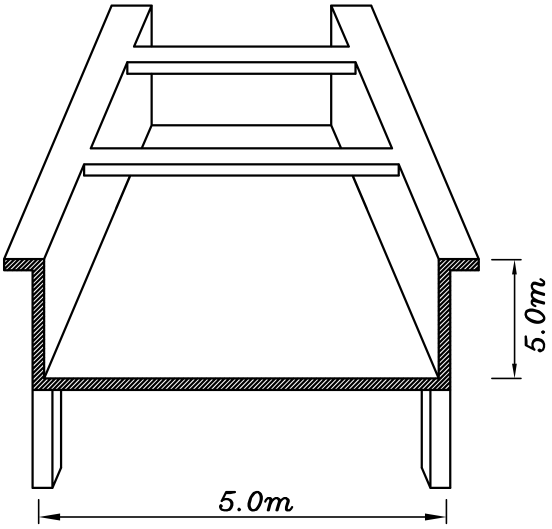
case (B)

Solution

1 – Concrete dimensions

$$t_w=t_f=\frac{L}{16}=\frac{500}{16}=31.25cm$$

$\Longrightarrow$ Take $t_w=t_f=30cm$

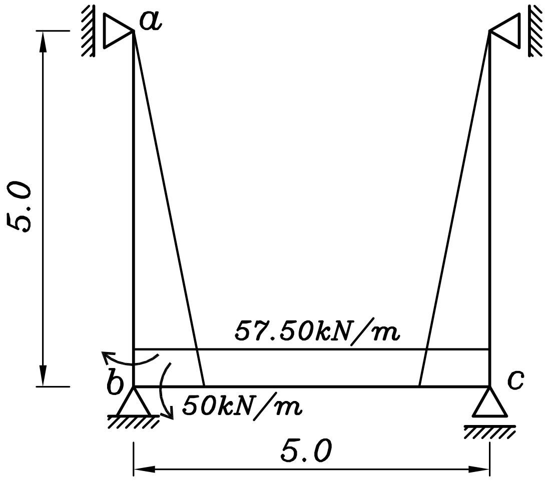


2 – Loads on floor

$$w_f=t_f\gamma_c+\gamma_w h=0.30*25+10*5$$

$$w_f=57.50\ kN/m^2$$

3– Analysis of strips



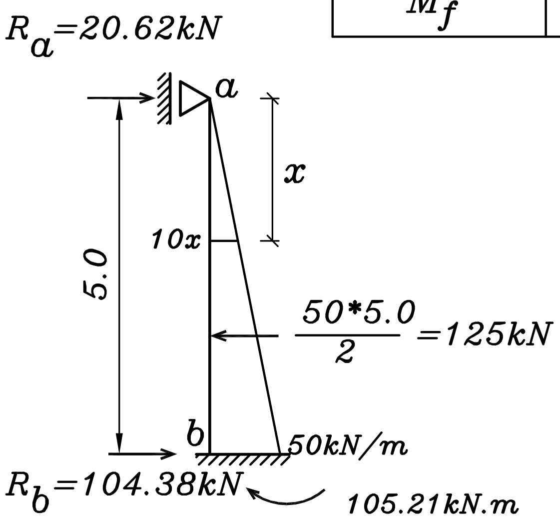
For Joint b

$$D.f_{ba}=\frac{0.75(I/5.0)}{0.75(I/5.0)+0.5(I/5)}=0.6$$

$$D.f_{bc}=\frac{0.5(I/5)}{0.75(I/5.0)+0.5(I/5)}=0.4$$

$$F.E.M._{ba}=\frac{50*(5)^2}{15}=83.33kN.m\ ,\ F.E.M._{bc}=\frac{-57.50*(5)^2}{12}=-119.79kN.m$$

Joint	b	
member	ba	bc
D.f.	0.60	0.40
F.E.M.	83.33	−119.79
Bal.M.	21.88	14.58
M_f	105.21	−105.21

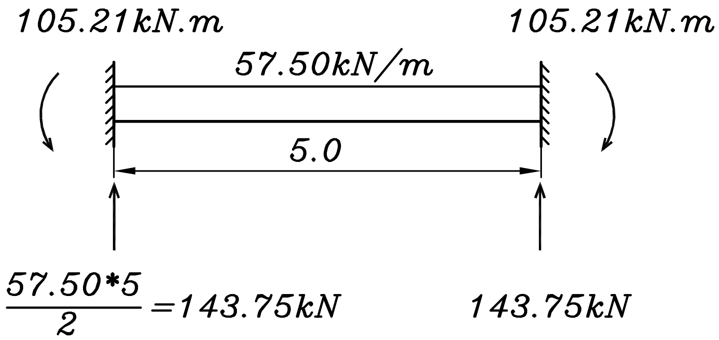


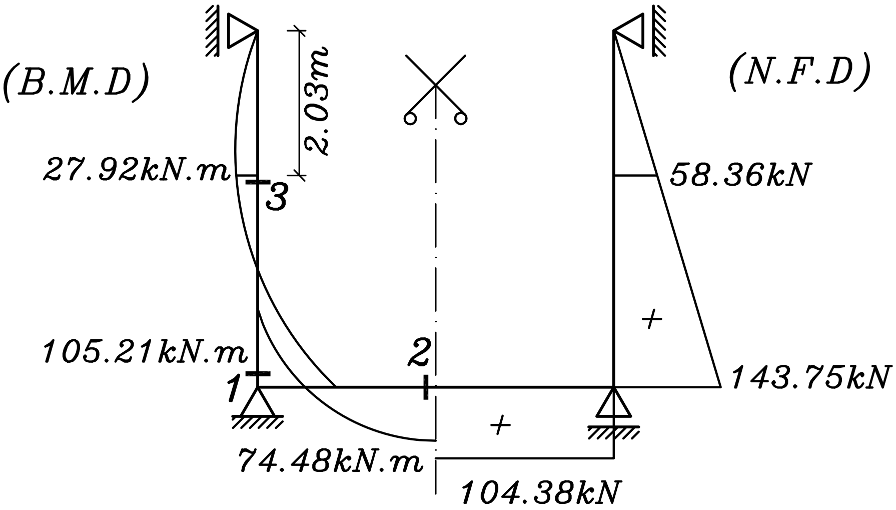
Point of zero shear

$$(10x)*\frac{x}{2}=20.62 \Longrightarrow x=2.03m$$

$$\Longrightarrow M_{+ve}=20.62x-(10x)*(\frac{x^2}{6})$$

$$M_{+ve}=27.92\ \ kN.m$$





4− Design of sections

Sec (1−1) water section

$M_{working}=105.21$ kN.m , $T_{working}=143.75$ kN , b=1000mm

Stage (I)

$$t_{(mm)}=\sqrt{\frac{M*10^3}{factor}}+40mm=\sqrt{\frac{105.21*10^3}{0.28}}+40mm=652.98mm$$

$\Longrightarrow$ Take t =700mm

Check stresses

$$f_t=+\frac{T}{A}+\frac{M}{Z}=+\frac{143.75*10^3}{1000*700}+\frac{105.21*10^6}{1000*(700)^2/6}$$

$$=0.21+1.29=1.50\ N/mm^2$$

$$\Longrightarrow f_{ct}=\frac{0.6\sqrt{25}}{1.7}=1.76N/mm^2$$

$$\Longrightarrow f_t < f_{ct} \quad (safe)$$

Stage (II)

$M_{u.l.}=1.5*105.21=157.82$ kN.m , $T_{u.l.}=1.5*143.75=215.63$ kN

$$e=\frac{M_{u.l.}}{T_{u.l.}}=\frac{157.82}{215.63}=0.73m > \frac{t}{2} - cover$$

$$e_s=e-\frac{t}{2}+c=0.73-\frac{0.70}{2}+0.04=0.42m$$

$$M_{us}=215.63*0.42=90.56kN.m$$

$$660=C_1\sqrt{\frac{90.56*10^6}{1000*25}} \qquad C_1=10.97 \quad \& \quad J=0.826$$

$$A_s=\frac{1}{\beta_{cr}}*[\frac{M_{us}}{J*d*f_y}+\frac{T_{u.l.}}{f_y/\gamma_s}]$$

assume $\phi 16$ used $\Longrightarrow$ $\beta_{cr}=0.75$

$$A_s=\frac{1}{0.75}[\frac{90.56*10^6}{0.826*660*360}+\frac{215.63*10^3}{360/1.15}]$$

$$A_s=1533.67mm^2/m' \Longrightarrow 8\phi 16/m'$$

Sec (2-2) air section

$M_{working}=74.48$ kN.m , $T_{working}=104.38$ kN , b=1000mm

Stage (II) , t=300mm

$M_{u.l.}=1.5*74.48=111.72$ kN.m , $T_{u.l.}=1.5*104.38=156.57$ kN

$$e=\frac{M_{u.l.}}{T_{u.l.}}=\frac{111.72}{156.57}=0.71m > \frac{t}{2} - cover$$

$$e_s=e-\frac{t}{2}+c=0.71-\frac{0.30}{2}+0.04=0.60m$$

$M_{us}=156.57*0.60=93.94kN.m$

$260=C_1\sqrt{\frac{93.94*10^6}{1000*25}} \qquad C_1=4.24 \quad \& \quad J=0.81$

$A_s=\frac{1}{\beta_{cr}}*[\frac{M_{us}}{J*d*f_y}+\frac{T_{u.l.}}{f_y/\gamma_s}]$ assume $\phi16$ used $\Longrightarrow \beta_{cr}=0.93$

$A_s=\frac{1}{0.93}[\frac{93.94*10^6}{0.81*260*360}+\frac{156.57*10^3}{360/1.15}]$

$A_s=1867.95mm^2 \Longrightarrow 10\phi16/m$

Sec (3-3) air section

$M_{working}=27.92\ kN.m \quad , \quad T_{working}=58.36\ kN \quad , \quad b=1000mm$

Stage (II) , $t=300mm$

$M_{u.l.}=1.5*27.92=41.88\ kN.m \quad , \quad T_{u.l.}=1.5*58.36=87.54\ kN$

$e=\frac{M_{u.l.}}{T_{u.l.}}=\frac{41.88}{87.54}=0.48m>\frac{t}{2}-cover$

$e_s=e-\frac{t}{2}+c=0.48-\frac{0.30}{2}+0.04=0.37m$

$M_{us}=87.54*0.37=32.39kN.m$

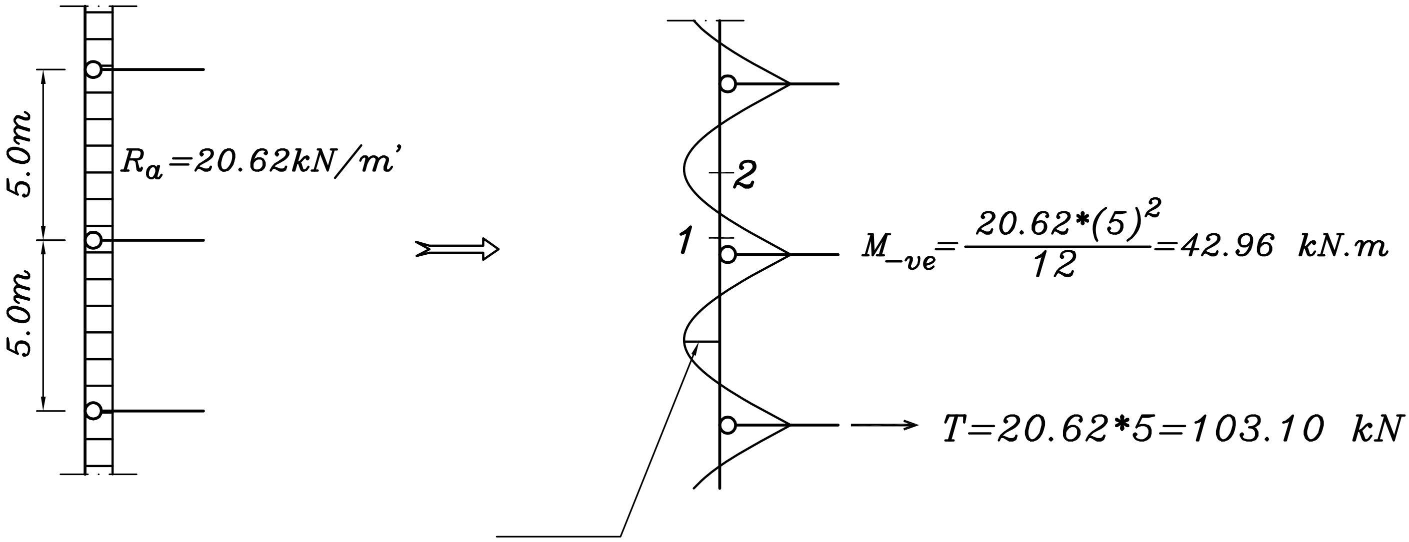
$260=C_1\sqrt{\frac{32.93*10^6}{1000*25}} \qquad C_1=7.16 \quad \& \quad J=0.826$

$A_s=\frac{1}{\beta_{cr}}*[\frac{M_{us}}{J*d*f_y}+\frac{T_{u.l.}}{f_y/\gamma_s}]$ assume $\phi12$ used $\Longrightarrow \beta_{cr}=1.00$

$A_s=\frac{1}{0.93}[\frac{32.93*10^6}{0.826*260*360}+\frac{87.54*10^3}{360/1.15}]$

$A_s=705.57mm^2/m' \Longrightarrow 7\phi12/m'$

5- Design of top hz. beam



$$M_{-ve}=\frac{20.62*(5)^2}{12}=42.96\ kN.m$$

$$T=20.62*5=103.10\ kN$$

$$M_{+ve}=\frac{20.62*(5)^2}{24}=21.48\ kN.m$$

- Design of tie

Stage (I)

$b*t_{(mm)}=1000\ k\ T_{kN}$ assume $b=300mm$

$300\ t\ =1000*0.98*103.10 \Longrightarrow t=336.79\ mm$

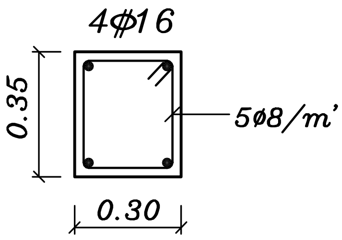
$\Longrightarrow$ Take $t\ =350mm$

Stage (II)

$$A_s=\frac{T_{u.l.}}{\beta_{cr}\cdot(f_y/\gamma_s)}$$ assume $\phi16$ used $\Longrightarrow \beta_{cr}=0.75$

$$A_s=\frac{103.1*1.5*10^3}{0.75*360/1.15}=658.69\ mm^2 \Longrightarrow \text{use}\ 4\phi16$$

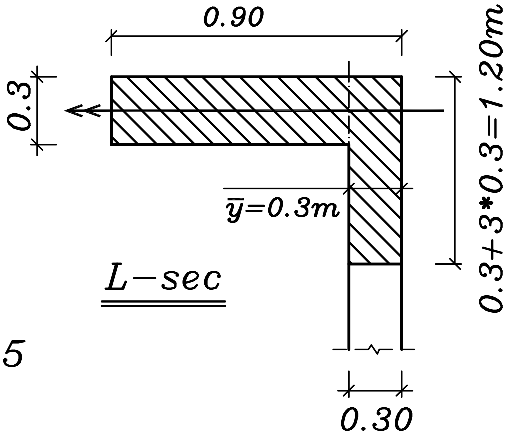
sec. at tie



- Design of beam

Assume $b=300mm$, $t=3t_w=3*300=900mm$

– Case (A)



Sec (1−1) water section

$M_{working}=42.96\ kN.m$

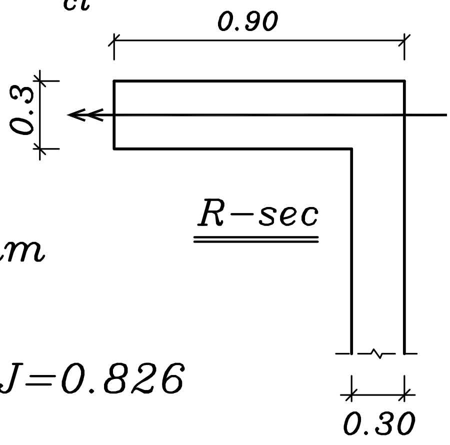
Stage (I) $\frac{t_s}{t}=\frac{0.3}{0.9}=0.33$, $\frac{b}{B}=\frac{0.3}{1.2}=0.25$

Fom charts $\eta=0.33$, $\mu=370$

$\Longrightarrow y=0.30m$, $I=3.24*10^{10}\ mm^4$

Check stresses

$$f_t=+\frac{M\bar{y}}{I}=\frac{42.96*10^6*300}{3.24*10^{10}}=0.40\ N/mm^2 < f_{ct}$$



Stage (II) R−sec:

$M_{u.l.}=1.5*42.96=64.44\ kN.m$, cover=60mm

$840=C_1\sqrt{\frac{64.44*10^6}{300*25}}$ $C_1=9.06$ & $J=0.826$

$A_s=\frac{1}{0.75}\ \frac{64.44*10^6}{0.826*840*360}$ assume $\phi16$ used $\Longrightarrow$ $\beta_{cr}=0.75$

$A_s=343.98mm^2$

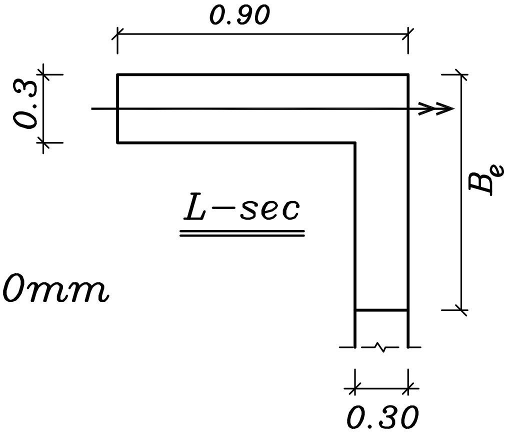
$$A_{s_{min}}=\frac{1.1}{f_y}bd=\frac{1.1}{360}300*840=770.00mm^2>A_s$$

$$A_{s_{min}}=\left|\begin{array}{l}\frac{1.1}{f_y}bd=\frac{1.1}{360}300*840=770.00mm^2\\ 1.3A_{s_{req}}=1.3*343.98=447.17mm^2\\ \frac{0.15}{100}bd=\frac{0.15}{100}300*840=378.00mm^2\end{array}\right.$$

$A_{s_{min}}=447.17mm^2$ $\Longrightarrow$ $4\phi12$

Sec (2−2) air section

$M_{working}=21.48\ kN.m$



Stage (II) L−sec:

$M_{u.l.}=1.5*21.48=32.22\ kN.m$, $cover=60mm$

$$B_e=\left[\begin{array}{l} 6*0.3+0.3=2.10m \\ C.L. \longrightarrow C.L.=\dfrac{H_w}{2}=2.50m \\ \dfrac{kL}{10}+b=\dfrac{0.76*5.0}{10}+0.3=0.68m \end{array}\right. \Longrightarrow \quad take\ B_e=680mm$$

$$840=C_1\sqrt{\frac{32.22*10^6}{680*25}} \qquad C_1=19.3 \quad \& \quad J=0.826$$

$$A_s=\frac{1}{1.00}\ \frac{32.22*10^6}{0.826*840*360} \quad assume\ \phi 12\ used \Longrightarrow \quad \beta_{cr}=1.00$$

$$A_s=128.99mm^2$$

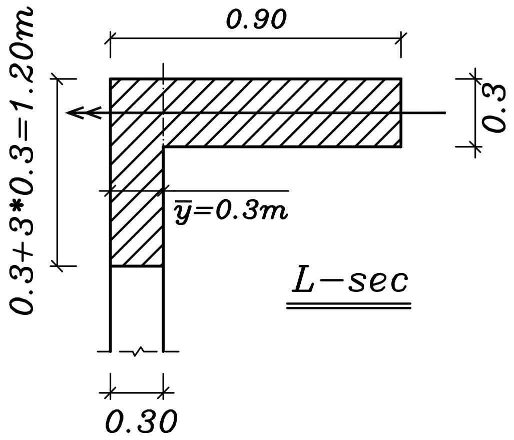
$$A_{s_{min}}=\frac{1.1}{f_y}bd=\frac{1.1}{360}300*840\ =770.00mm^2>A_s$$

$$A_{s_{min}}=\left|\begin{array}{l} \dfrac{1.1}{f_y}bd=\dfrac{1.1}{360}300*840=770.00mm^2 \\ 1.3A_{s_{req}}=1.3*128.99=167.69mm^2 \\ \dfrac{0.15}{100}bd=\dfrac{0.15}{100}300*840=378.00mm^2 \end{array}\right.$$

$$A_{s_{min}}=378.00mm^2 \Longrightarrow \quad 4\phi 12$$

– Case (B)

Sec (1–1) water section



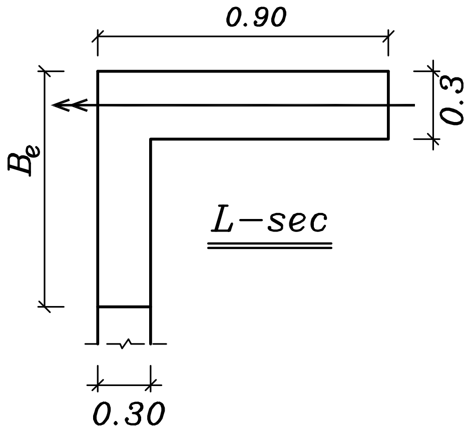
$M_{working}=42.96\ kN.m$

Stage (I)

Check stresses

$$f_t = \frac{M(t-\bar{y})}{I} = \frac{42.96*10^6*600}{3.24*10^{10}} = 0.80\ N/mm^2 < f_{ct}$$

Stage (II) L–sec:



$M_{u.l.}=1.5*42.96=64.44\ kN.m$

, cover=60mm , B_e =680mm (as before)

$$840=C_1\sqrt{\frac{64.44*10^6}{680*25}} \qquad C_1=13.6 \quad \& \quad J=0.826$$

$$A_s=\frac{1}{0.85}\ \frac{64.44*10^6}{0.826*840*360}$$ assume $\phi 12$ used $\Longrightarrow$ $\beta_{cr}=0.85$

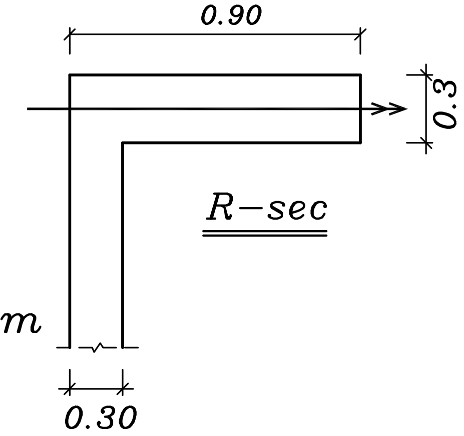
$$A_s=303.51mm^2$$

$$A_{s_{min}}=\frac{1.1}{f_y}bd=\frac{1.1}{360}300*840=770.00mm^2 > A_s$$

$$A_{s_{min}}=\left[\begin{array}{l} \frac{1.1}{f_y}\ bd = \frac{1.1}{360}\ 300*830=770.00mm^2 \\ 1.3A_{s_{req}}=1.3*303.51=394.60mm^2 \\ \frac{0.15}{100}\ bd = \frac{0.15}{100}\ 300*840=378.00mm^2 \end{array}\right.$$

$A_{s_{min}}=394.60mm^2 \Longrightarrow 4\phi 12$

Sec (2−2) air section



$M_{working}=21.48\ kN.m$

Stage (II) R−sec:

$M_{u.l.}=1.5*21.48=32.22\ kN.m$, cover=60mm

$$840=C_1\sqrt{\frac{32.22*10^6}{300*25}} \qquad C_1=12.8 \quad \& \quad J=0.826$$

$$A_s=\frac{1}{1.00}\frac{32.22*10^6}{0.826*840*360} \text{ assume } \phi 12 \text{ used} \Longrightarrow \beta_{cr}=1.00$$

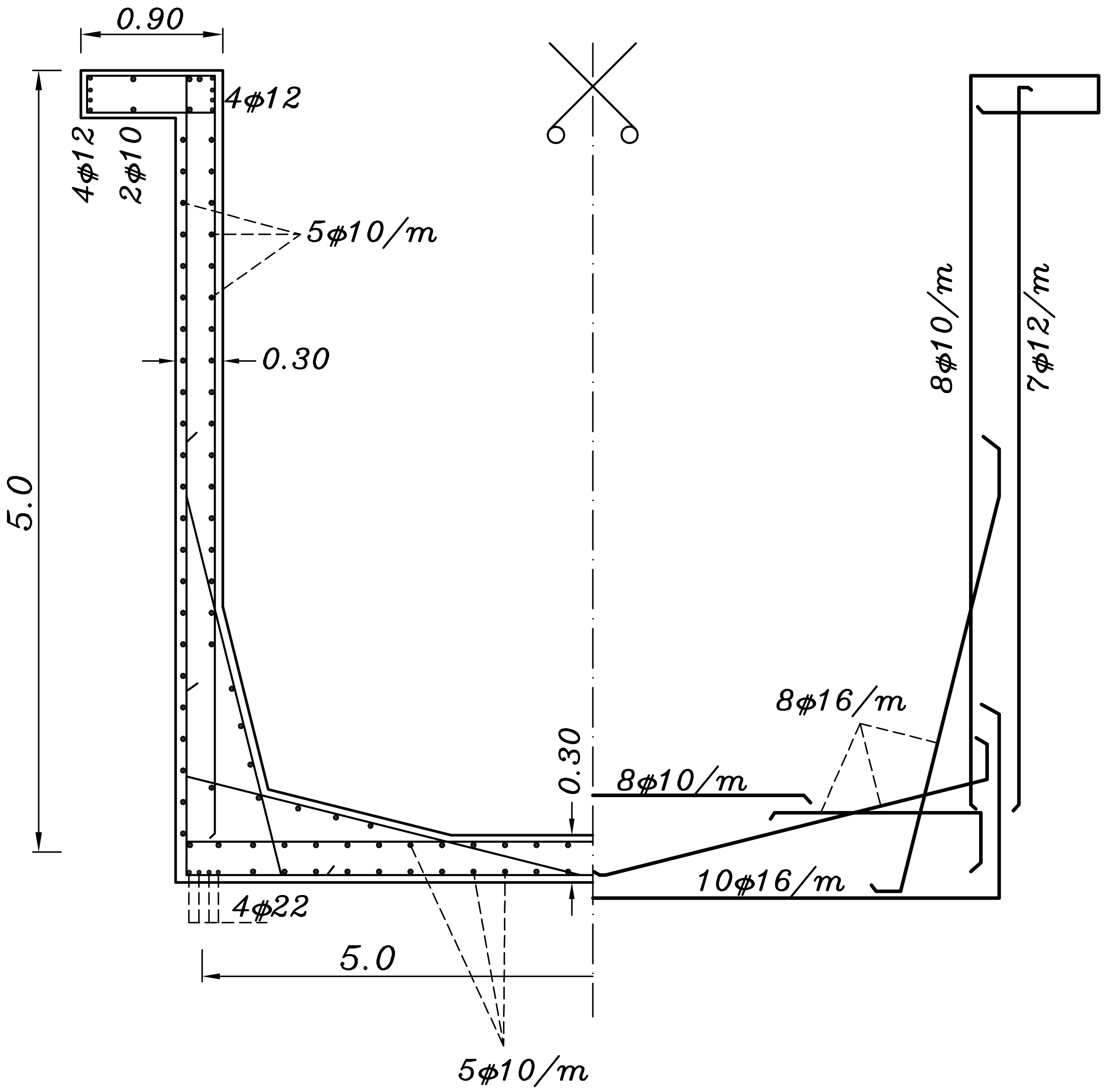
$$A_s=128.99mm^2$$

$$A_{s_{min}}=\frac{1.1}{f_y}bd=\frac{1.1}{360}300*840=770.00mm^2>A_s$$

$$A_{s_{min}}=\left[\begin{array}{l}\frac{1.1}{f_y}bd=\frac{1.1}{360}300*840=770.00mm^2\\ 1.3A_{s_{req}}=1.3*128.99=167.69mm^2\\ \frac{0.15}{100}bd=\frac{0.15}{100}300*840=378.00mm^2\end{array}\right.$$

$$A_{s_{min}}=378.00mm^2 \Longrightarrow 4\phi 12$$

Details of RFT.



Example(3)

Given:

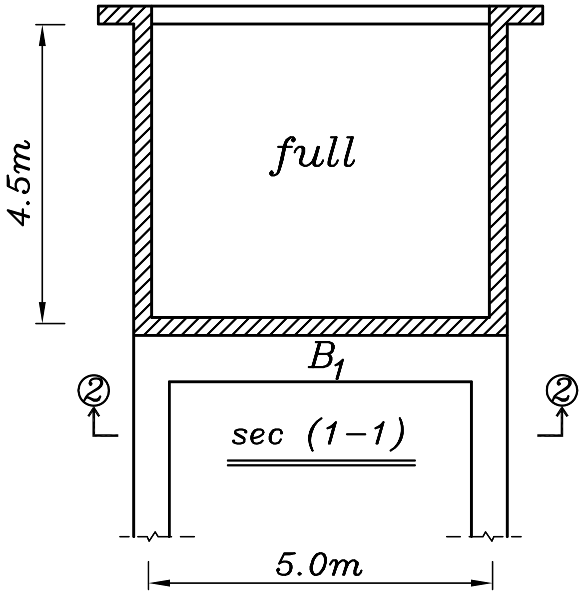
$f_{cu}=25\ N/mm^2$ &

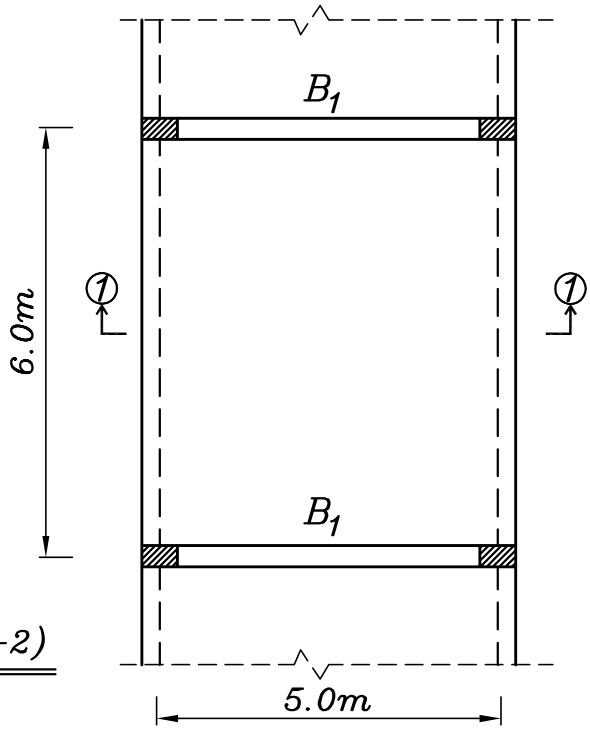
steel used is 360/520

Required

1 – Design the given tank.

2 – Calculate the loads acting on the floor beam (B_1)





sec (2–2)

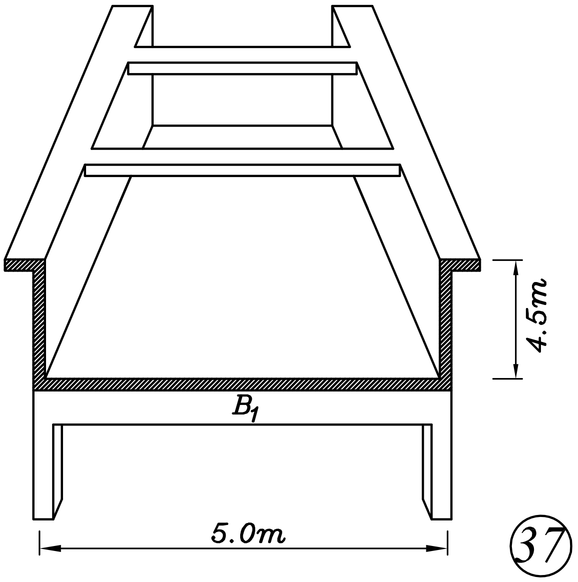
Solution

1 – Concrete dimensions

$$t_w=\frac{h}{16}=\frac{450}{16}=28.13cm$$

$$t_f=\frac{L}{16}=\frac{500}{16}=31.25cm$$

$\Longrightarrow$ Take $t_w=t_f=30cm$



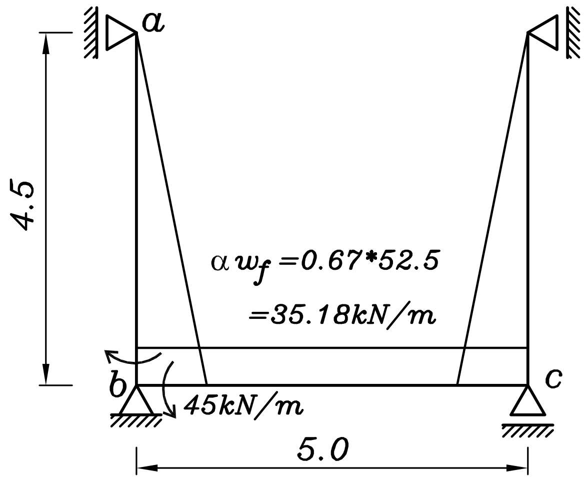
2− Loads on floor

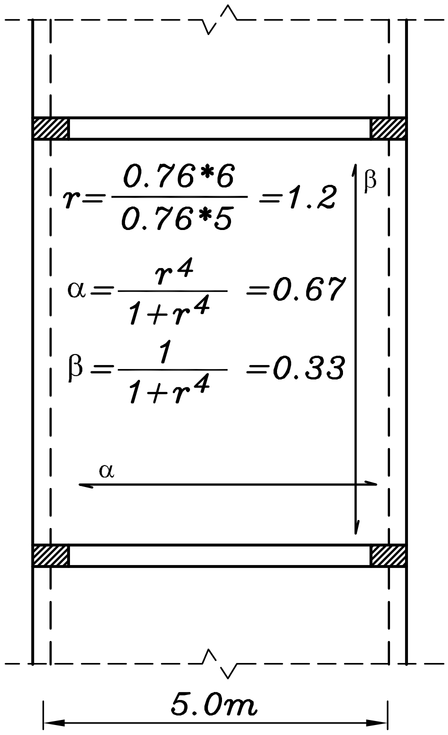
$$w_f = t_f \gamma_c + \gamma_w h = 0.30*25 + 10*4.5$$

$$w_f = 52.50 \ \ kN/m^2$$

3− Analysis of strips

− strip (1)





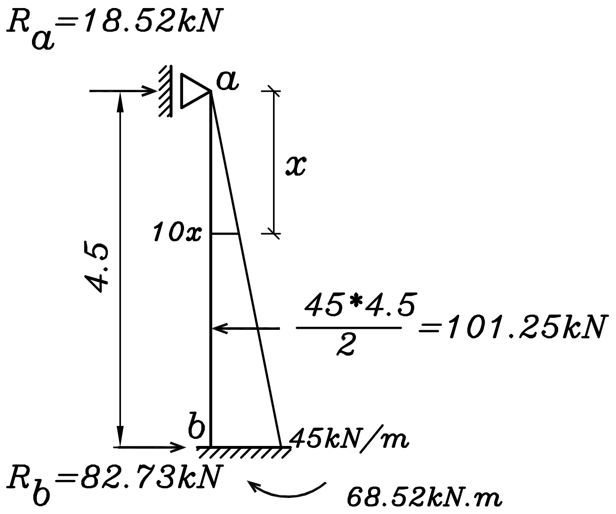
For Joint b

$$D.f_{ba} = \frac{0.75(I/4.5)}{0.75(I/4.5)+0.5(I/5)} = 0.62$$

$$D.f_{bc} = \frac{0.5(I/5)}{0.75(I/4.5)+0.5(I/5)} = 0.38$$

$$F.E.M._{ba} = \frac{45*(4.5)^2}{15} = 60.75kN.m \ , \ F.E.M._{bc} = \frac{-35.18*(5)^2}{12} = -73.29kN.m$$

Joint	b	
member	ba	bc
D.f.	0.62	0.38
F.E.M.	60.75	−73.29
Bal.M.	7.77	4.77
M_f	68.52	−68.52

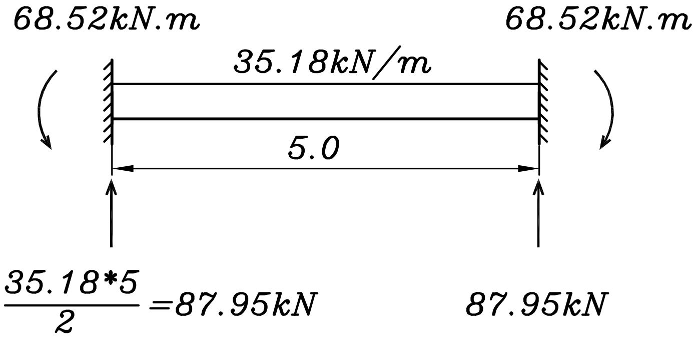


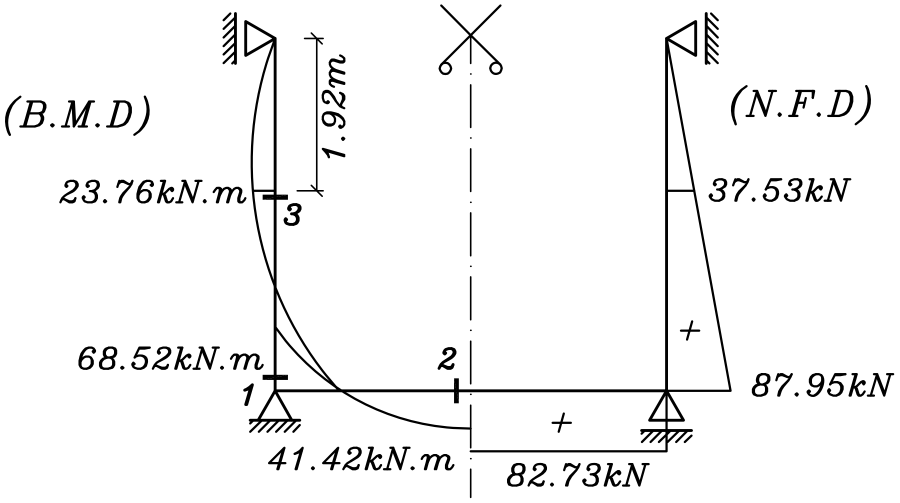
Point of zero shear

$$(10x)*\frac{x}{2}=18.52 \Longrightarrow x=1.92m$$

$$\Longrightarrow M_{+ve}=18.52x-(10x)*(\frac{x^2}{6})$$

$$M_{+ve}=23.76\ kN.m$$





4- Design of sections

Sec (1-1) water section

$M_{working}$=68.52 kN.m , $T_{working}$=87.95 kN , b=1000mm

Stage (I)

$$t_{(mm)}=\sqrt{\frac{M*10^3}{factor}}+40mm=\sqrt{\frac{68.52*10^3}{0.28}}+40mm=534.69mm$$

$\Longrightarrow$ Take t =550mm

Check stresses

$$f_t = + \frac{T}{A} + \frac{M}{Z} = + \frac{87.95*10^3}{1000*550} + \frac{68.52*10^6}{1000*(550)^2/6}$$

$$= 0.16 + 1.36 = 1.52 \ N/mm^2$$

$$\Longrightarrow f_{ct} = \frac{0.6\sqrt{25}}{1.7} = 1.76 N/mm^2 \quad \Longrightarrow f_t < f_{ct} \quad (safe)$$

Stage (II)

$$M_{u.l.} = 1.5*68.52 = 102.78 \ kN.m \quad , \quad T_{u.l.} = 1.5*87.95 = 131.93 \ kN$$

$$e = \frac{M_{u.l.}}{T_{u.l.}} = \frac{102.78}{131.93} = 0.78m > \frac{t}{2} - cover$$

$$e_s = e - \frac{t}{2} + c = 0.78 - \frac{0.55}{2} + 0.04 = 0.54m$$

$$M_{us} = 131.93*0.54 = 71.78 kN.m$$

$$510 = C_1 \sqrt{\frac{71.78*10^6}{1000*25}} \qquad C_1 = 9.52 \quad \& \quad J = 0.826$$

$$A_s = \frac{1}{\beta_{cr}} * [\frac{M_{us}}{J*d*f_y} + \frac{T_{u.l.}}{f_y/\gamma_s}]$$

$$\text{assume } \phi 16 \text{ used} \Longrightarrow \quad \beta_{cr} = 0.75$$

$$A_s = \frac{1}{0.75} [\frac{71.78*10^6}{0.826*510*360} + \frac{131.93*10^3}{360/1.15}]$$

$$A_s = 1193.01 mm^2/m' \Longrightarrow 6\phi 16/m'$$

Sec (2-2) air section

$$M_{working} = 41.42 \ kN.m \ , \quad T_{working} = 82.73 \ kN \quad , \quad b = 1000mm$$

Stage (II) , t=300mm

$$M_{u.l.}=1.5*41.42=62.13 \ kN.m \quad , \quad T_{u.l.}=1.5*82.73=124.10 \ kN$$

$$e=\frac{M_{u.l.}}{T_{u.l.}}=\frac{62.13}{124.10}=0.50m > \frac{t}{2} \ -cover$$

$$e_s=e-\frac{t}{2}+c=0.50-\frac{0.30}{2}+0.04=0.39m$$

$$M_{us}=124.10*0.39=48.40kN.m$$

$$260=C_1\sqrt{\frac{48.40*10^6}{1000*25}} \qquad C_1=5.91 \quad \& \quad J=0.826$$

$$A_s=\frac{1}{\beta_{cr}}*[\frac{M_{us}}{J*d*f_y}+\frac{T_{u.l.}}{f_y/\gamma_s}] \text{ assume } \phi 16 \text{ used} \Longrightarrow \quad \beta_{cr}=0.93$$

$$A_s=\frac{1}{0.93}[\frac{48.40*10^6}{0.826*260*360}+\frac{124.10*10^3}{360/1.15}]$$

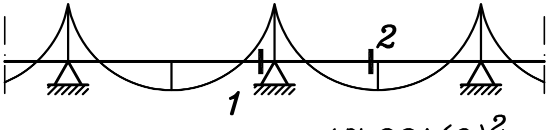
$$A_s=1099.41mm^2/m' \Longrightarrow 6\phi 16/m'$$

Sec (3-3) air section

$$A_s=5\phi 12/m$$

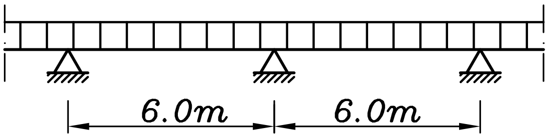
- strip (2)

$$M_{-ve}=\frac{17.33*(6)^2}{12}=51.99 \ kN.m$$



$$M_{+ve}=\frac{17.33*(6)^2}{24}=26 \ kN.m$$

$$\beta w_f=0.33*52.5$$
$$=17.33kN/m$$



Sec (1-1) water section

$$M_{working}=51.99 \ kN.m, \quad b=1000mm$$

Stage (I)

$$t_{(mm)}=\sqrt{\frac{M*10^3}{factor}}=\sqrt{\frac{51.99*10^3}{0.28}}=430.90mm$$

$\Longrightarrow$ Take t =450mm

Check stresses

$$f_t=+\frac{M}{Z}=+\frac{51.99*10^6}{1000*(450)^2/6}=1.54\ N/mm^2$$

$$\Longrightarrow f_{ct}=\frac{0.6\sqrt{25}}{1.7}=1.76N/mm^2 \quad \Longrightarrow f_t < f_{ct} \quad (safe)$$

Stage (II)

$M_{u.l.}=1.5*51.99=77.99\ kN.m$, cover=50mm at long direction

$$400=C_1\sqrt{\frac{77.99*10^6}{1000*25}} \qquad C_1=7.16 \quad \& \quad J=0.826$$

$$A_s=\frac{1}{0.85}\frac{77.99*10^6}{0.826*400*360}$$ assume $\phi 12$ used $\Longrightarrow \beta_{cr}=0.85$

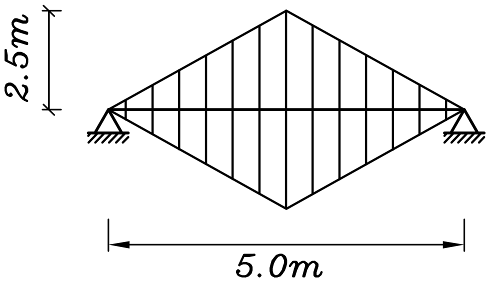
$A_s=771.40mm^2/m' \Longrightarrow 7\phi 12/m'$

Sec (2-2) air section

$A_s=5\phi 12/m$

– For beam B_1

Assume beam is (300*900)

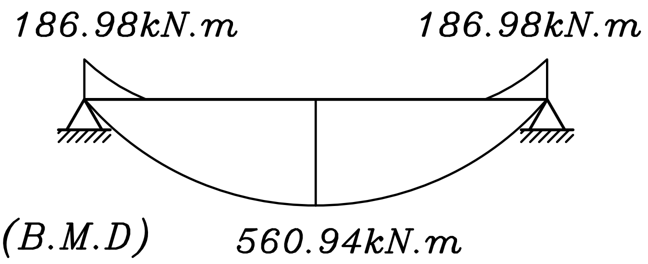


– Load for moment

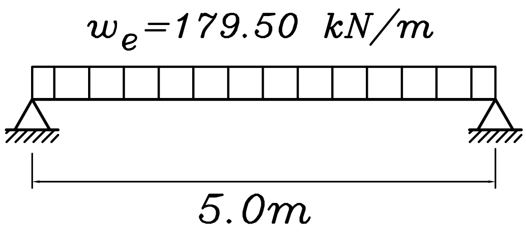
$$w_e = o.w. + c_e \frac{L_s}{2} .w_f *2$$

$$w_e = 0.3*(0.9-0.30)*25+2/3*5/2*52.50*2$$

$$w_e = 179.50 \;\; kN/m$$



(B.M.D)

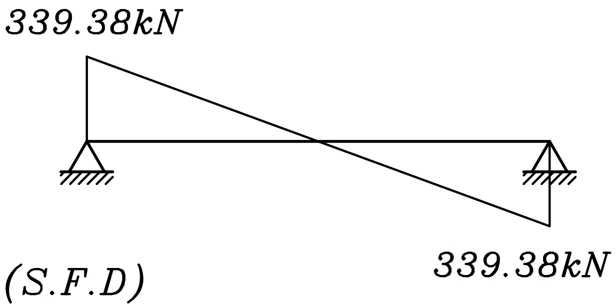


– Load for shear

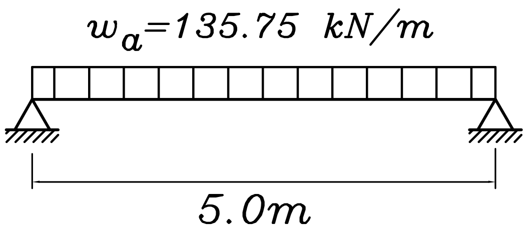
$$w_e = o.w. + c_a \frac{L_s}{2} .w_f *2$$

$$w_e = 0.3*(0.9-0.30)*25+1/2*5/2*52.50*2$$

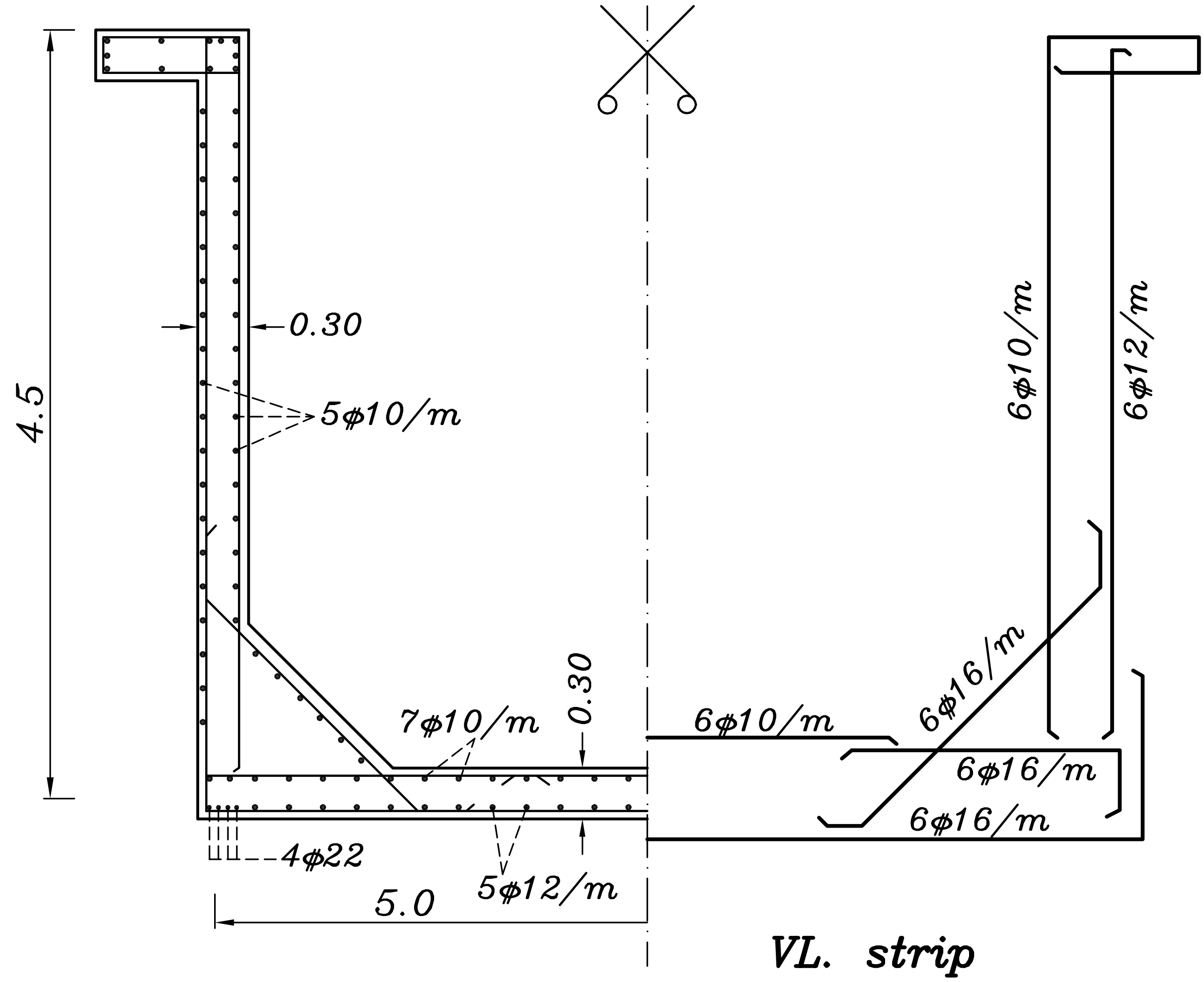
$$w_e = 135.75 \;\; kN/m$$



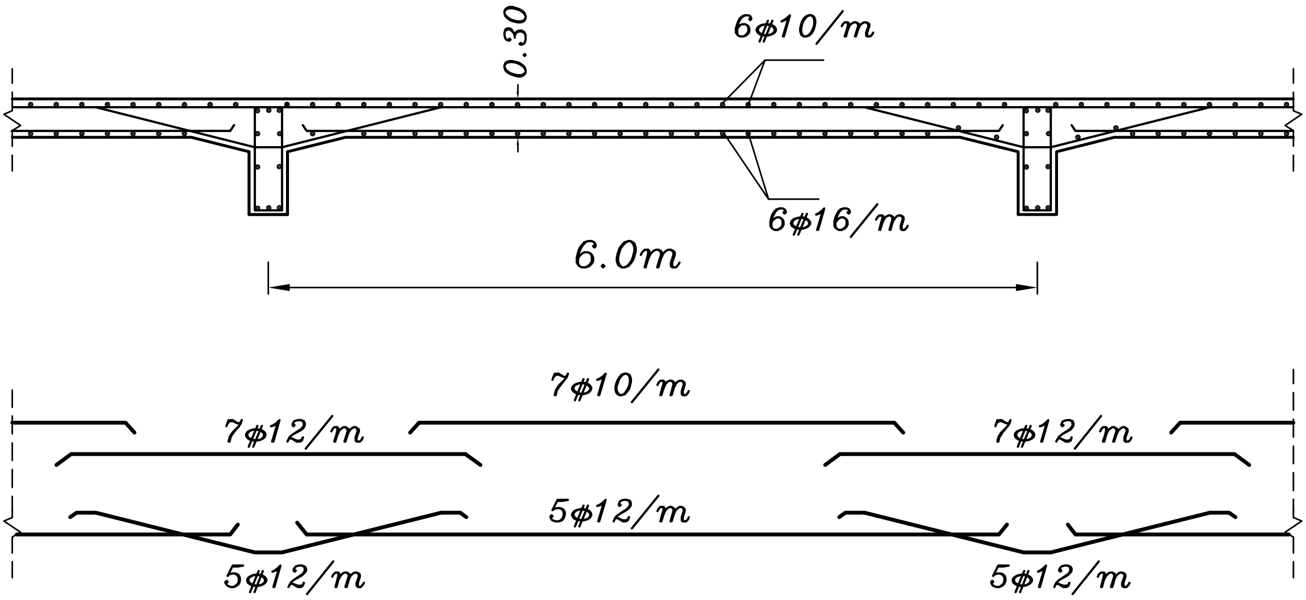
(S.F.D)



Details of RFT.



VL. strip



Hz. strip

Example(4)

Given:

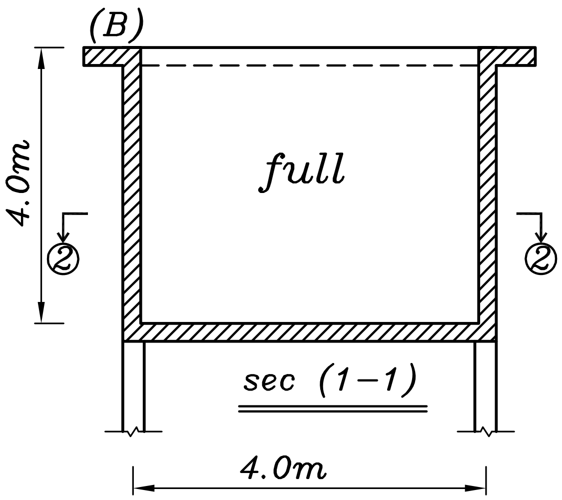
$f_{cu}=25\ N/mm^2$ &

steel used is 360/520

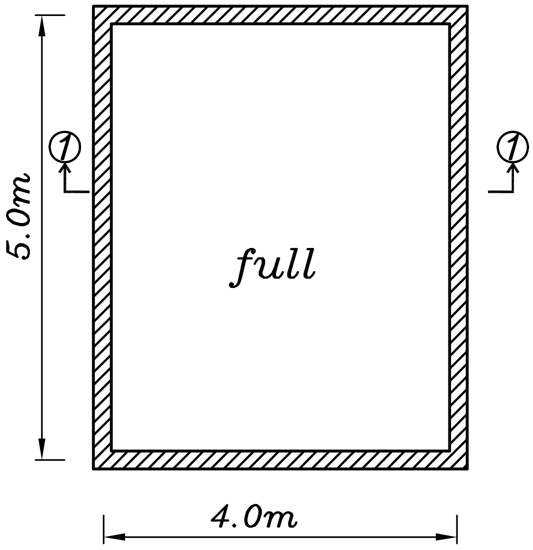
Required

1−Design the given tank.

2−Calculate the loads acting on the top hz. beam (B)



sec (1−1)



sec (2−2)

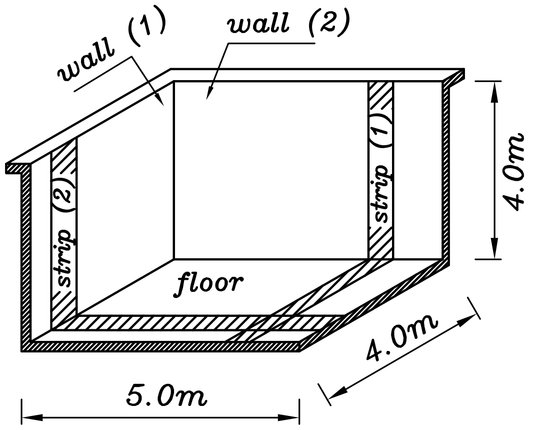
Solution

1− Concrete dimensions

$$t_w=t_f=\frac{L_s}{16}=\frac{400}{16}=25cm$$

$\Longrightarrow$ Take $t_w=t_f=25cm$

2− Loads on floor



$$w_f=t_f\gamma_c+\gamma_w h=0.25*25+10*4.0$$

$$w_f=46.25\ kN/m^2$$

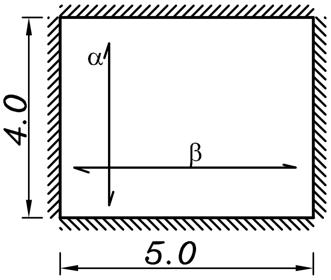
3– Load distribution

– Floor (4.0*5.0)

$$r=\frac{0.76*5}{0.76*4}=1.25$$

$$\alpha=\frac{r^4}{1+r^4}=0.71$$

$$\beta=\frac{1}{1+r^4}=0.29$$

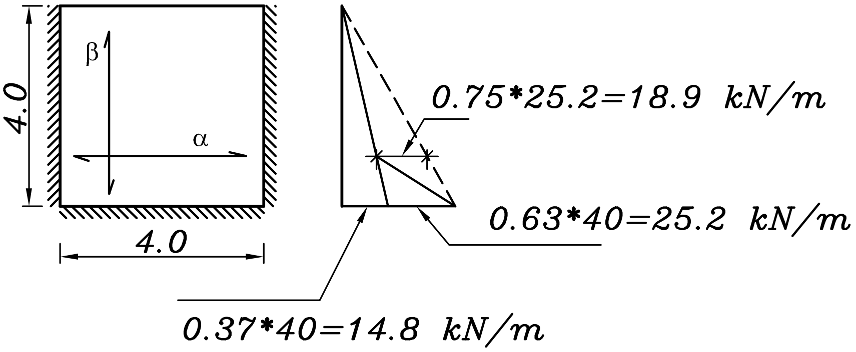


– Wall (1) (4.0*4.0)

$$r=\frac{0.87*4}{0.76*4}=1.14$$

$$\alpha=\frac{r^4}{1+r^4}=0.63$$

$$\beta=\frac{1}{1+r^4}=0.37$$

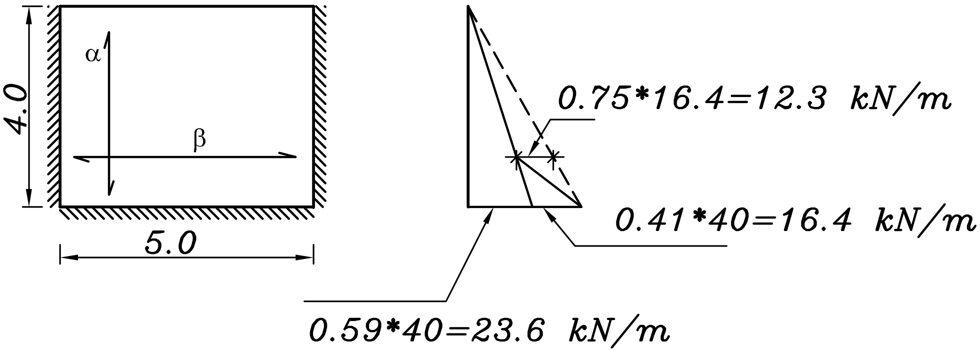


– Wall (2) (5.0*4.0)

$$r=\frac{0.76*5}{0.87*4}=1.09$$

$$\alpha=\frac{r^4}{1+r^4}=0.59$$

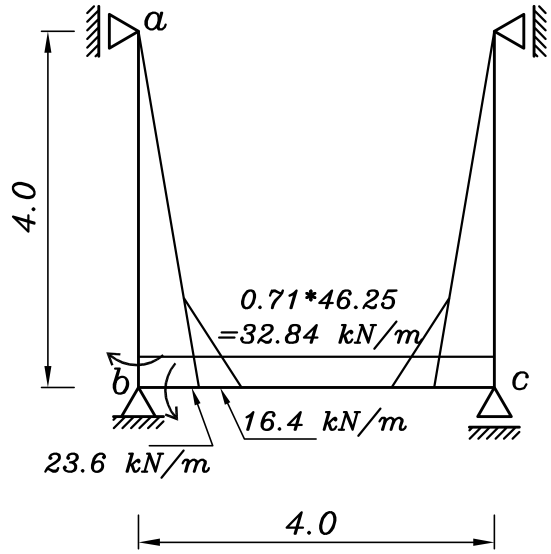
$$\beta=\frac{1}{1+r^4}=0.41$$



4– Analysis of strips

– VL. strip (1)

– VL. strip (1)



For Joint b

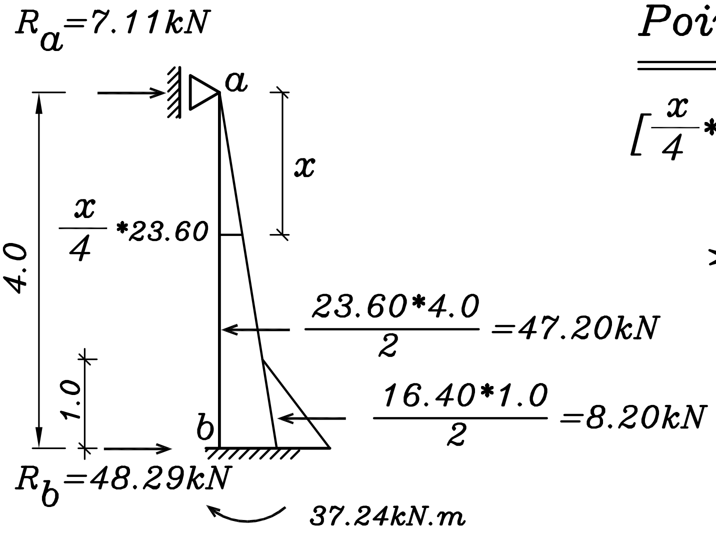
$$D.f_{ba} = \frac{0.75(I/4.0)}{0.75(I/4.0)+0.5(I/4.0)} = 0.60$$

$$D.f_{bc} = \frac{0.5(I/4.0)}{0.75(I/4.0)+0.5(I/4.0)} = 0.40$$

$$F.E.M._{ba} = \frac{23.60*(4)^2}{15} + \frac{16.40*(4)^2}{117} = 27.42kN.m$$

$$F.E.M._{bc} = \frac{-32.84*(4)^2}{12} = -43.79kN.m$$

Joint	b	
member	ba	bc
D.f.	0.60	0.40
F.E.M.	27.42	−43.79
Bal.M.	9.82	6.55
M_f	37.24	−37.24

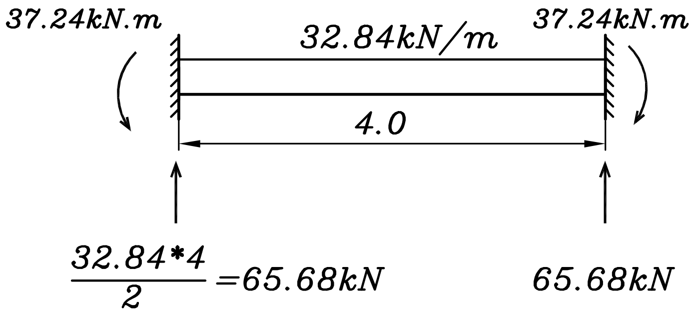


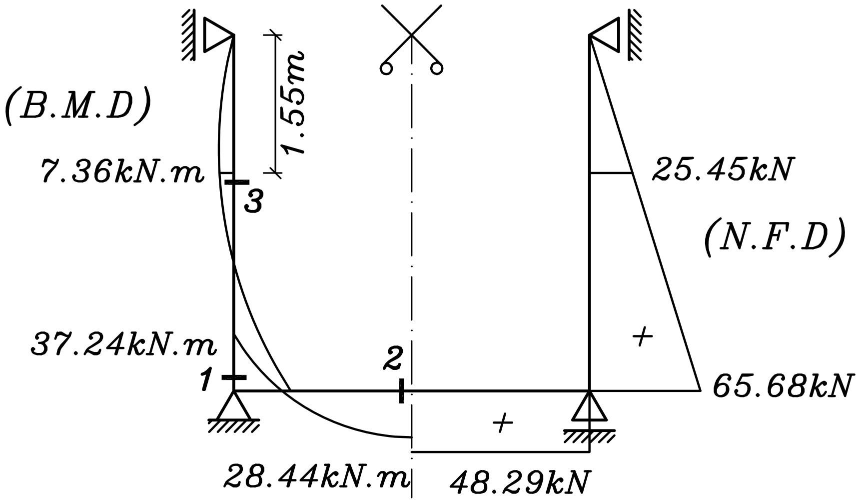
Point of zero shear

$$[\frac{x}{4}*23.60]*\frac{x}{2} = 7.11 \Longrightarrow x = 1.55m$$

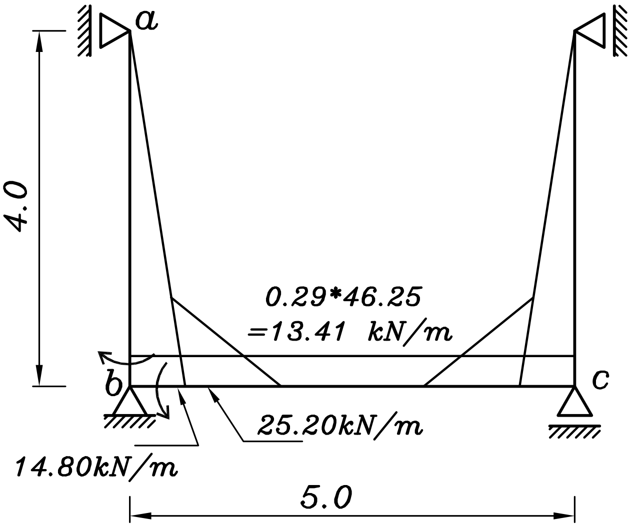
$$\Longrightarrow M_{+ve} = 7.11x - (\frac{x}{4}*23.60)*(\frac{x^2}{6})$$

$$M_{+ve} = 7.36 \ kN.m$$





– VL. strip (2)



For Joint b

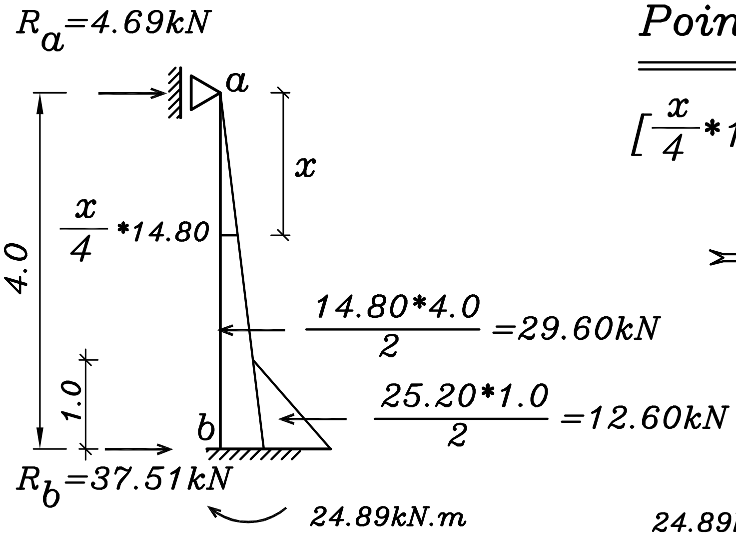
$$D.f_{ba}=\frac{0.75(I/4.0)}{0.75(I/4.0)+0.5(I/4.0)}=0.65$$

$$D.f_{bc}=\frac{0.5(I/4.0)}{0.75(I/4.0)+0.5(I/4.0)}=0.35$$

$$F.E.M._{ba}=\frac{14.80*(4)^2}{15}+\frac{25.20*(4)^2}{117}=19.23kN.m$$

$$F.E.M._{bc}=\frac{-13.41*(4)^2}{12}=-27.94kN.m$$

Joint	b	
member	ba	bc
D.f.	0.65	0.35
F.E.M.	19.23	−27.94
Bal.M.	5.66	3.05
M_f	24.89	−24.89

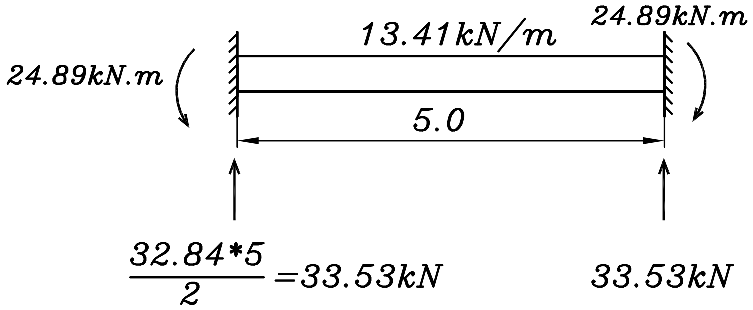


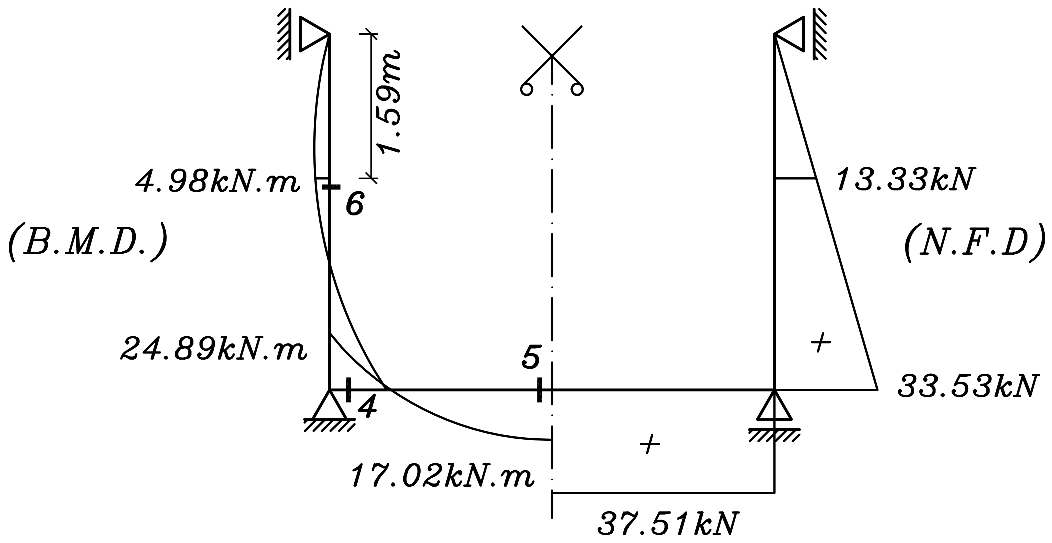
Point of zero shear

$$[\frac{x}{4}*14.80]*\frac{x}{2}=4.69 \Longrightarrow x=1.59m$$

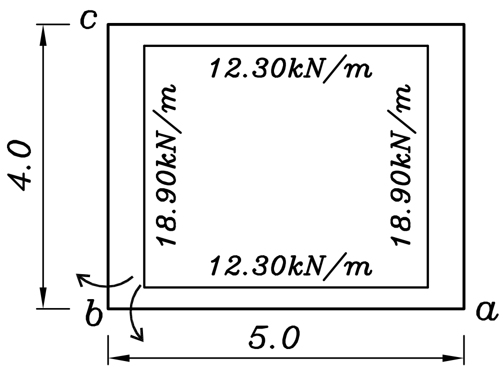
$$\Longrightarrow M_{+ve}=4.69x-(\frac{x}{4}*14.80)*(\frac{x^2}{6})$$

$$M_{+ve}=4.98\ kN.m$$





– HZ. strip (3) at (h/4)



For Joint b

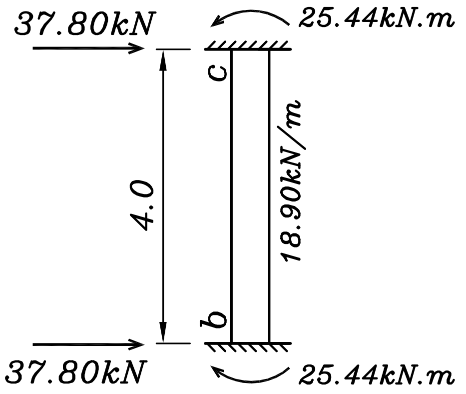
$$D.f_{ba} = \frac{0.5(I/5.0)}{0.5(I/5.0)+0.5(I/4.0)} = 0.44$$

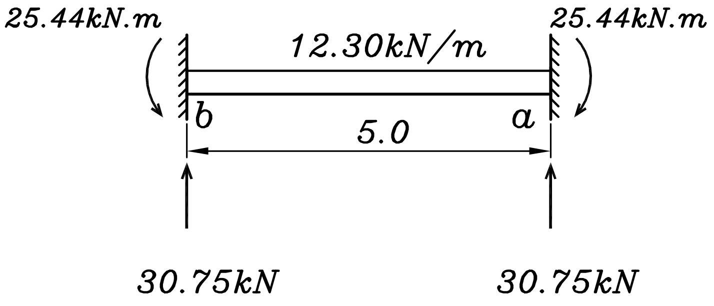
$$D.f_{bc} = \frac{0.5(I/4.0)}{0.5(I/5.0)+0.5(I/4.0)} = 0.56$$

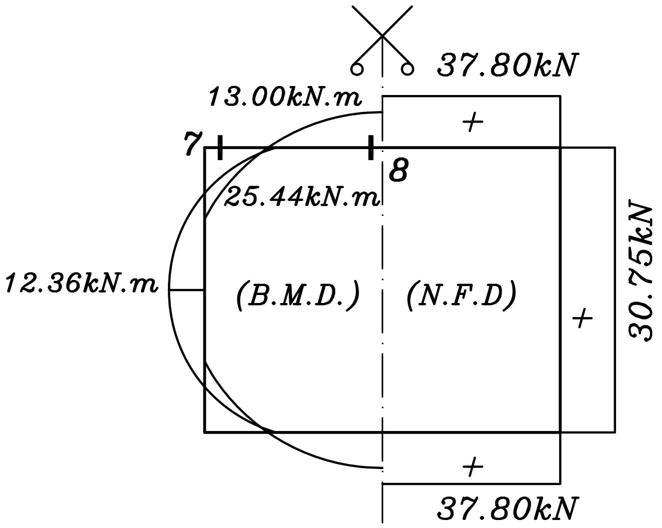
$$F.E.M._{ba} = \frac{-12.3*(5.0)^2}{12} = -25.63kN.m$$

$$F.E.M._{bc} = \frac{18.9*(4.0)^2}{12} = 25.20kN.m$$

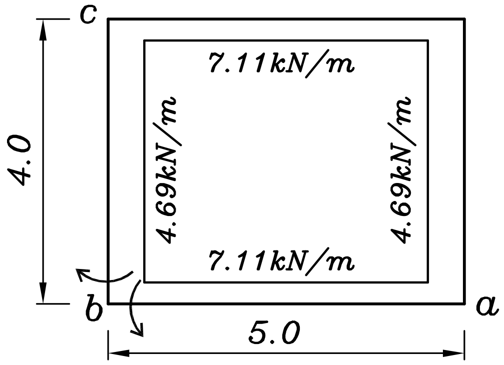
Joint	b	
member	ba	bc
D.f.	0.44	0.56
F.E.M.	−25.63	25.20
Bal.M.	0.19	0.24
M_f	−25.44	25.44







– Loads on top hz. beam



For Joint b

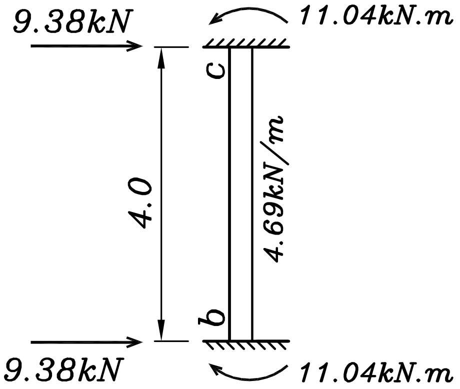
$$D.f_{ba}=\frac{0.5(I/5.0)}{0.5(I/5.0)+0.5(I/4.0)}=0.44$$

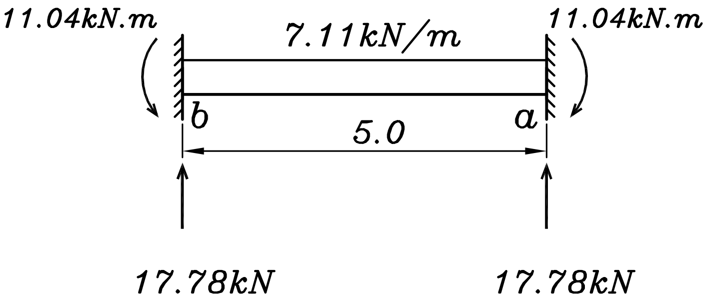
$$D.f_{bc}=\frac{0.5(I/4.0)}{0.5(I/5.0)+0.5(I/4.0)}=0.56$$

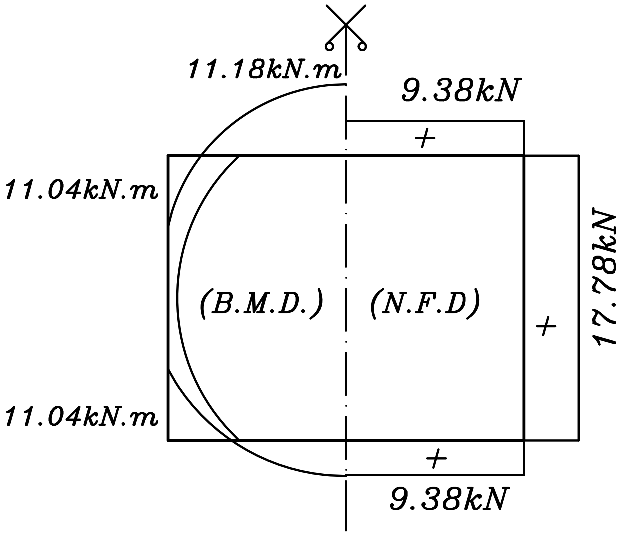
$$F.E.M._{ba}=\frac{-7.11*(5.0)^2}{12}=-14.81kN.m$$

$$F.E.M._{bc}=\frac{4.69*(4.0)^2}{12}=6.25kN.m$$

Joint	b	
member	ba	bc
D.f.	0.44	0.56
F.E.M.	−14.81	6.25
Bal.M.	3.77	4.79
M_f	−11.04	11.04







5- Design of sections

Sec (1-1) water section

$M_{working}=37.24\ kN.m\ ,\quad T_{working}=65.68\ kN\quad ,\quad b=1000mm$

Stage (I)

$$t_{(mm)}=\sqrt{\frac{M*10^{3}}{factor}}+40mm=\sqrt{\frac{37.24*10^{3}}{0.30}}+40mm=392.33mm$$

$\Longrightarrow$ Take t =400mm

Check stresses

$$f_t=+\frac{T}{A}+\frac{M}{Z}=+\frac{65.68*10^{3}}{1000*400}+\frac{37.24*10^{6}}{1000*(400)^2/6}$$

$$=0.16+1.40=1.56\ N/mm^2$$

$$\Longrightarrow f_{ct}=\frac{0.6\sqrt{25}}{1.7}=1.76N/mm^2\quad\Longrightarrow f_t<f_{ct}\quad (safe)$$

Stage (II)

$M_{u.l.}=1.5*37.24=55.86\ kN.m\quad ,\ T_{u.l.}=1.5*65.68=98.52\ kN$

$$e=\frac{M_{u.l.}}{T_{u.l.}}=\frac{55.86}{98.52}=0.57m>\frac{t}{2}\ -cover$$

$$e_s=e-\frac{t}{2}+c=0.57-\frac{0.40}{2}+0.04=0.41m$$

$M_{us}=98.52*0.41=40.39kN.m$

$$360=C_1\sqrt{\frac{40.39*10^{6}}{1000*25}}\qquad C_1=8.96\quad \&\quad J=0.826$$

$$A_s=\frac{1}{\beta_{cr}}*[\frac{M_{us}}{J*d*f_y}+\frac{T_{u.l.}}{f_y/\gamma_s}]$$

assume $\phi 12$ used $\Longrightarrow$ $\beta_{cr} = 0.85$

$$A_s = \frac{1}{0.85}\left[\frac{40.39*10^6}{0.826*360*360} + \frac{98.52*10^3}{360/1.15}\right]$$

$$A_s = 814.14 mm^2/m' \Longrightarrow 8\phi 12/m'$$

Sec (2-2) air section

$M_{working} = 28.44$ kN.m , $T_{working} = 48.29$ kN , $b = 1000mm$

Stage (II) , t=250mm

$M_{u.l.} = 1.5*28.44 = 42.66$ kN.m , $T_{u.l.} = 1.5*48.29 = 72.44$ kN

$$e = \frac{M_{u.l.}}{T_{u.l.}} = \frac{42.66}{72.44} = 0.59m > \frac{t}{2} - cover$$

$$e_s = e - \frac{t}{2} + c = 0.59 - \frac{0.25}{2} + 0.04 = 0.50m$$

$$M_{us} = 72.44*0.50 = 36.22kN.m$$

$$210 = C_1 \sqrt{\frac{36.22*10^6}{1000*25}} \qquad C_1 = 5.52 \quad \& \quad J = 0.826$$

$$A_s = \frac{1}{\beta_{cr}}*\left[\frac{M_{us}}{J*d*f_y} + \frac{T_{u.l.}}{f_y/\gamma_s}\right]$$ assume $\phi 12$ used $\Longrightarrow$ $\beta_{cr} = 1.00$

$$A_s = \frac{1}{1.00}\left[\frac{36.22*10^6}{0.826*210*360} + \frac{72.44*10^3}{360/1.15}\right]$$

$$A_s = 811.43 mm^2/m' \Longrightarrow 8\phi 12/m'$$

Sec (3-3) air section

$$A_s = 5\phi 12/m'$$

Sec (4−4) water section

$M_{working}=24.89\ kN.m$, $T_{working}=37.51\ kN$, $b=1000mm$

Stage (I)

$$t_{(mm)}=\sqrt{\frac{M*10^3}{factor}}+40mm=\sqrt{\frac{24.89*10^3}{0.30}}+40mm=328.04mm$$

$\Longrightarrow$ Take $t=350mm$

Check stresses

$$f_t=+\frac{T}{A}+\frac{M}{Z}=+\frac{37.51*10^3}{1000*350}+\frac{24.89*10^6}{1000*(350)^2/6}$$

$$=0.11+1.22=1.33\ N/mm^2$$

$$t_v=350[1+\frac{0.13}{1.22}]=387mm \Longrightarrow f_{ct}=\frac{0.6\sqrt{25}}{1.6}=1.88N/mm^2$$

$$\Longrightarrow f_t < f_{ct} \quad (safe)$$

Stage (II)

$M_{u.l.}=1.5*24.89=37.34\ kN.m$, $T_{u.l.}=1.5*37.51=56.27\ kN$

$A_s=6\phi 12/m'$

Sec (5−5) & (6−6) air section

$A_s=5\phi 12/m$

Sec (7–7) water section

$M_{working}=25.44\ kN.m$, $T_{working}=37.80\ kN$, $b=1000mm$

Stage (I)

$$t_{(mm)}=\sqrt{\frac{M*10^3}{factor}}+40mm=\sqrt{\frac{25.44*10^3}{0.30}}+40mm=331.20mm$$

$\Longrightarrow$ Take $t=350mm$

Check stresses

$$f_t=+\frac{T}{A}+\frac{M}{Z}=+\frac{37.80*10^3}{1000*350}+\frac{25.44*10^6}{1000*(350)^2/6}$$

$$=0.11+1.25=1.36\ N/mm^2$$

$$t_v=350[1+\frac{0.11}{1.25}]=381mm \Longrightarrow f_{ct}=\frac{0.6\sqrt{25}}{1.6}=1.88N/mm^2$$

$$\Longrightarrow f_t < f_{ct} \quad (safe)$$

Stage (II)

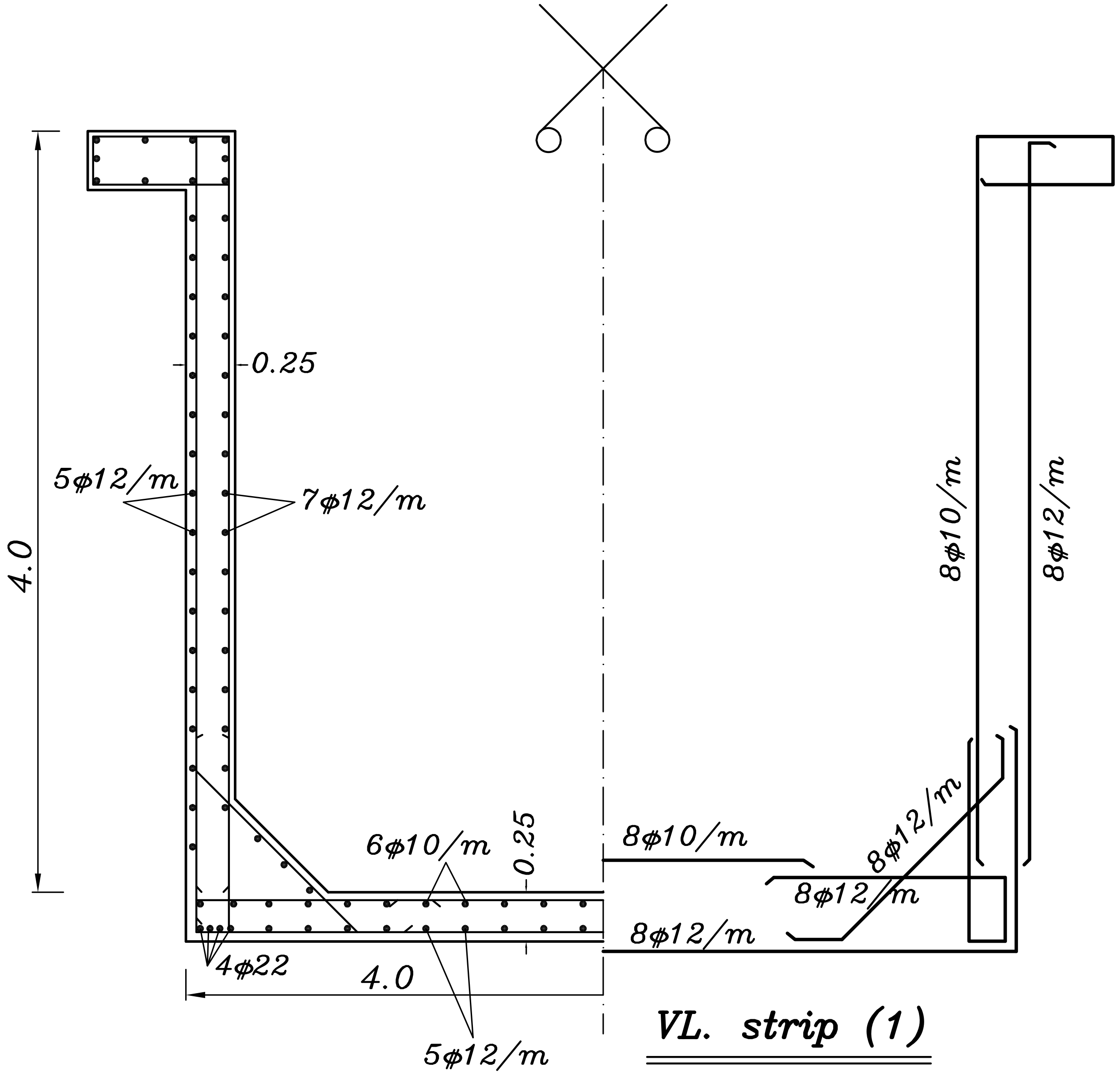
$M_{u.l.}=1.5*25.44=38.16\ kN.m$, $T_{u.l.}=1.5*37.80=56.70\ kN$

$A_s=7\phi12/m'$

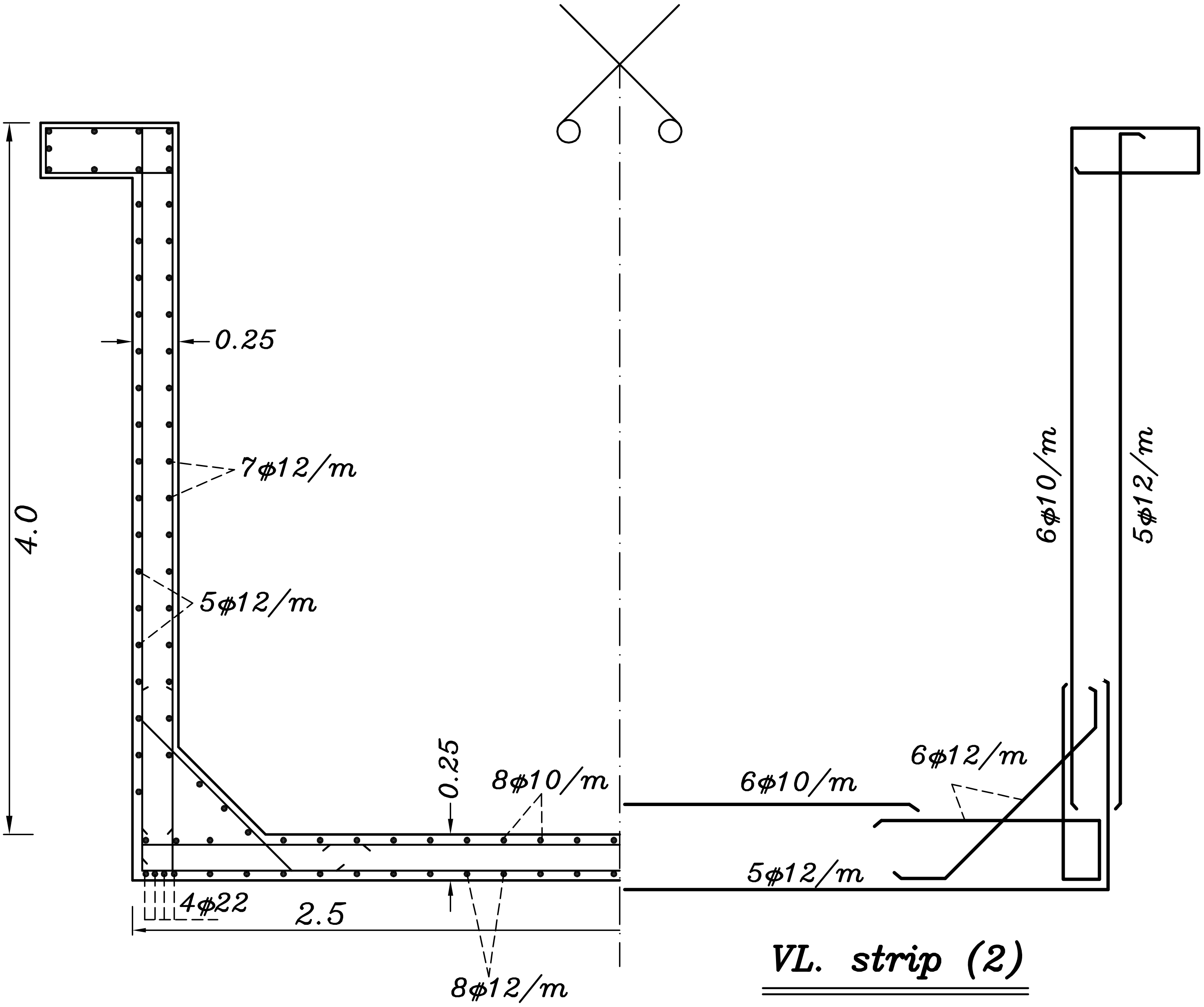
Sec (8–8) air section

$A_s=5\phi12/m$

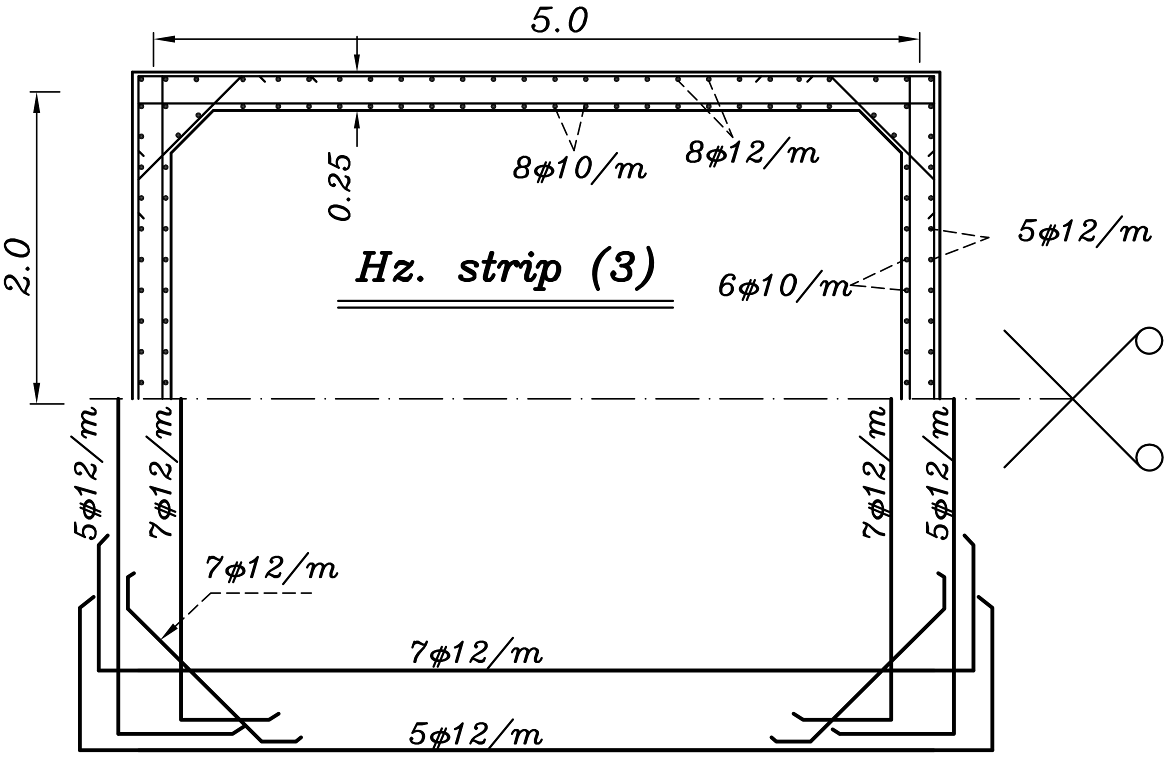
Details of RFT.



VL. strip (1)



VL. strip (2)



Hz. strip (3)

Example(5)

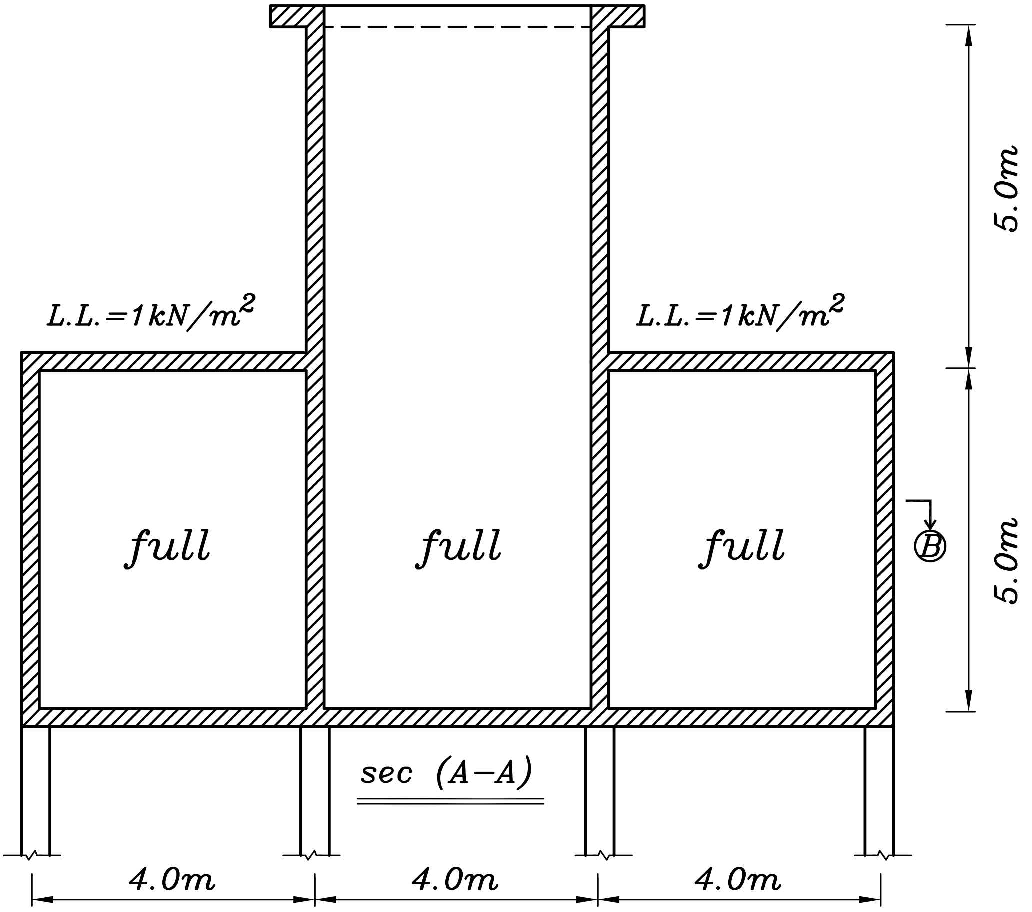
Given:

$f_{cu}=25\ N/mm^2$ &

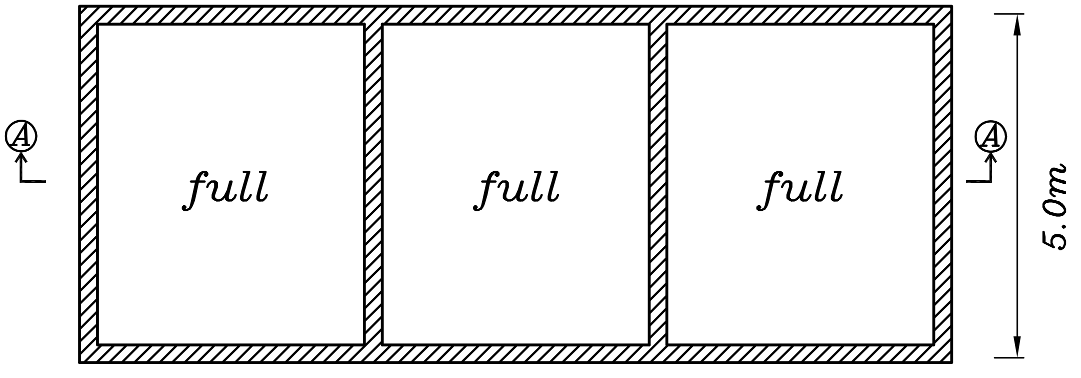
steel used is 360/520

Required

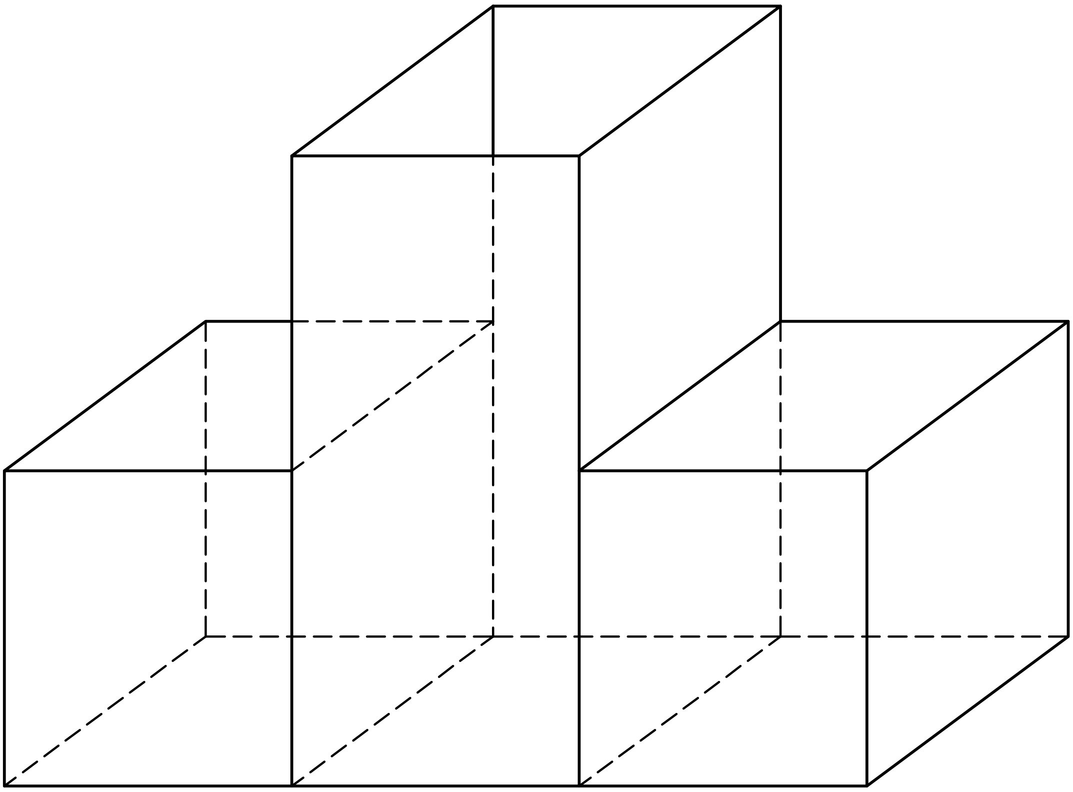
Design the given tank.

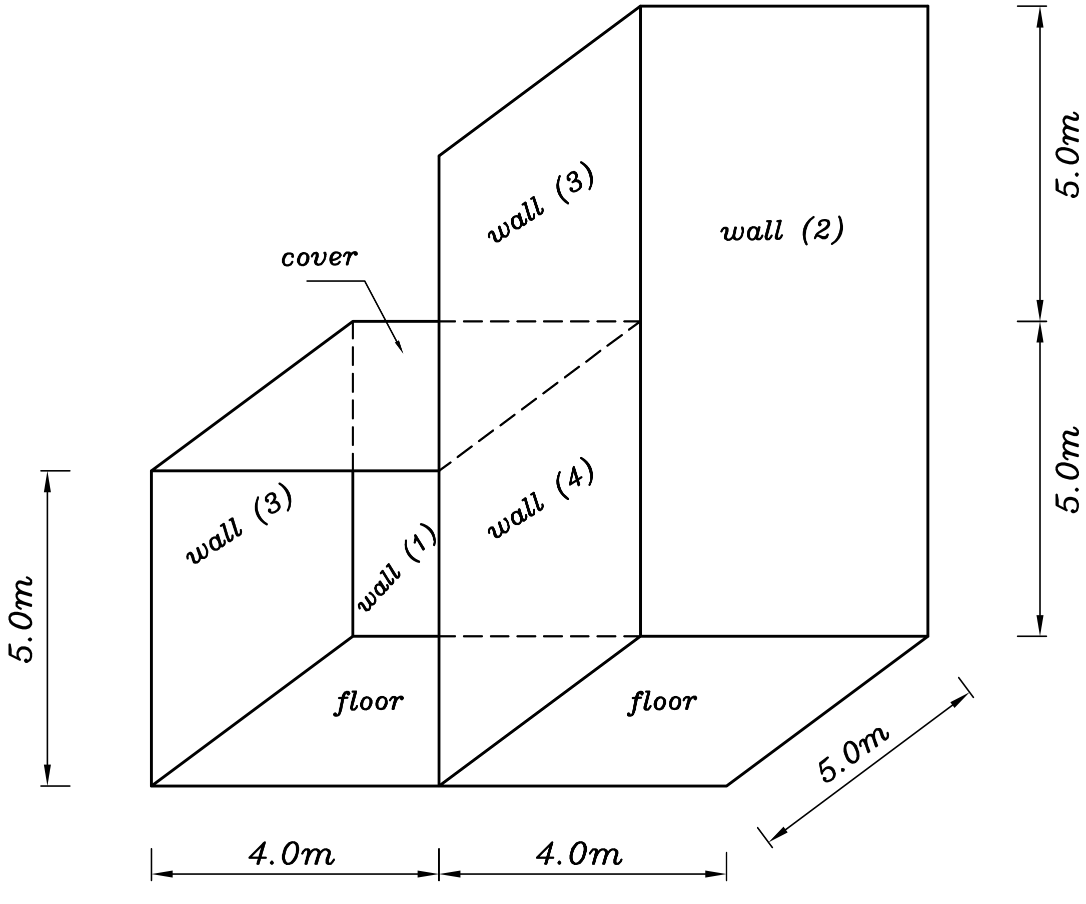


sec (A–A)



sec (B–B)




wall (3)
wall (2)
cover
wall (3)
wall (1)
wall (4)
floor
floor
5.0m
5.0m
5.0m
5.0m
4.0m
4.0m

Solution

1- Concrete dimensions

$$t_w = \frac{500}{16} = 31.25cm$$

$$t_f = \frac{400}{16} = 25cm$$

$\Longrightarrow$ Take $t_w = t_f = 30cm$, $t_{cover} = 15cm$

ـ ملحوظة

طالما ان ال (cover) ليس عليه اوزان ثقيلة مثل وزن الماء فاننا ناخذ تخانته (15cm) ونهمل اتصاله مع الحوائط ونعتبره كمرة .

2- Loads on floor

$$w_f = t_f \gamma_c + \gamma_w h$$

for $h=10m$

$$w_f = 0.30*25+10*10=107.50 \ kN/m^2$$

for $h=5m$

$$w_f = 0.30*25+10*5=57.50 \ kN/m^2$$

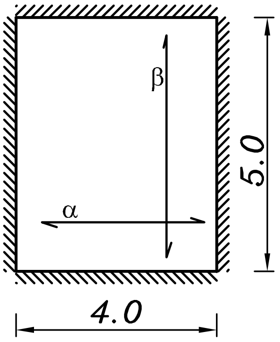
3- Load distribution

- Floor (4.0*5.0)

$$r = \frac{0.76*5}{0.76*4} = 1.25$$

$$\alpha = \frac{r^4}{1+r^4} = 0.71$$

$$\beta = \frac{1}{1+r^4} = 0.29$$

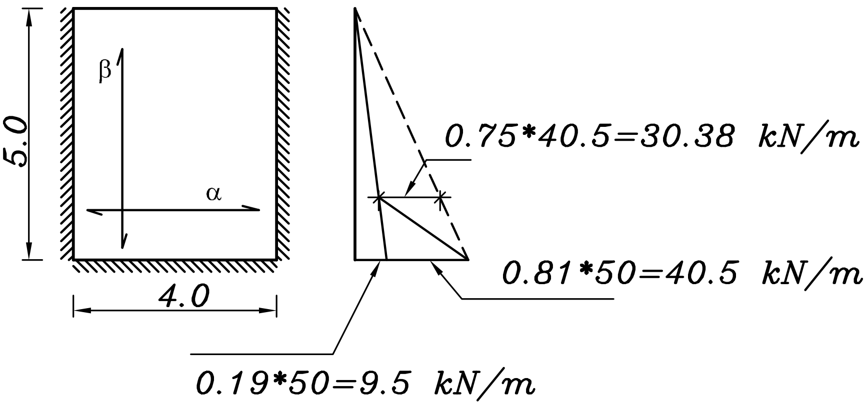


– Wall (1) (4.0*5.0)

$$r=\frac{0.87*5}{0.76*4}=1.43$$

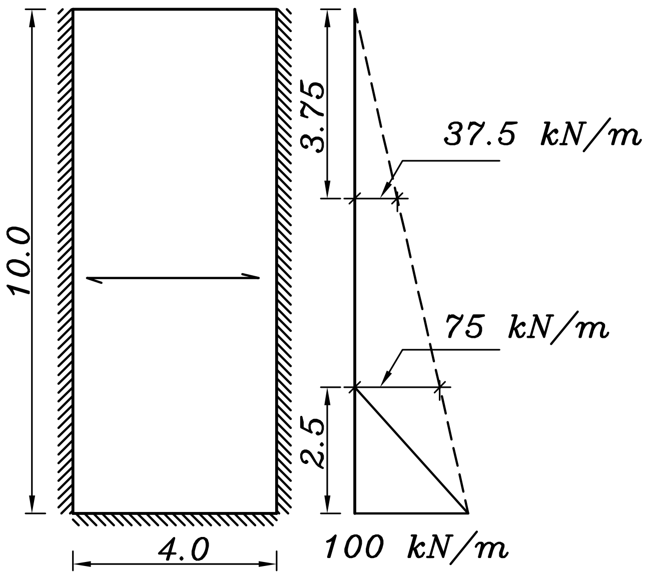
$$\alpha=\frac{r^4}{1+r^4}=0.81$$

$$\beta=\frac{1}{1+r^4}=0.19$$



– Wall (2) (4.0*10.0)

one way in hz. direction

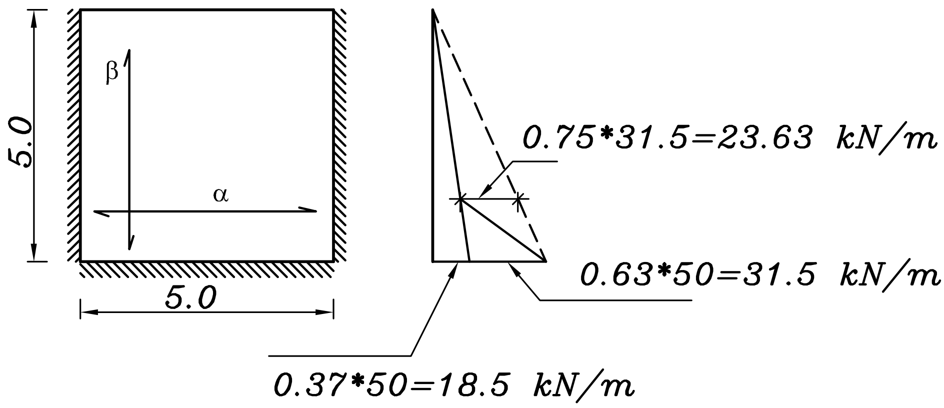


– Wall (3) (5.0*5.0)

$$r=\frac{0.87*5}{0.76*5}=1.14$$

$$\alpha=\frac{r^4}{1+r^4}=0.63$$

$$\beta=\frac{1}{1+r^4}=0.37$$

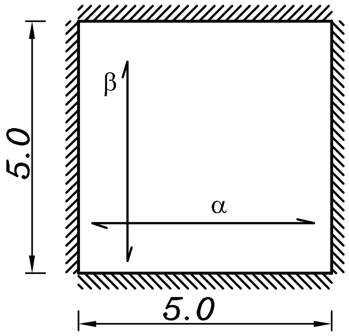


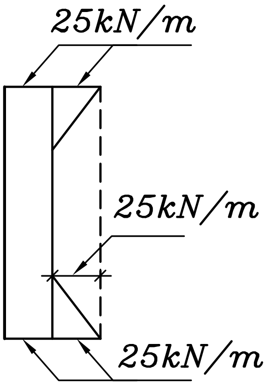
– Wall (4) (5.0*5.0)

$$r=\frac{0.76*5}{0.76*5}=1.0$$

$$\alpha=\frac{r^4}{1+r^4}=0.50$$

$$\beta=\frac{1}{1+r^4}=0.50$$





– Cover (4.0*5.0)

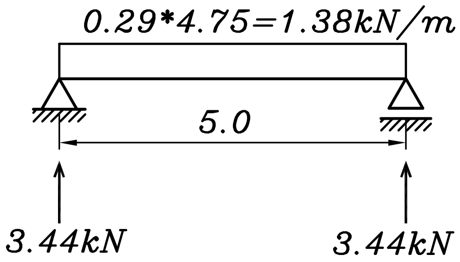
$$r=\frac{1.0*5}{1.0*4}=1.25$$

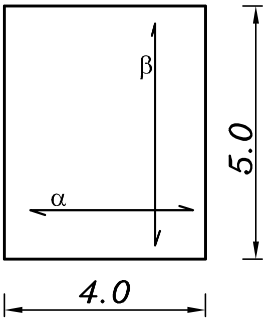
$$\alpha=\frac{r^4}{1+r^4}=0.71$$

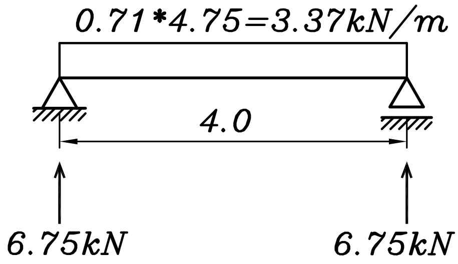
$$\beta=\frac{1}{1+r^4}=0.29$$

$$w_s=t_s\gamma_c+L.L.=0.15*25+1.0$$

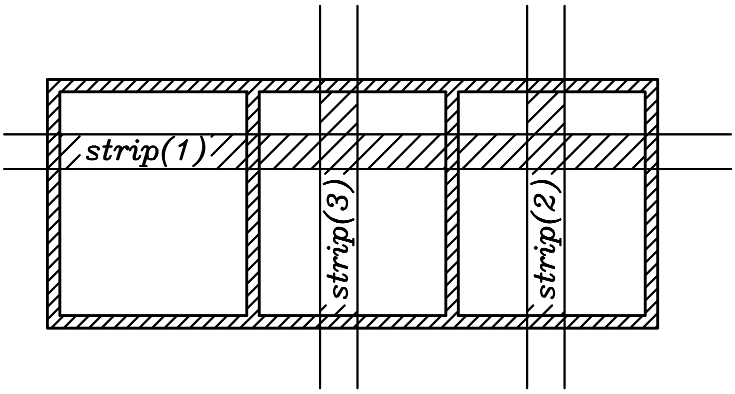
$$w_s=4.75\ \ kN/m^2$$



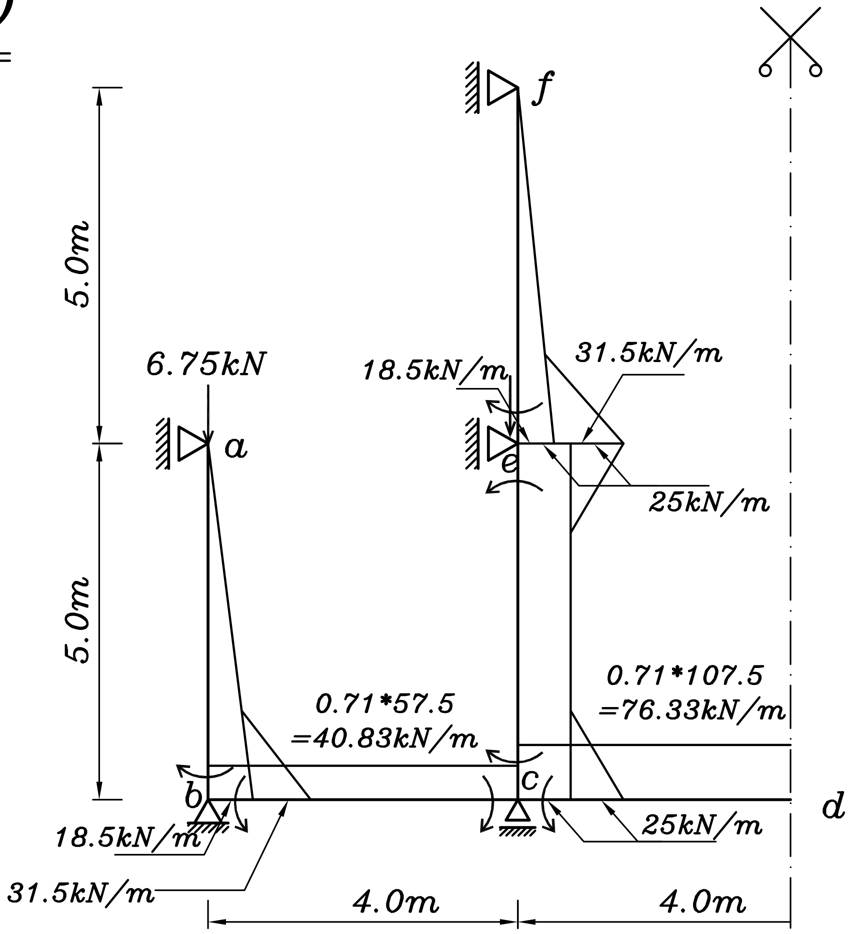




4– Analysis of strips



– VL. strip (1)



For Joint b

$$D.f_{ba} = \frac{0.75(I/5.0)}{0.75(I/5.0)+(I/4.0)} = 0.38$$

$$D.f_{bc} = \frac{(I/4.0)}{0.75(I/5.0)+(I/4.0)} = 0.62$$

For Joint c

$$D.f_{cb} = \frac{(I/4.0)}{(I/4.0)+0.5(I/4)+(I/5.0)} = 0.43$$

$$D.f_{cd} = \frac{0.5(I/4.0)}{(I/4.0)+0.5(I/4)+(I/5.0)} = 0.22$$

$$D.f_{ce} = \frac{(I/5.0)}{(I/4.0)+0.5(I/4)+(I/5.0)} = 0.35$$

For Joint e

$$D.f_{ec} = \frac{(I/5.0)}{(I/5.0)+0.75(I/5.0)} = 0.57 \quad , \quad D.f._{ef} = 0.43$$

$$F.E.M._{\substack{ba\\ef}}=\frac{18.50*(5)^2}{15}+\frac{31.50*(5)^2}{117}=37.56kN.m$$

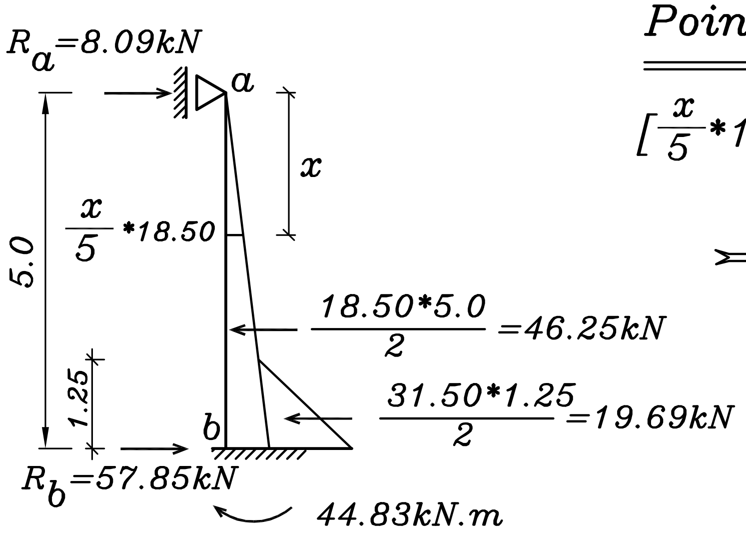
$$F.E.M._{bc}=\frac{-40.83*(4)^2}{12}=-54.44kN.m \quad \& \quad F.E.M._{cb}=54.44kN.m$$

$$F.E.M._{cd}=\frac{-76.33*(4)^2}{12}=-101.77kN.m$$

$$F.E.M._{ec}=-\frac{25*(5)^2}{12}-\frac{25*(5)^2}{124}-\frac{25*(5)^2}{904}$$

$$F.E.M._{ec}=-57.82kN.m \quad \& \quad F.E.M._{ce}=57.82kN.m$$

Joint	b		c			e	
member	ba	bc	cb	cd	ce	ec	ef
D.f.	0.38	0.62	0.43	0.22	0.35	0.57	0.43
F.E.M.	37.56	−54.44	54.44	−101.77	57.82	−57.82	37.56
Bal.M.	6.41	10.47	−4.51	−2.31	−3.67	11.55	8.71
C.O.M.	0	−2.26	5.24	0	5.78	−1.84	0
Bal.M.	0.86	1.40	−4.74	−2.42	−3.86	1.05	0.79
M_f	44.83	−44.83	50.43	−106.5	56.07	−47.06	47.06

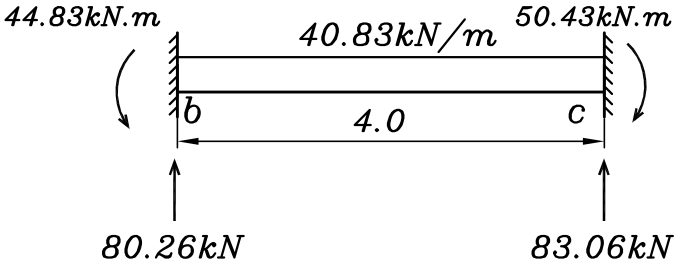


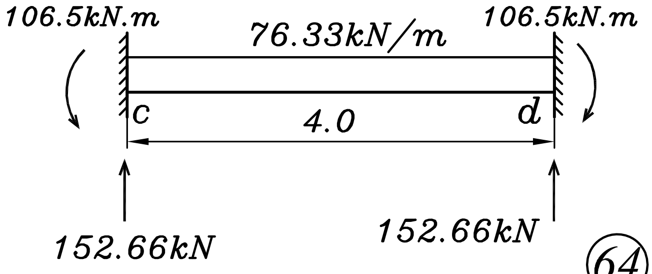
Point of zero shear

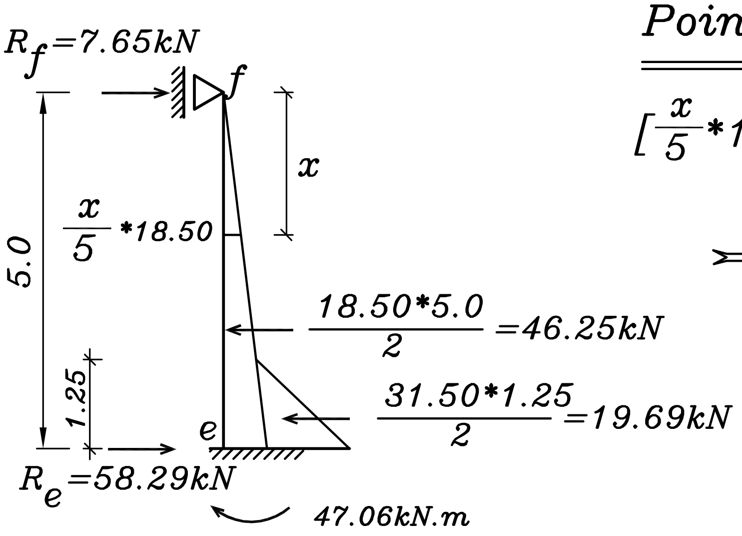
$$[\frac{x}{5}*18.50]*\frac{x}{2}=8.09 \Longrightarrow x=2.09m$$

$$\Longrightarrow M_{+ve}=8.09x-(\frac{x}{5}*18.50)*(\frac{x^2}{6})$$

$$M_{+ve}=11.28 \ kN.m$$





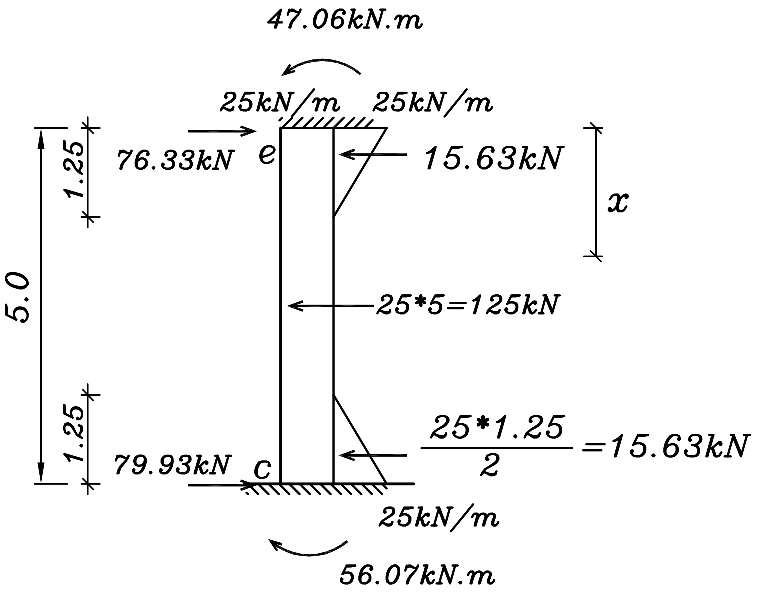


Point of zero shear

$$\left[\frac{x}{5}*18.50\right]*\frac{x}{2}=7.65 \Longrightarrow x=2.03m$$

$$\Longrightarrow M_{+ve}=7.65x-(\frac{x}{5}*18.50)*(\frac{x^2}{6})$$

$$M_{+ve}=10.37\ kN.m$$

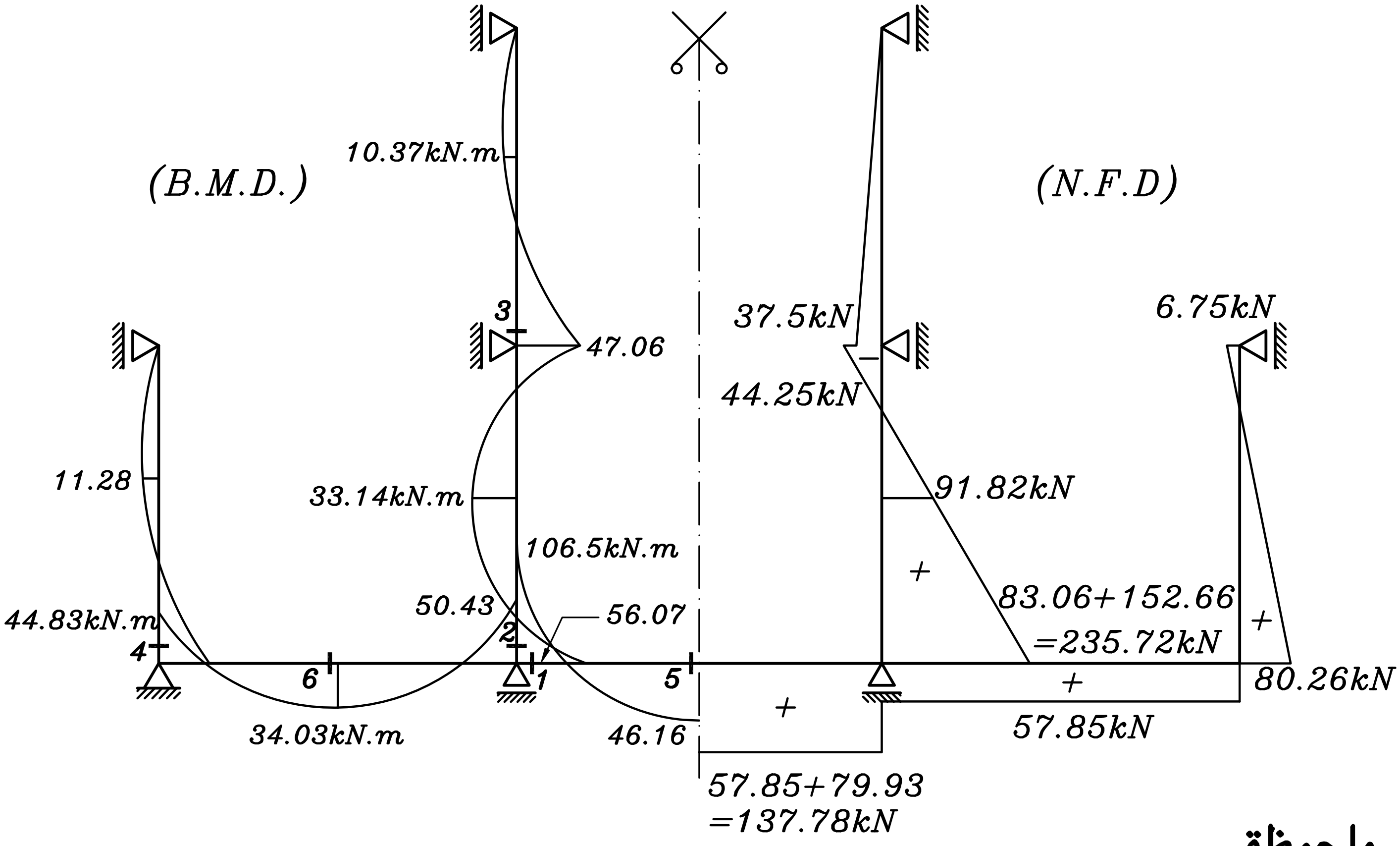


Point of zero shear

$$[25x]+15.63=76.33 \Longrightarrow x=2.43m$$

$$\Longrightarrow M_{+ve}=76.33x-47.06-25x^2/2-15.63(x-1.25/3)$$

$$M_{+ve}=33.14\ kN.m$$

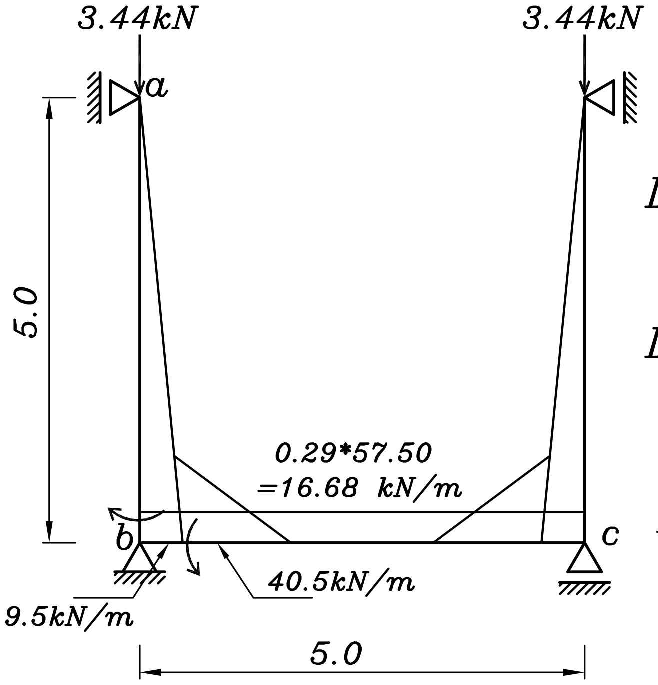


ـ ملحوظة

لان الحائط (ef) مرتكز على الحائط (ce) لذلك فان (N.F.) المتولدة داخله هى

(o.w=0.30*5*25=37.5kN)

– VL. strip (2)



For Joint b

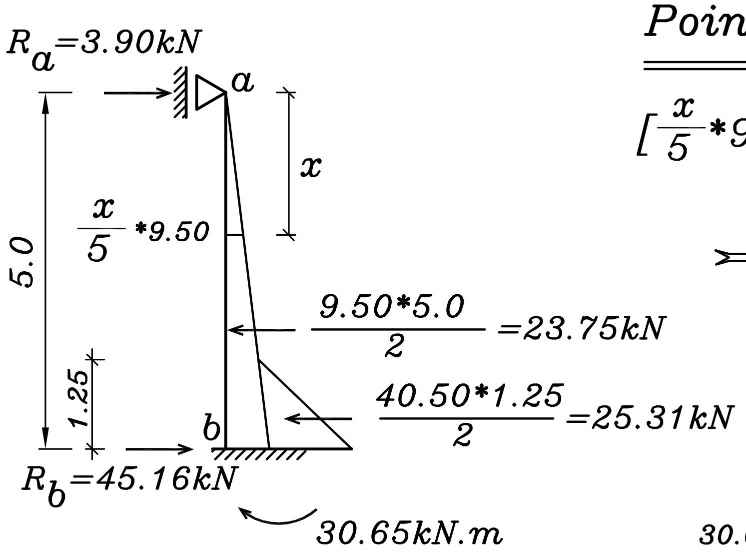
$$D.f_{ba}=\frac{0.75(I/5.0)}{0.75(I/5.0)+0.5(I/5.0)}=0.60$$

$$D.f_{bc}=\frac{0.5(I/5.0)}{0.75(I/5.0)+0.5(I/5.0)}=0.40$$

$$F.E.M._{bc}=\frac{-16.68*(5)^2}{12}=-34.75kN.m$$

$$F.E.M._{ba}=\frac{9.50*(5)^2}{15}+\frac{40.50*(5)^2}{117}=24.49kN.m$$

Joint	b	
member	ba	bc
D.f.	0.60	0.40
F.E.M.	24.49	−34.75
Bal.M.	6.16	4.10
M_f	30.65	−30.65

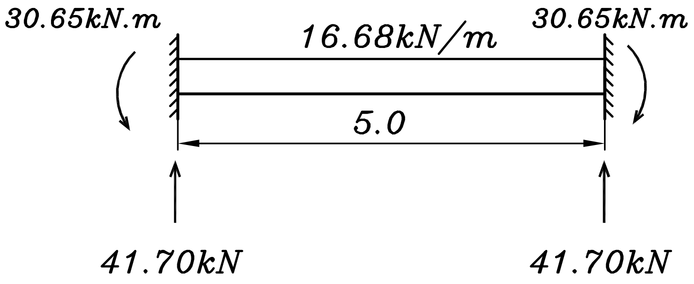


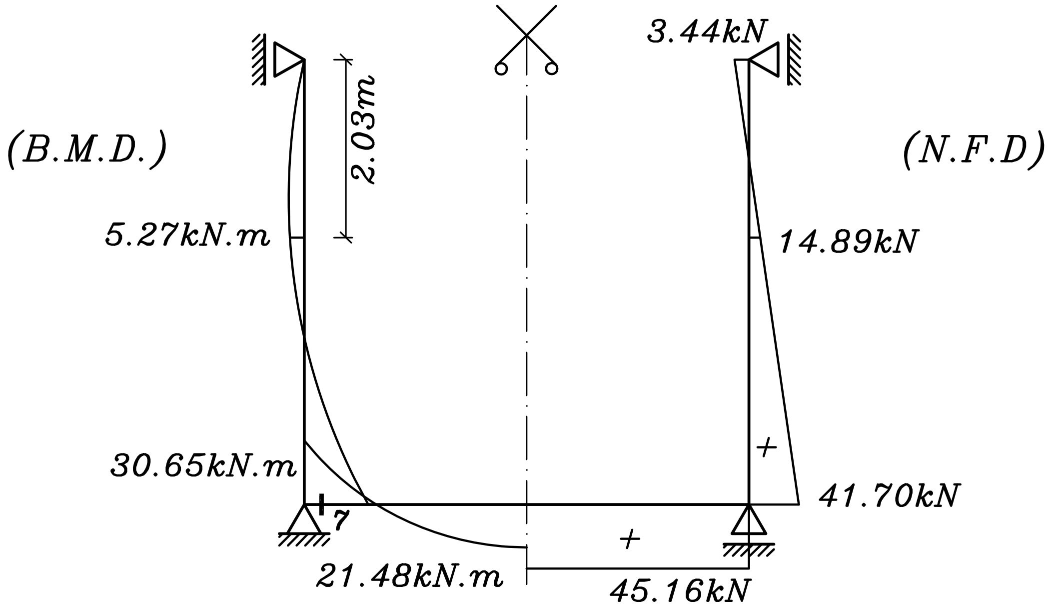
Point of zero shear

$$[\frac{x}{5}*9.50]*\frac{x}{2}=3.90 \Longrightarrow x=2.03m$$

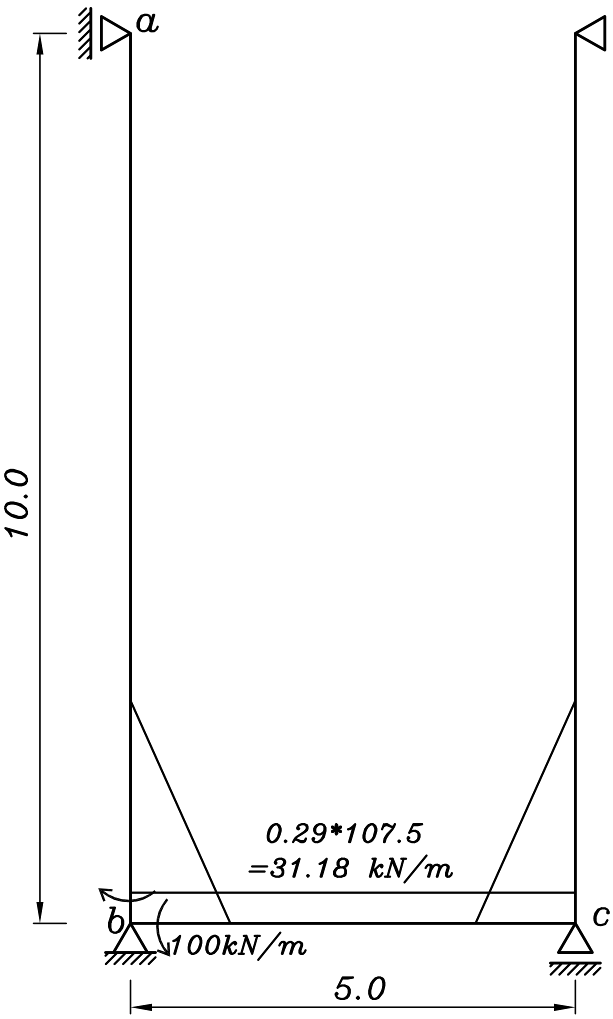
$$\Longrightarrow M_{+ve}=3.90x-(\frac{x}{5}*9.50)*(\frac{x^2}{6})$$

$$M_{+ve}=5.27 \ kN.m$$





– VL. strip (3)



For Joint b

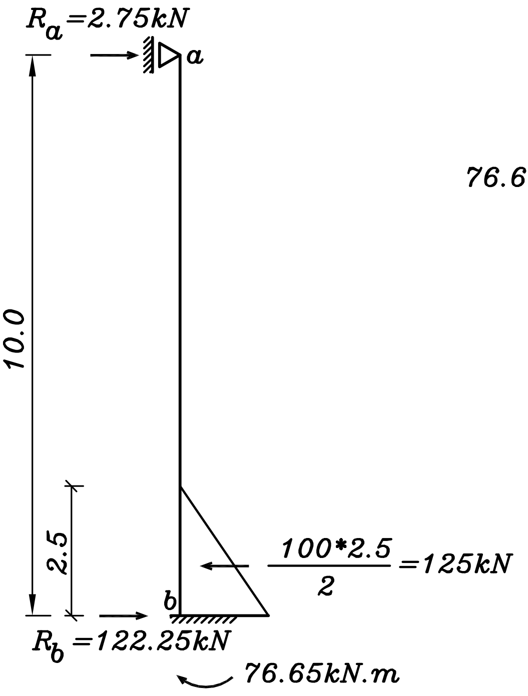
$$D.f_{ba} = \frac{0.75(I/10)}{0.75(I/10)+0.5(I/5.0)} = 0.43$$

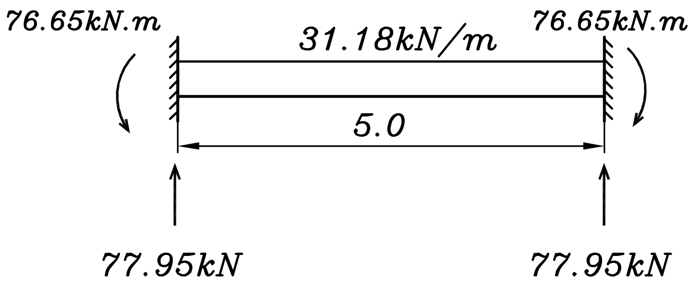
$$D.f_{bc} = \frac{0.5(I/5.0)}{0.75(I/10)+0.5(I/5.0)} = 0.57$$

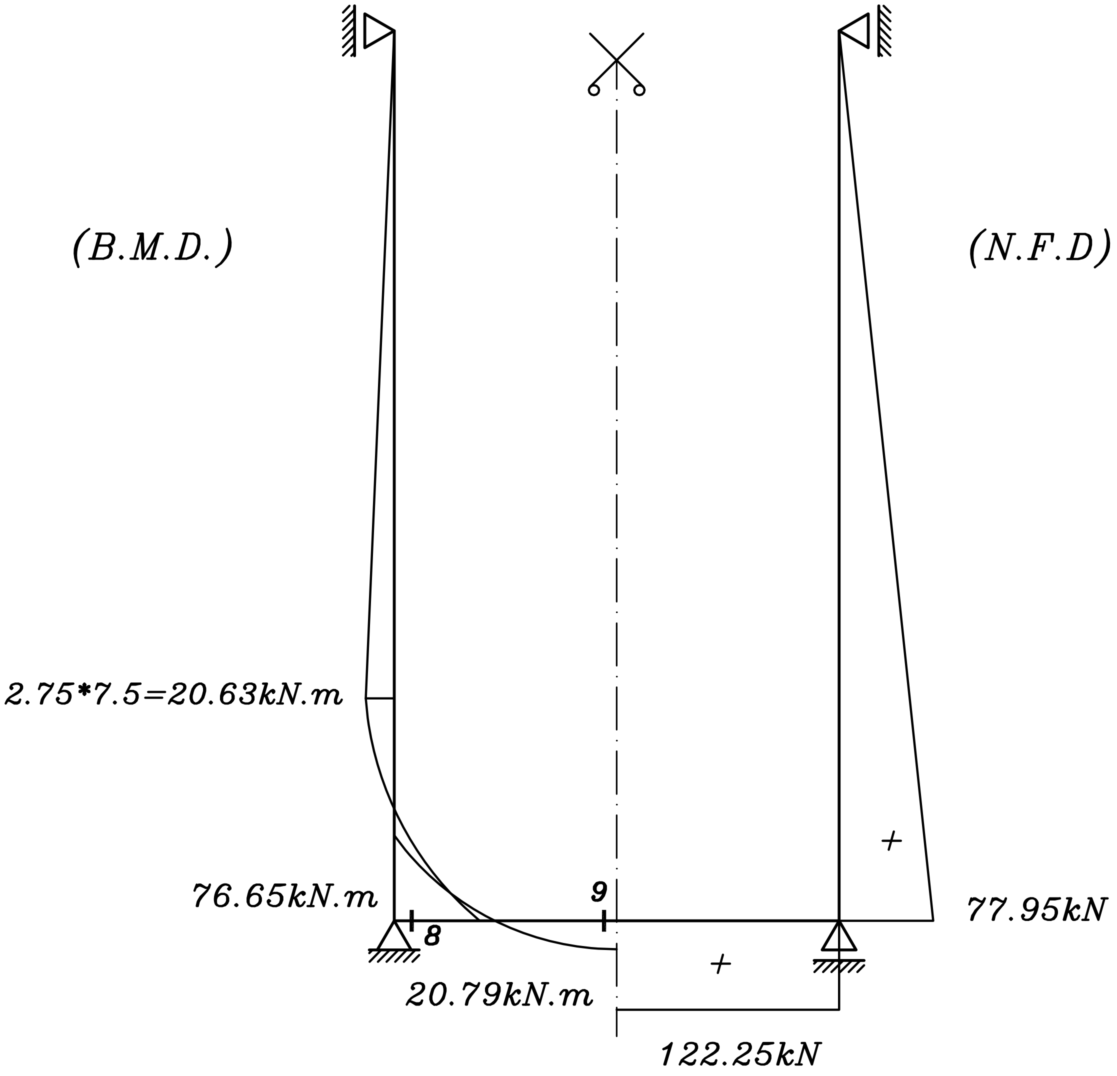
$$F.E.M._{ba} = \frac{100*(10)^2}{117} = 85.47kN.m$$

$$F.E.M._{bc} = \frac{-31.18*(5)^2}{12} = -64.96kN.m$$

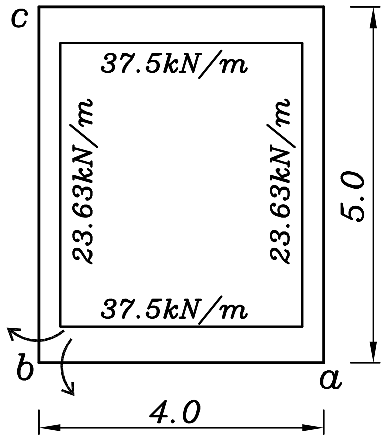
Joint	b	
member	ba	bc
D.f.	0.43	0.57
F.E.M.	85.47	−64.96
Bal.M.	−8.82	−11.69
M_f	76.65	−76.65







– HZ. strip (4) at h=6.25



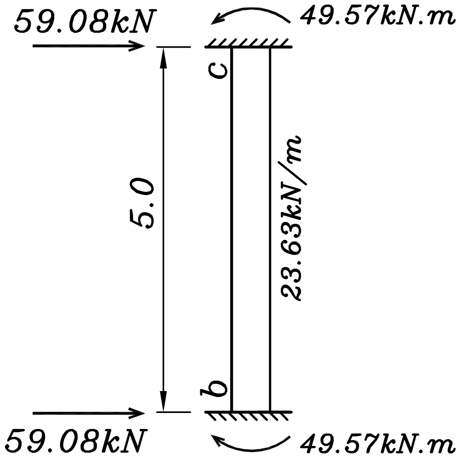
For Joint b

$$D.f_{ba}=\frac{0.5(I/4.0)}{0.5(I/4.0)+0.5(I/5.0)}=0.56$$

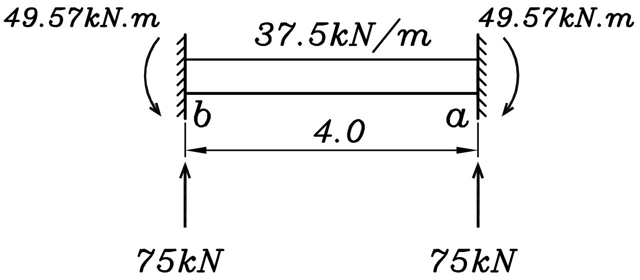
$$D.f_{bc}=\frac{0.5(I/5.0)}{0.5(I/4.0)+0.5(I/5.0)}=0.44$$

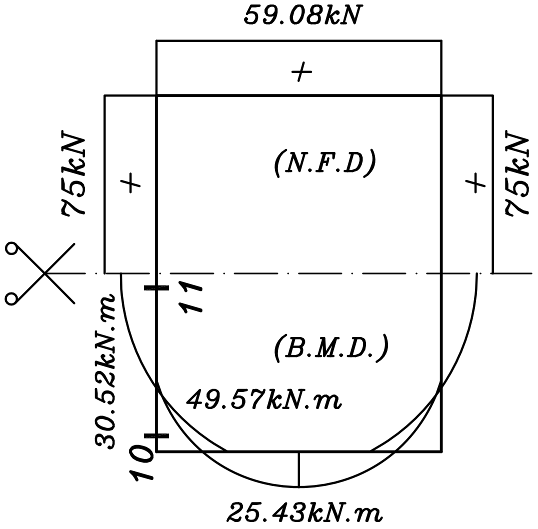
$$F.E.M._{ba}=\frac{-37.5*(4.0)^2}{12}=-50.0kN.m$$

$$F.E.M._{bc}=\frac{23.63*(5.0)^2}{12}=49.23kN.m$$

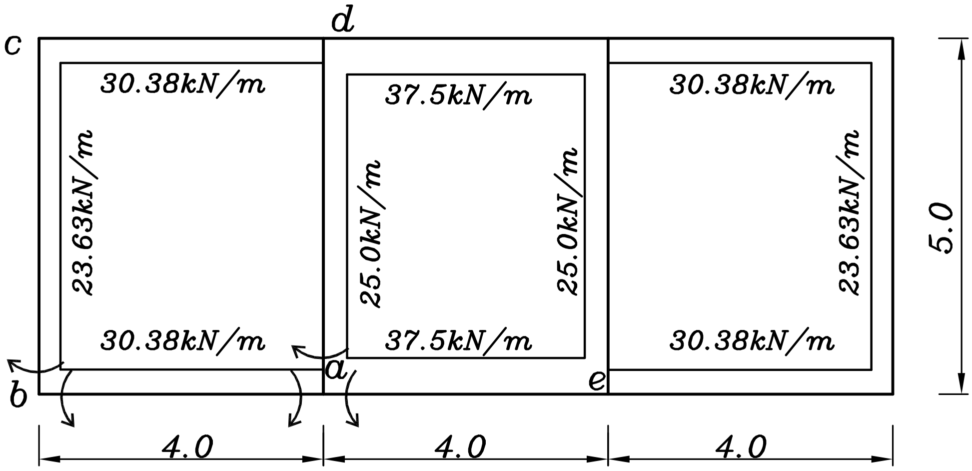


Joint	b	
member	ba	bc
D.f.	0.56	0.44
F.E.M.	−50.00	49.23
Bal.M.	0.43	0.34
M_f	−49.57	49.57





– HZ. strip (5) at h=1.25



or Joint b

$$D.f_{ba}=\frac{(I/4.0)}{(I/4.0)+0.5(I/5.0)}=0.71$$

$$D.f_{bc}=\frac{0.5(I/5.0)}{(I/4.0)+0.5(I/5.0)}=0.29$$

or Joint a

$$.f_{ab}=\frac{(I/4.0)}{(I/4.0)+0.5(I/4)+0.5(I/5.0)}=0.53$$

$$.f_{ae}=\frac{0.5(I/4.0)}{(I/4.0)+0.5(I/4)+0.5(I/5.0)}=0.26$$

$$.f_{ad}=\frac{0.5(I/5.0)}{(I/4.0)+0.5(I/4)+0.5(I/5.0)}=0.21$$

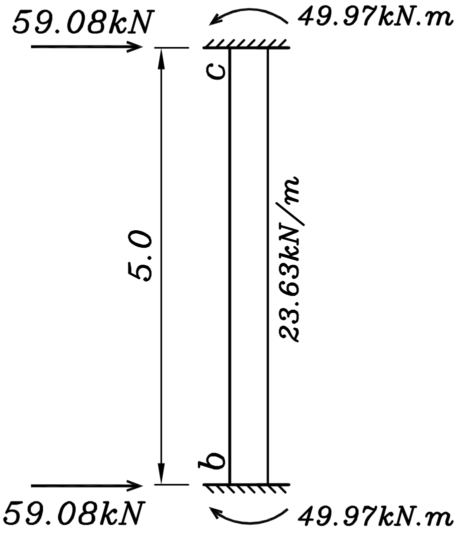
$$E.M._{ba}=\frac{-30.38*(4.0)^2}{12}=-40.51kN.m \quad \& \quad F.E.M._{ab}=40.51kN.m$$

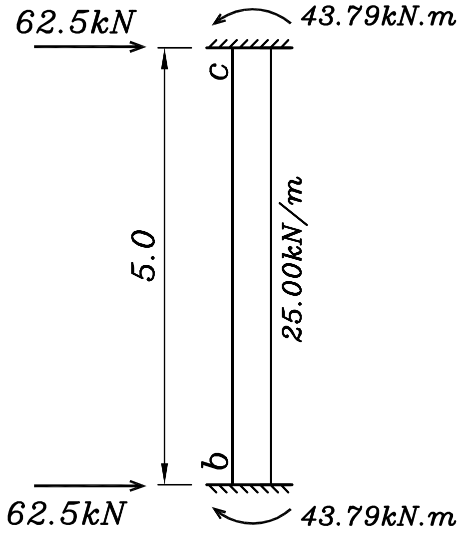
$$E.M._{bc}=\frac{23.63*(5.0)^2}{12}=49.23kN.m$$

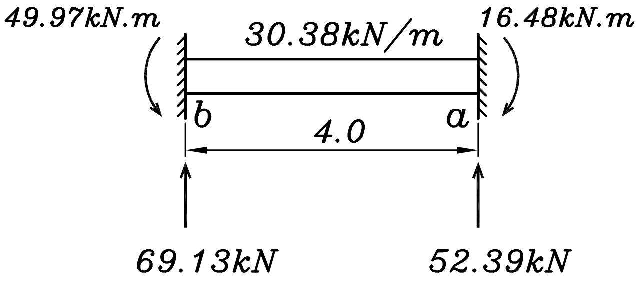
$$E.M._{ae}=\frac{-37.50*(4.0)^2}{12}=-50.0kN.m$$

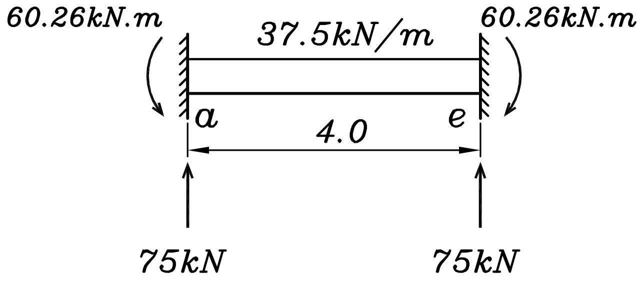
$$E.M._{ad}=\frac{25.00*(5.0)^2}{12}=52.08kN.m$$

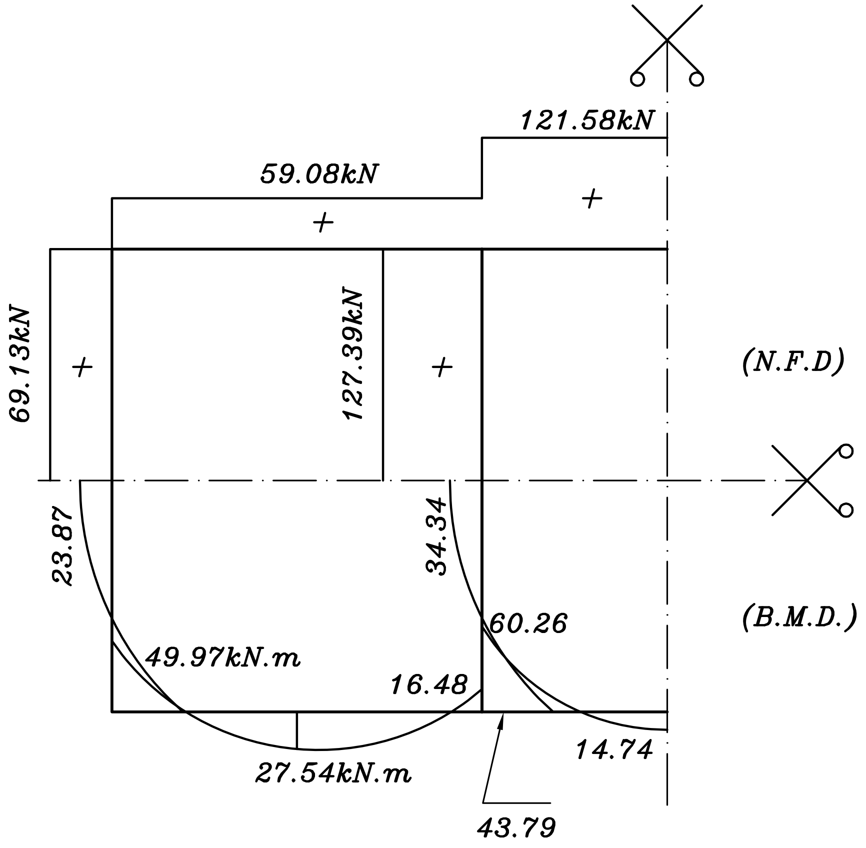
Joint	b		a		
member	bc	ba	ab	ae	ad
D.f.	0.29	0.71	0.53	0.26	0.21
F.E.M.	49.23	−40.51	40.51	−50.00	52.08
Bal.M.	−2.53	−6.19	−22.57	−11.07	−8.94
C.O.M.	0	−11.29	−3.10	0	0
Bal.M.	3.27	8.02	1.64	0.81	0.65
M_f	49.97	−49.97	16.48	−60.26	43.79


59.08kN
49.97kN.m
c
5.0
23.63kN/m
b
59.08kN
49.97kN.m


62.5kN
43.79kN.m
c
5.0
25.00kN/m
b
62.5kN
43.79kN.m


49.97kN.m
30.38kN/m
16.48kN.m
b
4.0
a
69.13kN
52.39kN


60.26kN.m
37.5kN/m
60.26kN.m
a
4.0
e
75kN
75kN


121.58kN
59.08kN
+
+
69.13kN
+
127.39kN
+
(N.F.D)
23.87
34.34
60.26
49.97kN.m
16.48
(B.M.D.)
27.54kN.m
14.74
43.79

5- Design of sections

Sec (1-1) water section

$M_{working}=106.5\ kN.m$, $T_{working}=137.78\ kN$, $b=1000mm$

Stage (I)

$$t_{(mm)}=\sqrt{\frac{M*10^{3}}{factor}}+40mm=\sqrt{\frac{106.5*10^{3}}{0.28}}+40mm=656.73mm$$

$\Longrightarrow$ Take $t=700mm$

Check stresses

$$f_t=+\frac{T}{A}+\frac{M}{Z}=+\frac{137.78*10^{3}}{1000*700}+\frac{106.5*10^{6}}{1000*(700)^{2}/6}$$

$$=0.20+1.30=1.50\ N/mm^{2}$$

$$\Longrightarrow f_{ct}=\frac{0.6\sqrt{25}}{1.7}=1.76N/mm^{2}\quad\Longrightarrow f_t<f_{ct}\quad(safe)$$

Stage (II)

$M_{u.l.}=1.5*106.5=159.75\ kN.m$, $T_{u.l.}=1.5*137.78=206.67\ kN$

$$e=\frac{M_{u.l.}}{T_{u.l.}}=\frac{159.75}{206.67}=0.77m>\frac{t}{2}-cover$$

$$e_s=e-\frac{t}{2}+c=0.77-\frac{0.70}{2}+0.04=0.46m$$

$$M_{us}=206.67*0.46=95.07kN.m$$

$$660=C_1\sqrt{\frac{95.07*10^{6}}{1000*25}}\qquad C_1=10.7\quad\&\quad J=0.826$$

$$A_s=\frac{1}{\beta_{cr}}*[\frac{M_{us}}{J*d*f_y}+\frac{T_{u.l.}}{f_y/\gamma_s}]$$

assume $\phi 16$ used $\Longrightarrow$ $\beta_{cr} = 0.75$

$$A_s = \frac{1}{0.75}\left[\frac{95.07*10^6}{0.826*660*360} + \frac{206.67*10^3}{360/1.15}\right]$$

$A_s = 1526.15 mm^2/m' \Longrightarrow 8\phi 16/m'$

Sec (2-2) water section

$M_{working} = 56.07$ kN.m , $T_{working} = 235.72$ kN , $b = 1000mm$

$t = 550mm$, $A_s = 8\phi 16/m'$

Sec (3-3) water section

$M_{working} = 47.06$ kN.m , $N_{working} = 37.5$ kN , $b = 1000mm$

$t = 400mm$, $A_s = 6\phi 12/m'$

Sec (4-4) water section

$M_{working} = 44.83$ kN.m , $T_{working} = 80.26$ kN , $b = 1000mm$

$t = 450mm$, $A_s = 8\phi 12/m'$

Sec (5-5) air section , t=300mm

$M_{working} = 46.16$ kN.m , $T_{working} = 137.78$ kN , $b = 1000mm$

$A_s = 7\phi 16/m'$

Sec (6-6) air section , t=300mm

$M_{working} = 34.03$ kN.m , $T_{working} = 57.85$ kN , $b = 1000mm$

$A_s = 8\phi 12/m'$

Sec (7−7) water section

$M_{working}$=30.65 kN.m , $T_{working}$=45.16 kN , b=1000mm

t=350mm , A_s =7ϕ12/m'

Sec (8−8) water section

$M_{working}$=76.65 kN.m , $T_{working}$=122.25 kN , b=1000mm

t=600mm , A_s =7ϕ16/m'

Sec (9−9) air section , t=300mm

$M_{working}$=20.79 kN.m , $T_{working}$=122.25 kN , b=1000mm

A_s =7ϕ12/m'

Sec (10−10) water section

$M_{working}$=49.57 kN.m , $T_{working}$=75.00 kN , b=1000mm

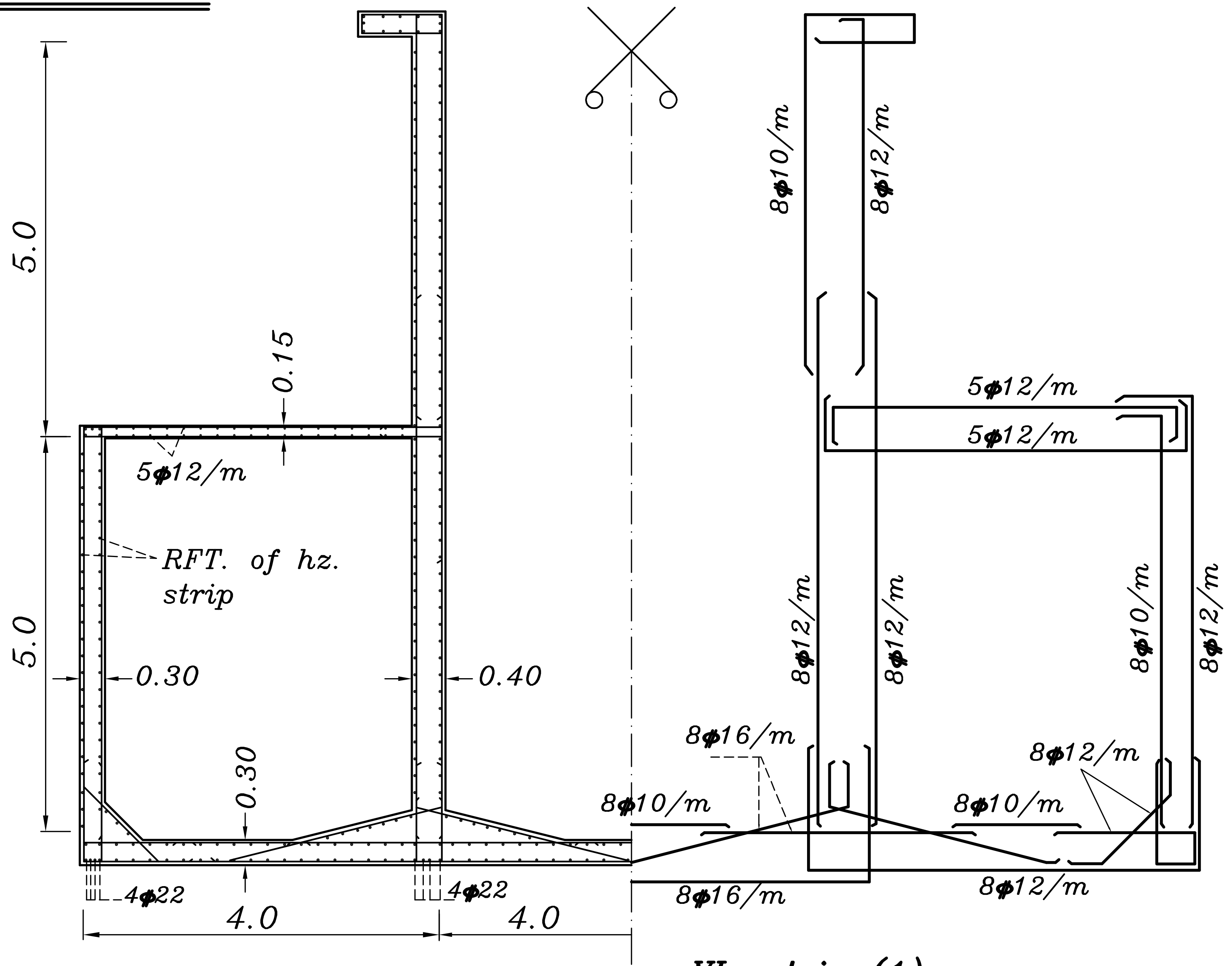
t=450mm , A_s =9ϕ12/m'

Sec (11−11) air section , t=300mm

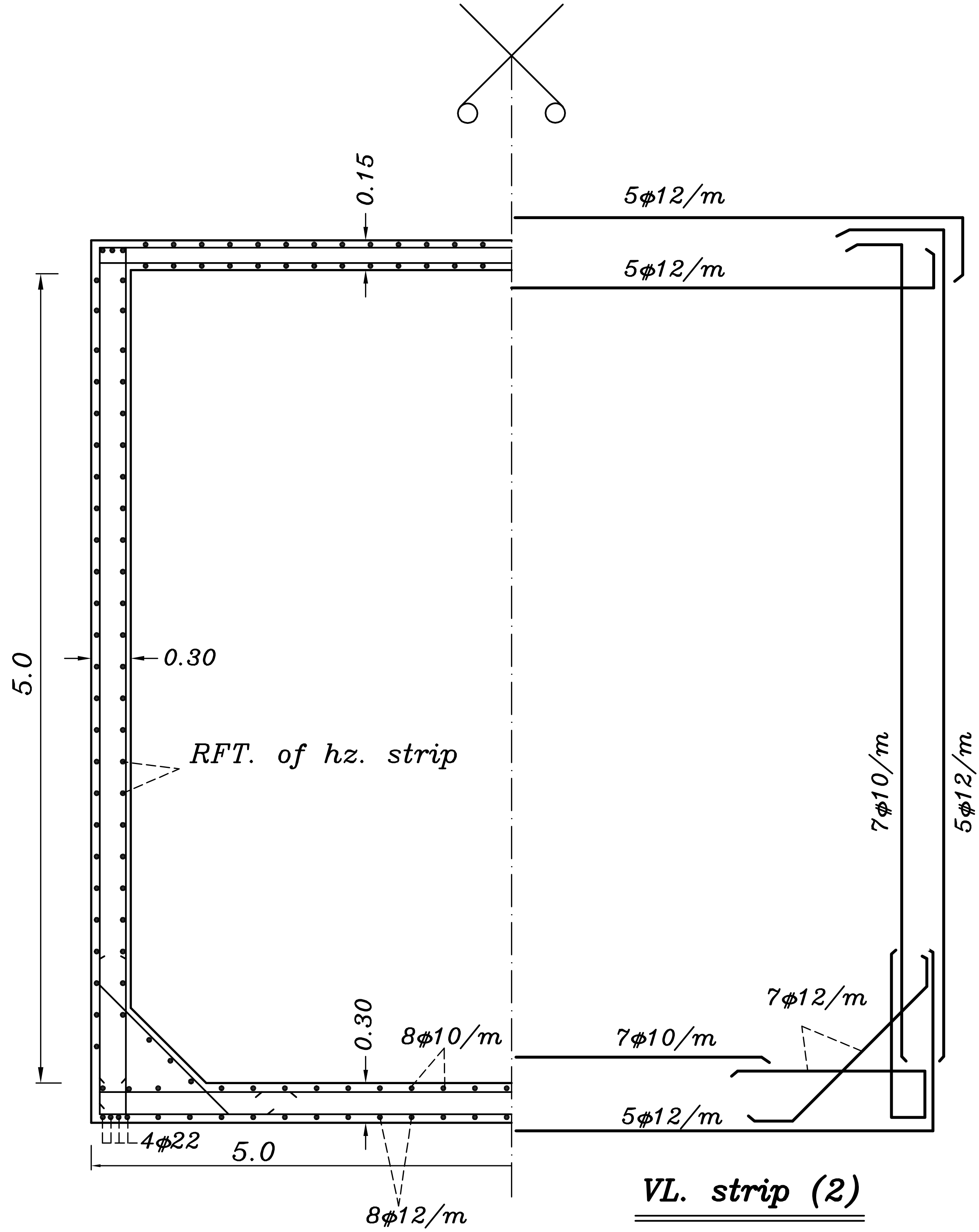
$M_{working}$=30.52 kN.m , $T_{working}$=75.00 kN , b=1000mm

A_s =7ϕ12/m'

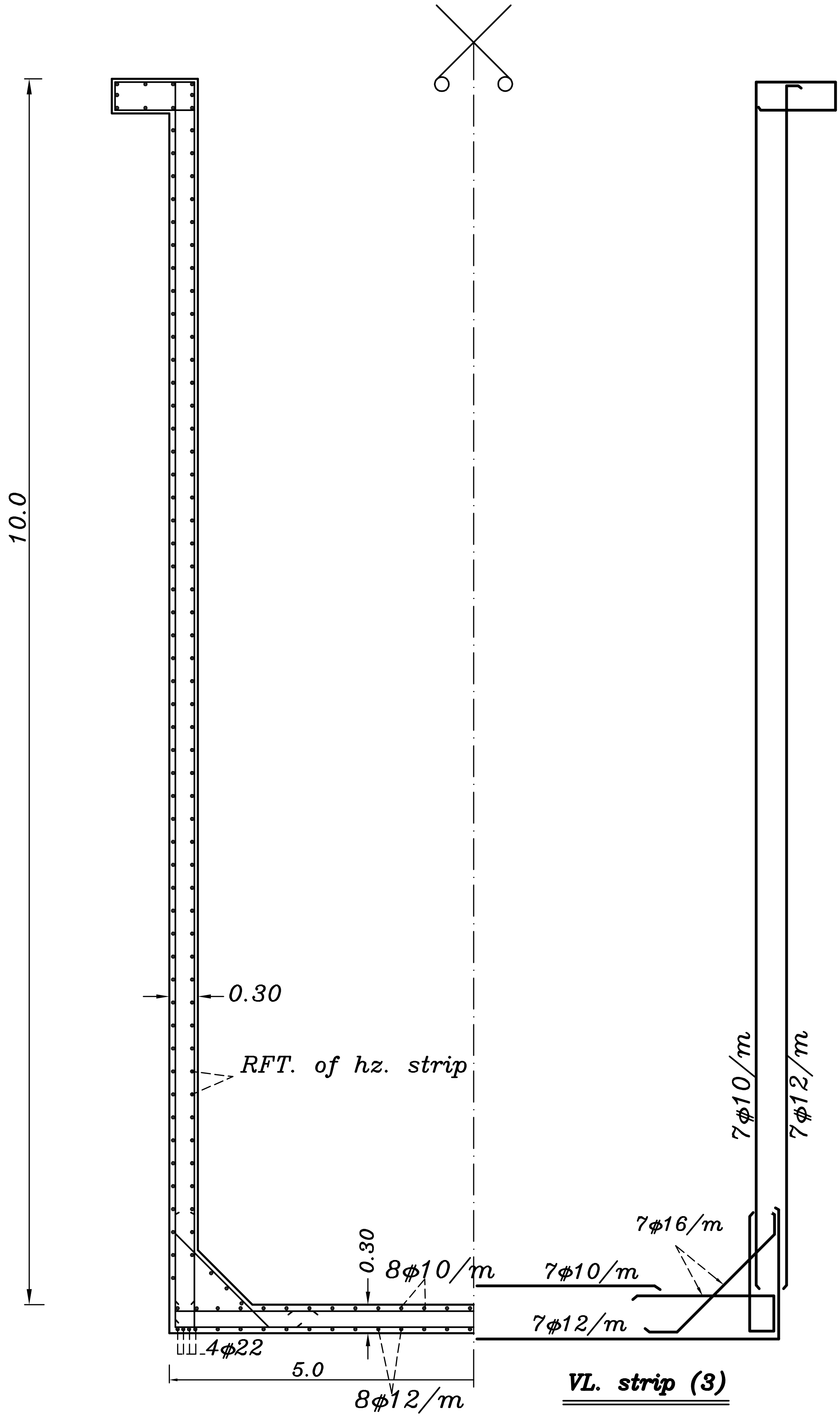
Details of RFT.



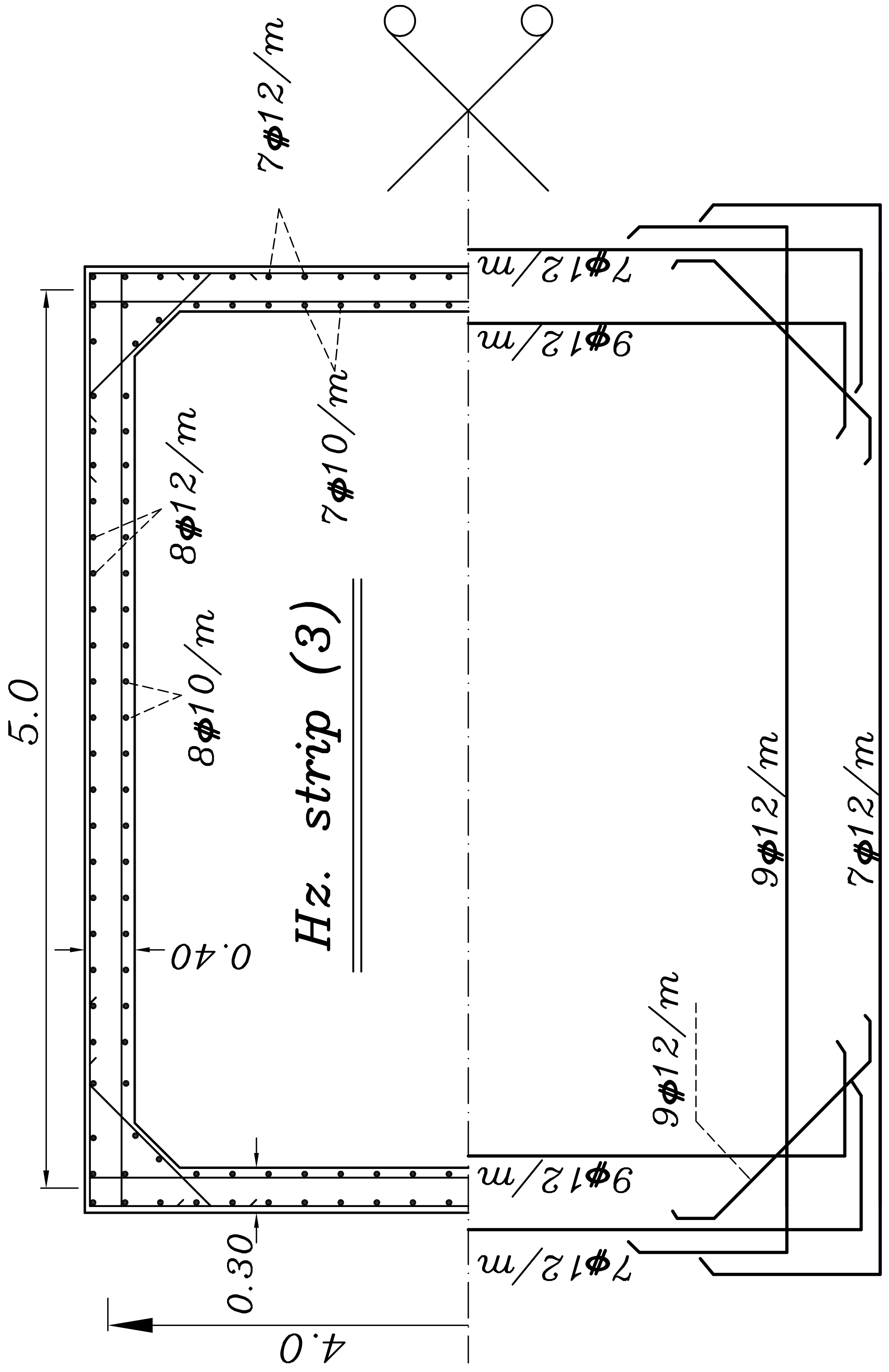
VL. strip (1)


0.15
5φ12/m
5φ12/m
5.0
0.30
RFT. of hz. strip
7φ10/m
5φ12/m
7φ12/m
0.30
8φ10/m
7φ10/m
5φ12/m
4φ22
5.0
8φ12/m

VL. strip (2)

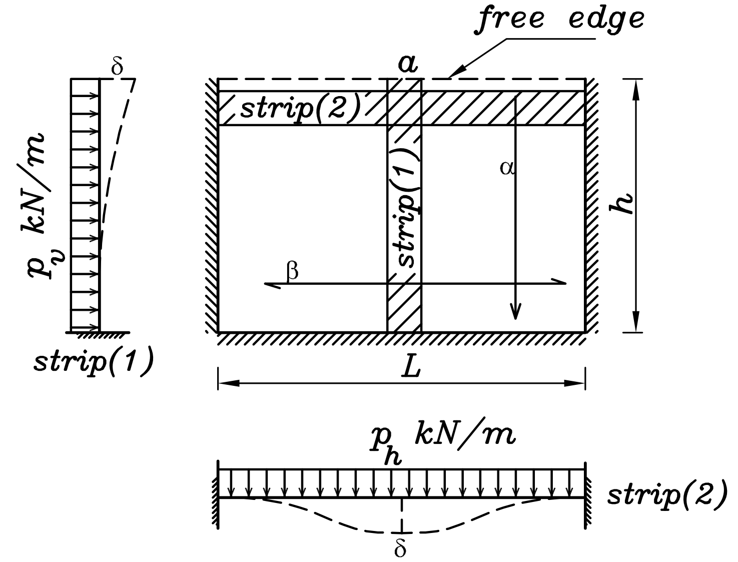

10.0
0.30
RFT. of hz. strip
0.30
8φ10/m
7φ10/m
7φ16/m
7φ12/m
4φ22
5.0
8φ12/m
7φ10/m
7φ12/m

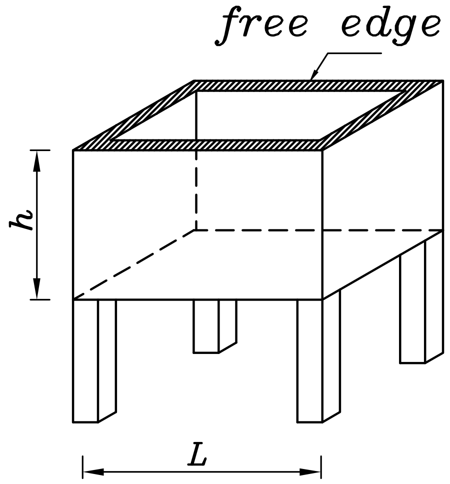
VL. strip (3)


Hz. strip (3)
7φ12/m
7φ10/m
8φ12/m
8φ10/m
9φ12/m
7φ12/m
9φ12/m
9φ12/m
7φ12/m
9φ12/m
7φ12/m
5.0
0.40
0.30
4.0

– Some special cases

1– Walls supported on three sides





deflection of strip (1) at joint (a)

=deflection of strip (2) at joint (a)

$$\Longrightarrow \frac{p_v\,.h^4}{8EI}=\frac{p_h\,.L^4}{384EI} \quad \Longrightarrow \quad p_v=\frac{p_h\,.L^4}{48h^4} \quad \Longrightarrow \quad (1)$$

$$p_v+p_h=\gamma_w\,h \quad \Longrightarrow \quad (2)$$

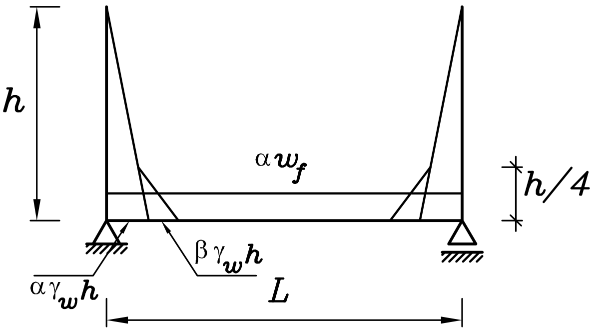
بالتعويض من(1) فى(2) فان

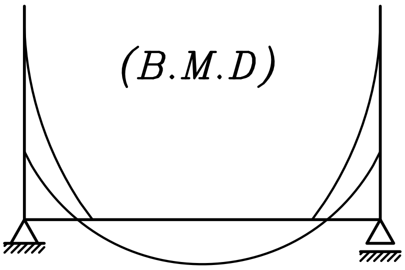
$$\Longrightarrow \frac{p_h\,.L^4}{48h^4}+p_h=\gamma_w\,h \quad \Longrightarrow \quad p_h\,[\frac{L^4+48h^4}{48h^4}]=\gamma_w\,h$$

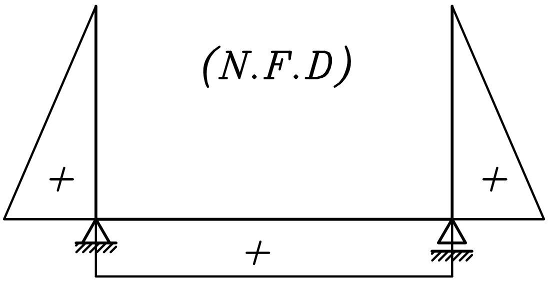
$$\Longrightarrow \boxed{p_h=[\frac{48h^4}{L^4+48h^4}]\gamma_w\,h \quad , \quad p_v=[\frac{L^4}{L^4+48h^4}]\gamma_w\,h}$$

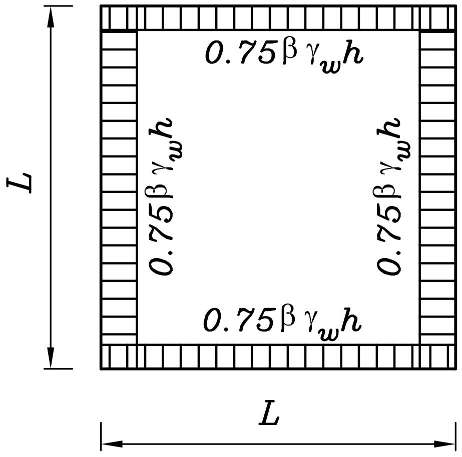
$$\because \quad \alpha=\frac{p_v}{\gamma_w\,h} \quad , \quad \beta=\frac{p_h}{\gamma_w\,h}$$

$$\Longrightarrow \boxed{\alpha=[\frac{L^4}{L^4+48h^4}] \quad , \quad \beta=[\frac{48h^4}{L^4+48h^4}]}$$







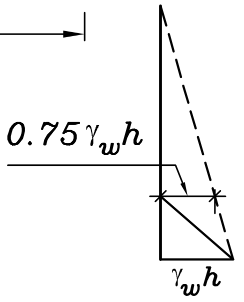


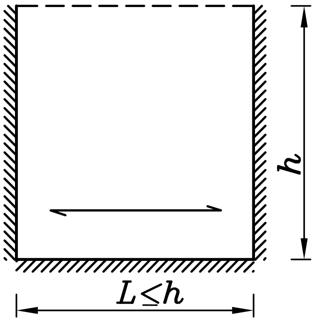
hz strip at h/4

specail cases

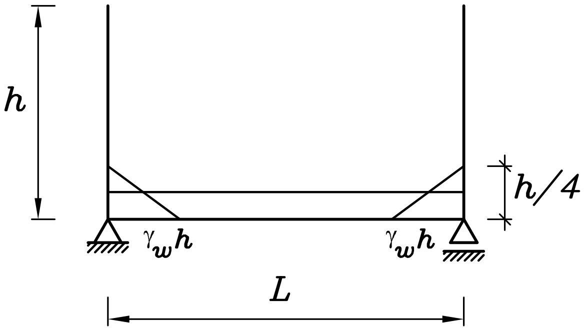
1− if $L = h$

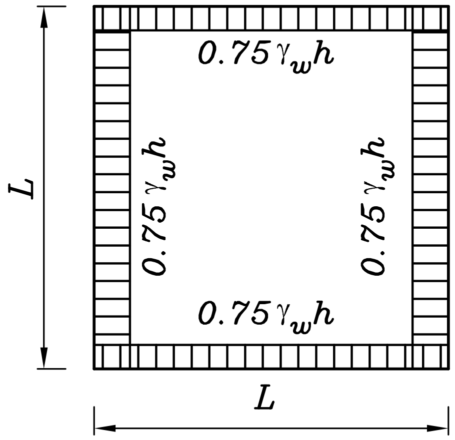
$$\Longrightarrow \alpha=\left[\frac{L^4}{L^4+48L^4}\right]=0.02\simeq 0$$





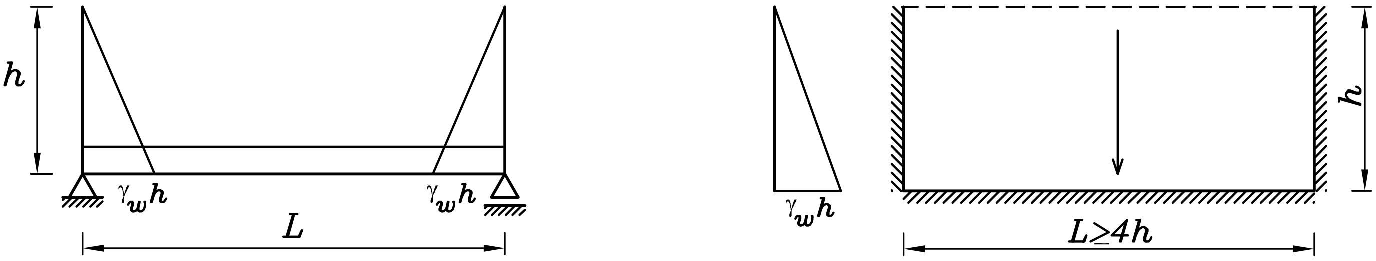
$\Longrightarrow$ for $L \leq h$ walls are one way in hz. direction





hz strip at h/4

2− if $L = 4h \Longrightarrow \beta = [\frac{48h^4}{(4h)^4 + 48h^4}] = 0.16$



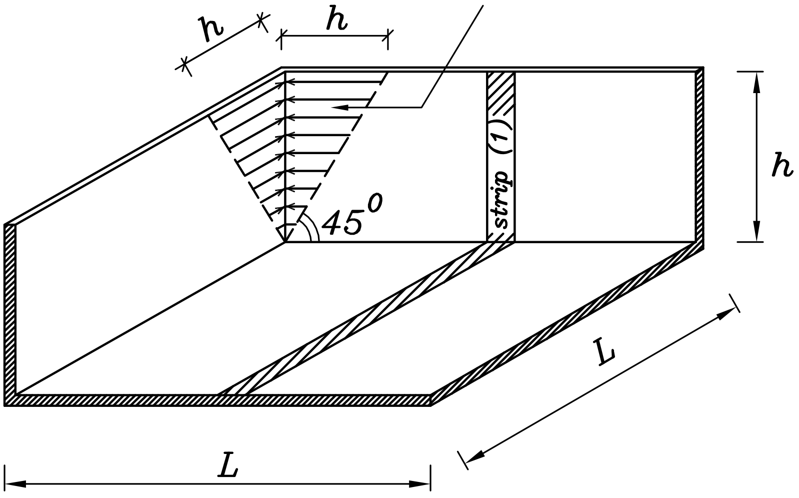
for $L \geq 4h$ walls are one way in vertical direction

2− Corner effect هام جدا

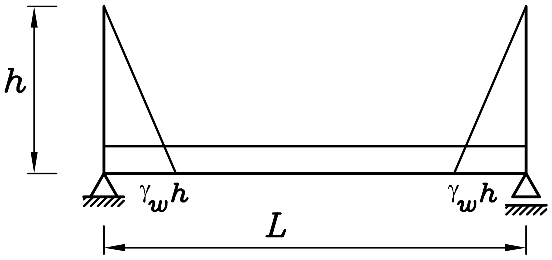
a− Cantilever wall

($L \geq 4h$)

load carried by hz. direction



Strip (1) (vl. strip)



– Load carried by hz. direction

Force on the triangle$=p_{av}*$area

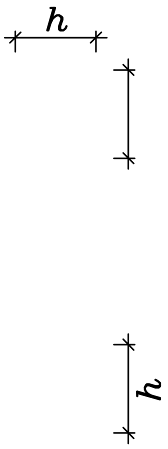
Force on the triangle$= [\frac{\gamma_w h}{2}]*[\frac{h.h}{2}]= \frac{\gamma_w h^3}{4}$

w (load in hz. direction)$= \frac{\text{Force on the tringle}}{\text{area of rectangle}}$

$w=[\frac{\gamma_w h^3}{4}]/(h*h)$

$$\boxed{w=\frac{\gamma_w h}{4} \qquad kN/m^2}$$

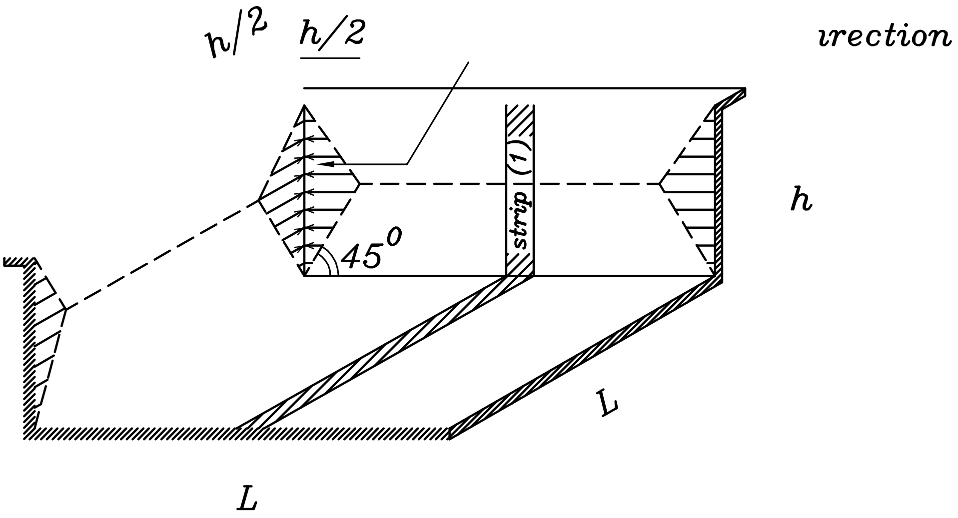
Strip (2) (hz. strip)



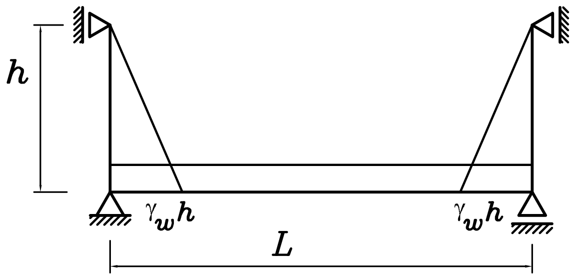
(B.M.D.)

(N.F.D)

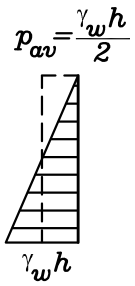
b– One way in vl. dir



Strip (1) (vl. strip)



– Load carried by hz. direction



$$Force\ on\ the\ triangle=p_{av}*area$$

$$Force\ on\ the\ triangle=[\frac{\gamma_w h}{2}]*[\frac{h.h/2}{2}]=\frac{\gamma_w h^3}{8}$$

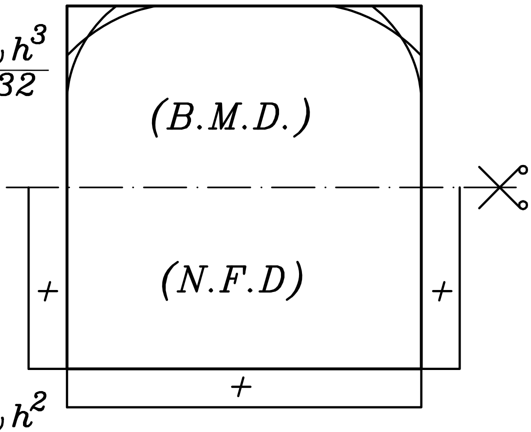
$$w\ (load\ in\ hz.\ direction)=\frac{Force\ on\ the\ tringle}{area\ of\ rectangle}$$

$$w=[\frac{\gamma_w h^3}{8}]/(h*h/2)$$

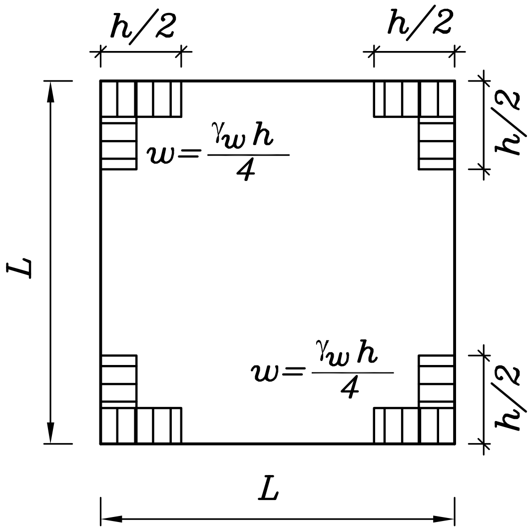
$$\boxed{w=\frac{\gamma_w h}{4} \qquad kN/m^2}$$

Strip (2) (hz. strip)

$$M=\frac{\gamma_w h}{4}\ \frac{h^2}{8}=\frac{\gamma_w h^3}{32}$$



$$T=\frac{\gamma_w h}{4}\ \frac{h}{2}=\frac{\gamma_w h^2}{8}$$



الخلاصة

(corner effect)يظهر فى حالة الحوائط (one way) فى الاتجاه الراسى فقط

للخزانات (rectangular) وفيه ناخذ شريحة افقية و يكون الحمل المؤثر عليها

$(w=\frac{\gamma_w h}{4})$ ويؤثر لمسافة (h) فى (cantilever walls) ويؤثر لمسافة (0.5h) فى الحوائط

(one way in vl. direction)

Example(6)

Given:

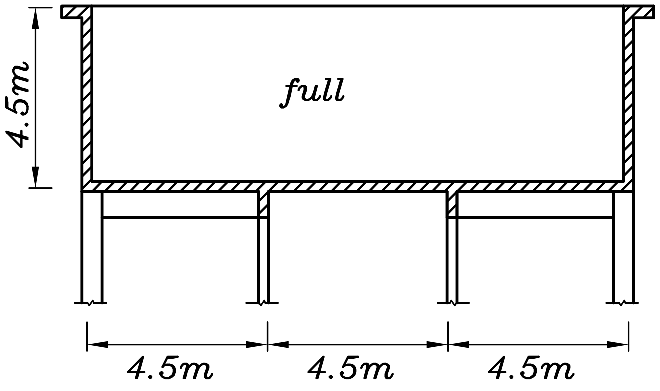
$f_{cu}=25\ N/mm^2$ &

steel used is 360/520

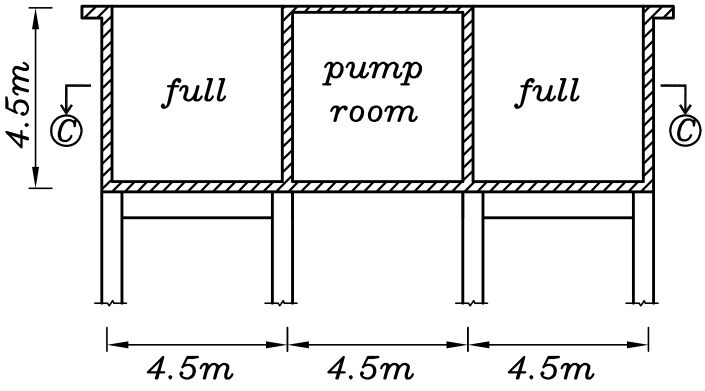
Required

1–Design the given tank.

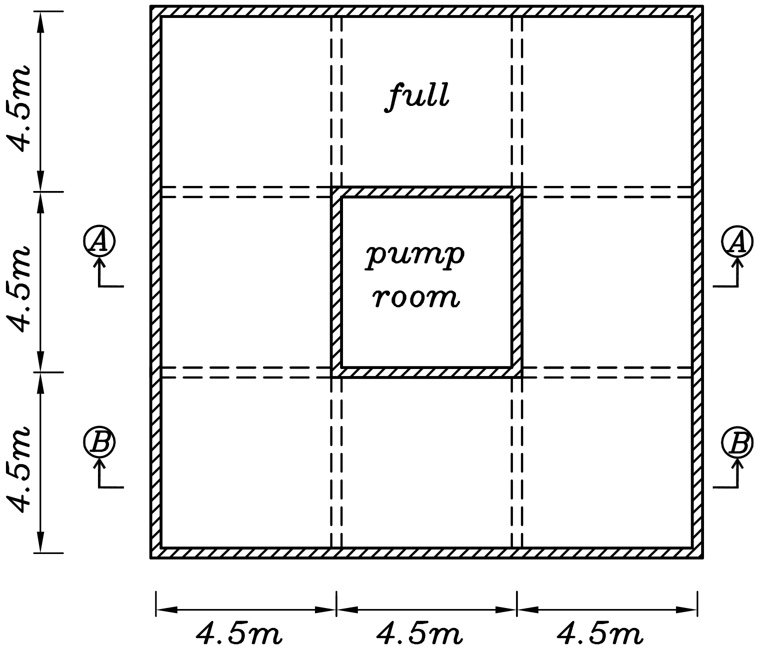
2–Calculate the loads acting on the top hz. beam.



sec (B–B)



sec (A–A)



sec (C–C)

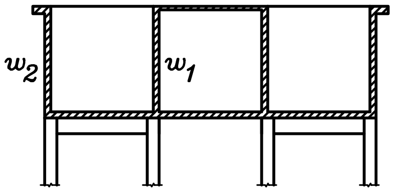
Solution

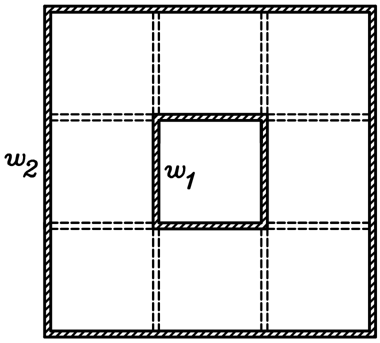
1- Concrete dimensions

$$t_w = t_f = \frac{L}{16} = \frac{450}{16} = 28.13 cm$$

$\Longrightarrow$ Take $t_w = t_f = 25 cm$, $t_{cover} = 15 cm$

2- Loads on floor





for outer floor (full of water)

$w_f = 0.25*25+10*4.5 = 51.25 \ kN/m^2$

for inner floor of pump room

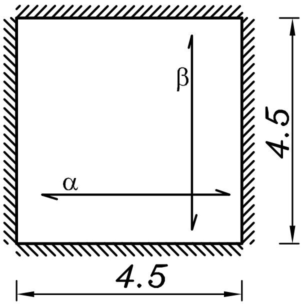
$w_f = 0.25*25 = 6.25 \ kN/m^2$

3- Load distribution

- for floor (4.5*4.5)

$r = \frac{0.76*4.5}{0.76*4.5} = 1.00$

$\alpha = \beta = 0.50$

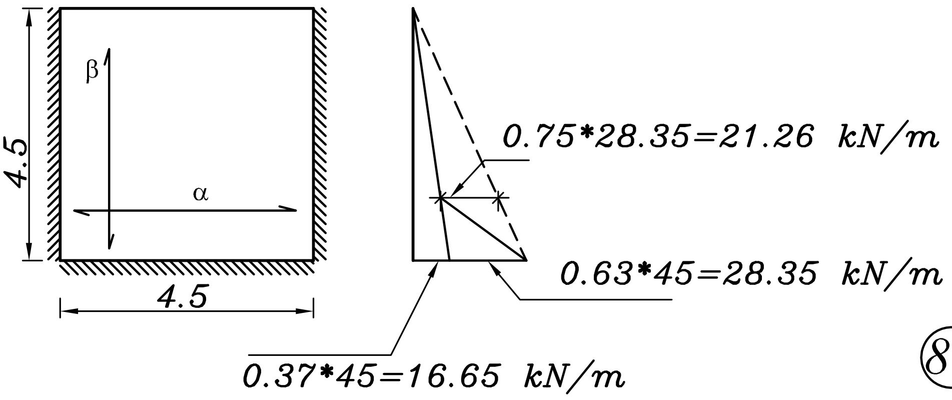


- Wall (1) (4.5*4.5)

$r = \frac{0.87*4.5}{0.76*4.5} = 1.14$

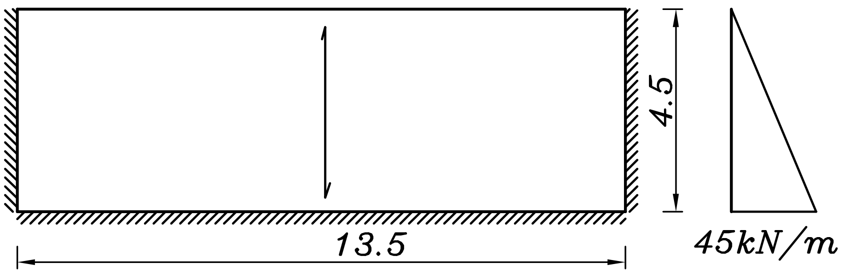
$\alpha = \frac{r^4}{1+r^4} = 0.63$

$\beta = \frac{1}{1+r^4} = 0.37$



– Wall (2) (13.5*4.5)

one way in vl. direction

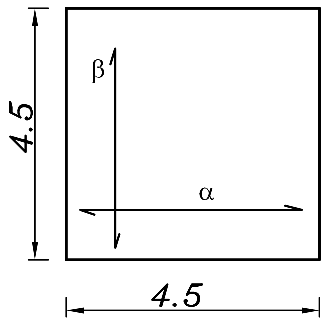


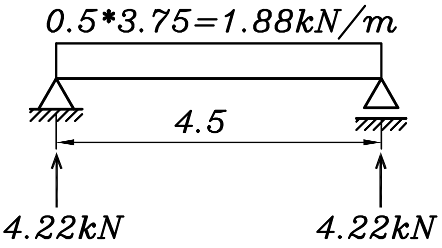
– Cover (4.5*4.5)

$$r=\frac{1*4.5}{1*4.5}=1.00$$

$$\alpha=\beta=0.50$$

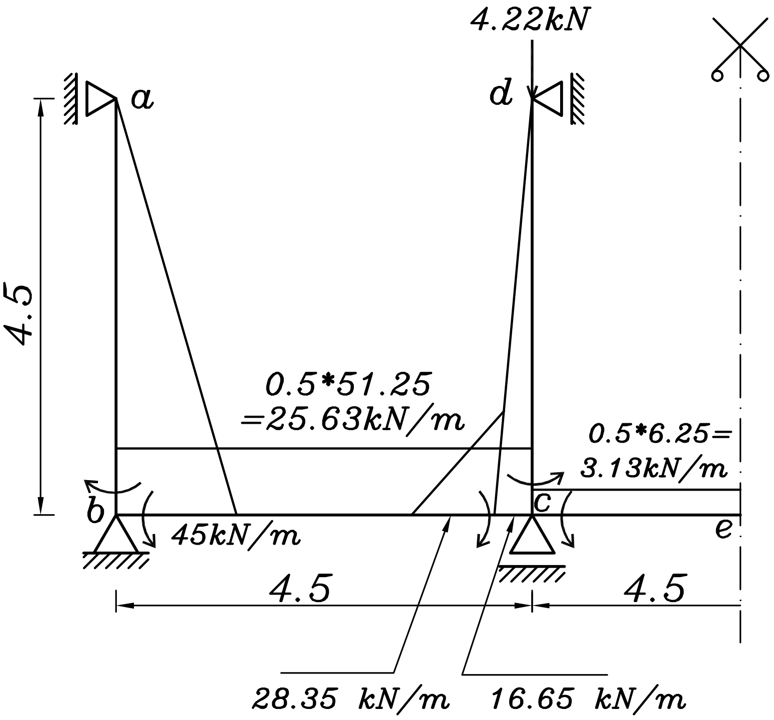
$$w_s=0.15*25=3.75 \ kN/m^2$$





4– Analysis of strips

– VL. strip (1) sec (A–A)



$$F.E.M._{ba}=\frac{45*(4.5)^2}{15}=60.75kN.m$$

$$F.E.M._{bc}=\frac{-25.63*(4.5)^2}{12}$$

$$F.E.M._{bc}=-43.25 \ kN.m$$

$$F.E.M._{cb}=43.25 \ kN.m$$

$$F.E.M._{ce}=\frac{-3.13*(4.5)^2}{12}$$

$$F.E.M._{ce}=-5.28 \ kN.m$$

$$F.E.M._{cd}=\frac{-16.65*(4.5)^2}{15}-\frac{28.35*(4.5)^2}{117}=-27.38kN.m$$

For Joint b

$$D.f_{ba}=\frac{0.75(I/4.5)}{0.75(I/4.5)+(I/4.5)}=0.43$$

$$D.f_{bc}=\frac{(I/4.5)}{0.75(I/4.5)+(I/4.5)}=0.57$$

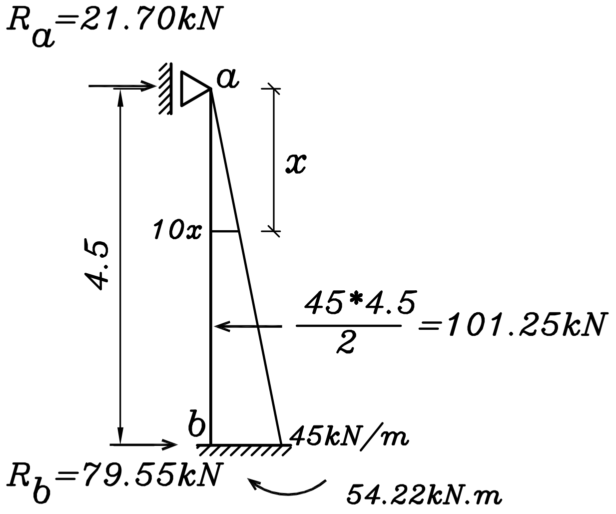
For Joint c

$$D.f_{cb}=\frac{(I/4.5)}{(I/4.5)+0.75(I/4.5)+0.5(I/4.5)}=0.44$$

$$D.f_{cd}=\frac{0.75(I/4.5)}{(I/4.5)+0.75(I/4.5)+0.5(I/4.5)}=0.33$$

$$D.f_{ce}=\frac{0.5(I/4.5)}{(I/4.5)+0.75(I/4.5)+0.5(I/4.5)}=0.23$$

Joint	b		c		
member	ba	bc	cb	cd	ce
D.f.	0.43	0.57	0.44	0.33	0.23
F.E.M.	60.75	−43.25	43.25	−27.38	−5.28
Bal.M.	−7.53	−9.98	−4.66	−3.49	−2.44
C.O.M.	0	−2.33	−4.99	0	0
Bal.M.	1.00	1.33	2.20	1.65	1.15
M_f	54.22	−54.22	35.80	−29.22	−6.57



Point of zero shear

$$(10x)*\frac{x}{2}=21.70 \Longrightarrow x=2.08m$$

$$\Longrightarrow M_{+ve}=21.70x-(10x)*(\frac{x^2}{6})$$

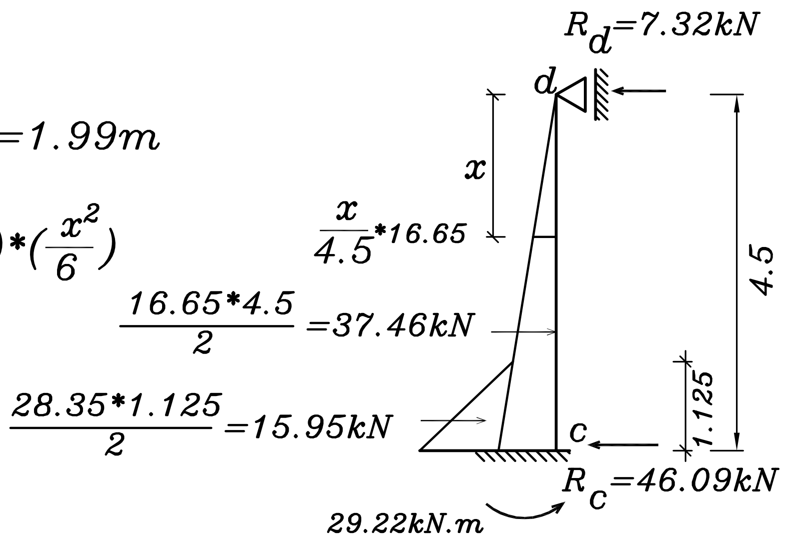
$$M_{+ve}=30.14 \ kN.m$$

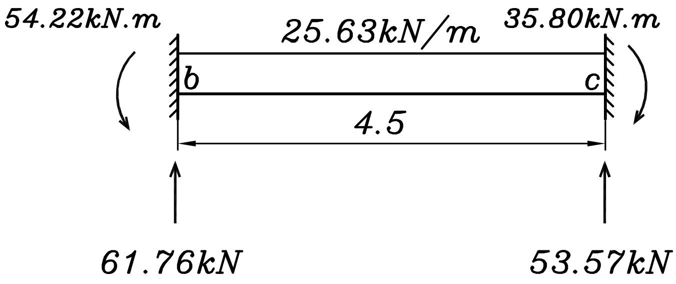
Point of zero shear

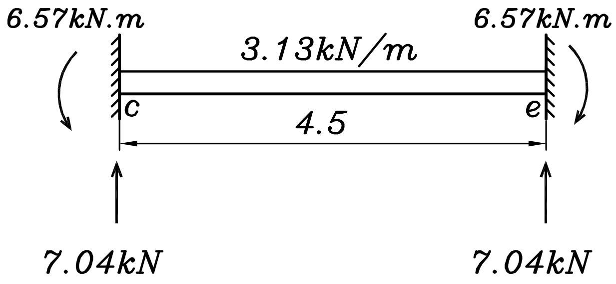
$$[\frac{x}{4.5}*16.65]*\frac{x}{2}=7.32 \Longrightarrow x=1.99m$$

$$\Longrightarrow M_{+ve}=7.32x-(\frac{x}{4.5}*16.65)*(\frac{x^2}{6})$$

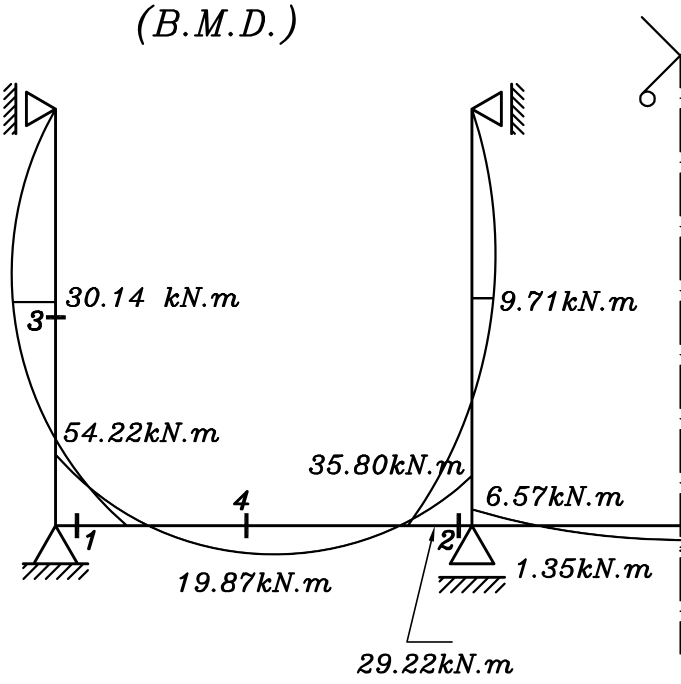
$$M_{+ve}=9.71 \quad kN.m$$



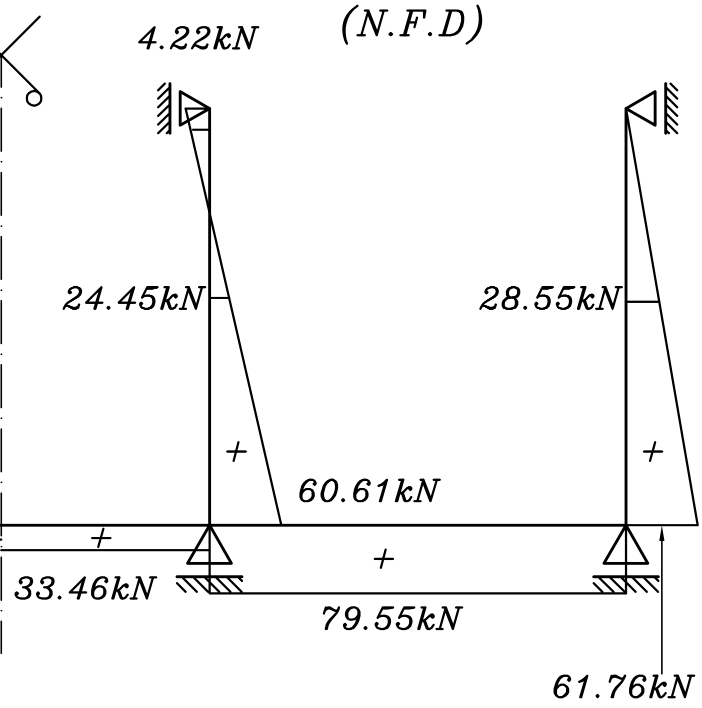




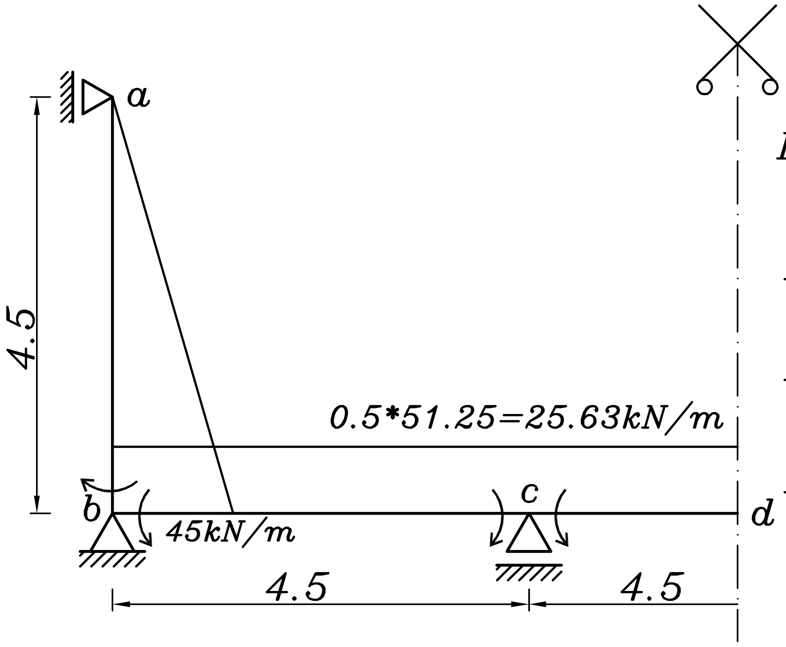
(B.M.D.)



(N.F.D)



– VL. strip (2) sec (B–B)



$$F.E.M._{ba} = \frac{45*(4.5)^2}{15} = 60.75 kN.m$$

$$F.E.M._{\substack{bc\\cd}} = \frac{-25.63*(4.5)^2}{12}$$

$$F.E.M._{\substack{bc\\cd}} = -43.25 \; kN.m$$

$$F.E.M._{cb} = 43.25 \; kN.m$$

For Joint b

$$D.f_{ba} = \frac{0.75(I/4.5)}{0.75(I/4.5)+(I/4.5)} = 0.43$$

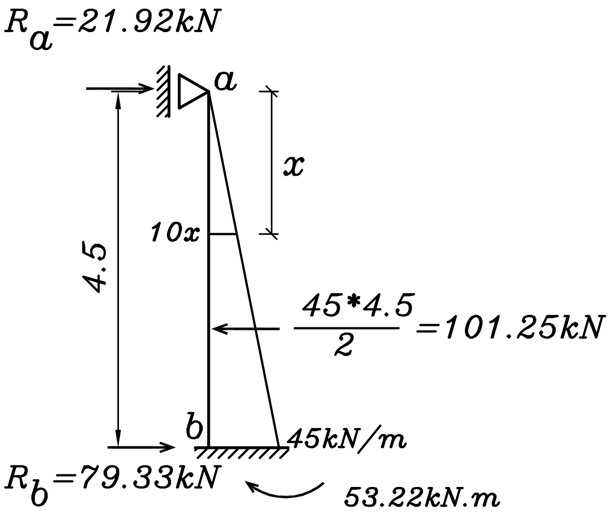
$$D.f_{bc} = \frac{(I/4.5)}{0.75(I/4.5)+(I/4.5)} = 0.57$$

For Joint c

$$D.f_{cb} = \frac{(I/4.5)}{(I/4.5)+0.5(I/4.5)} = 0.67$$

$$D.f_{cd} = \frac{0.5(I/4.5)}{(I/4.5)+0.5(I/4.5)} = 0.33$$

Joint	b		c	
member	ba	bc	cb	cd
D.f.	0.43	0.57	0.67	0.33
F.E.M.	60.75	−43.25	43.25	−43.25
Bal.M.	−7.53	−9.98	0	0
C.O.M.	0	0	−4.99	0
Bal.M.	0	0	3.34	1.65
M_f	53.22	−53.22	41.60	−41.60

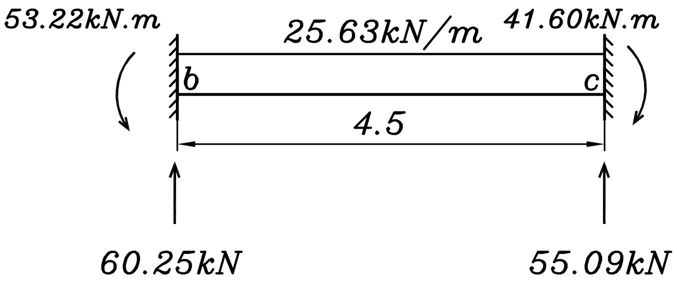


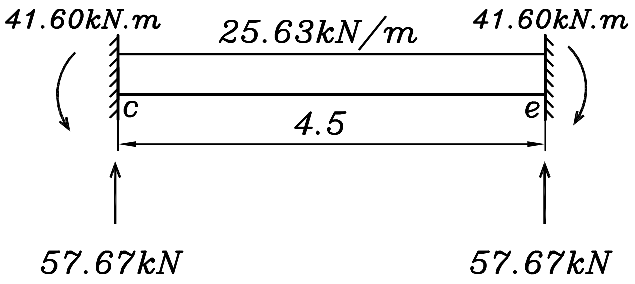
Point of zero shear

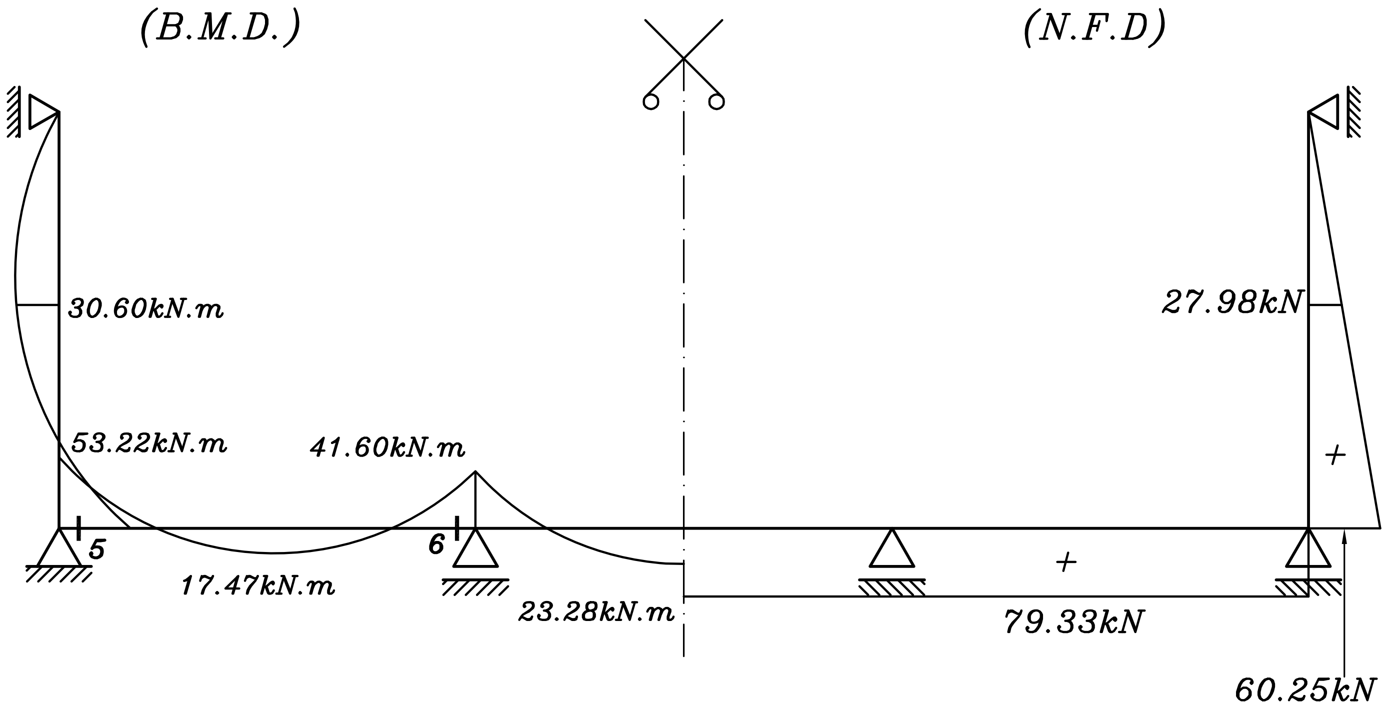
$$(10x)*\frac{x}{2}=21.92 \Longrightarrow x=2.09m$$

$$\Longrightarrow M_{+ve}=21.92x-(10x)*(\frac{x^2}{6})$$

$$M_{+ve}=30.60 \ kN.m$$

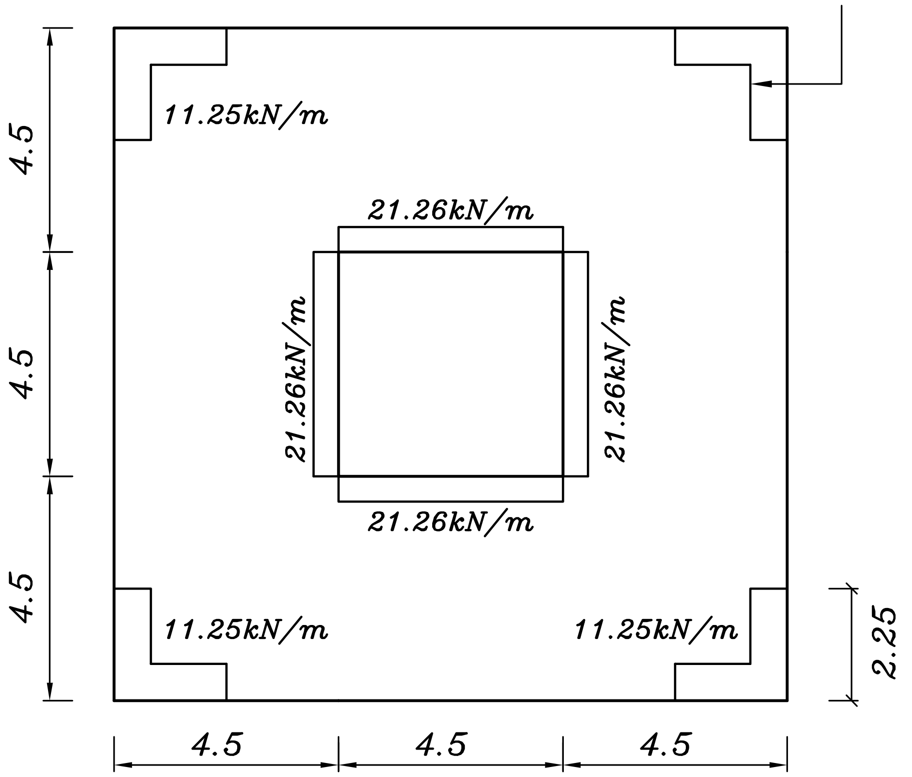


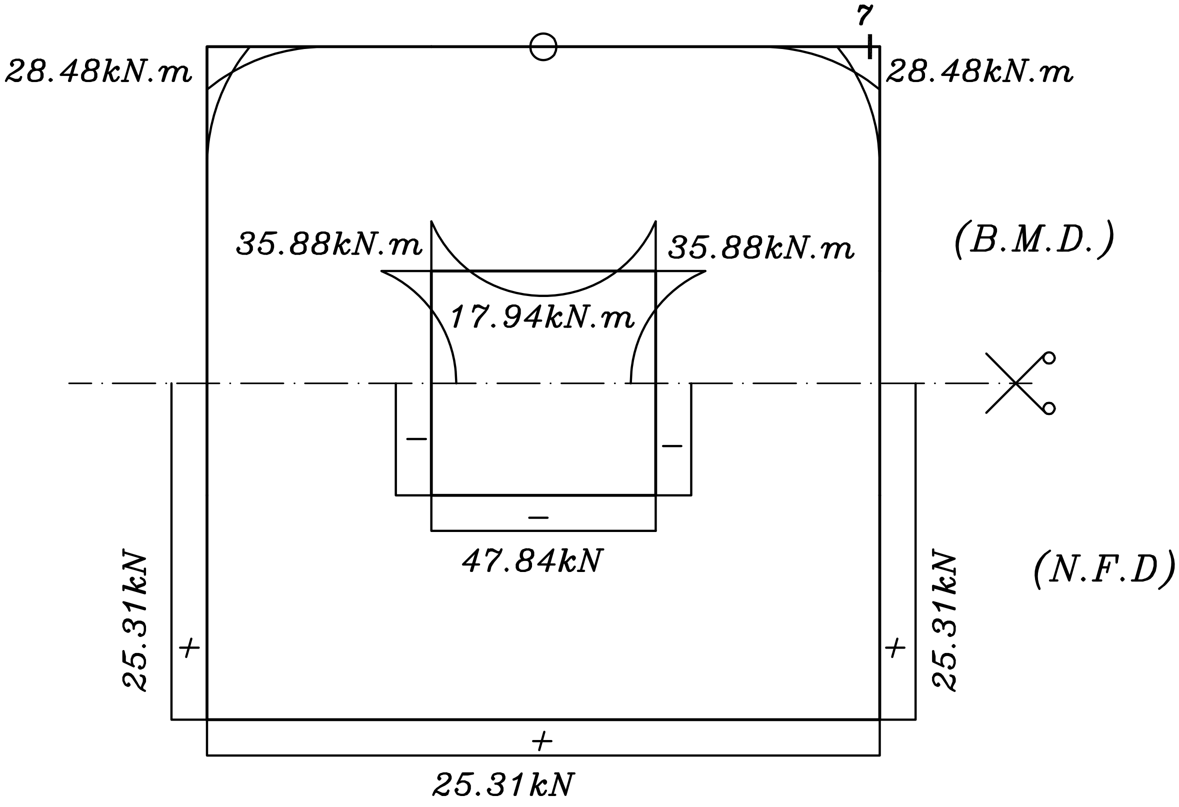




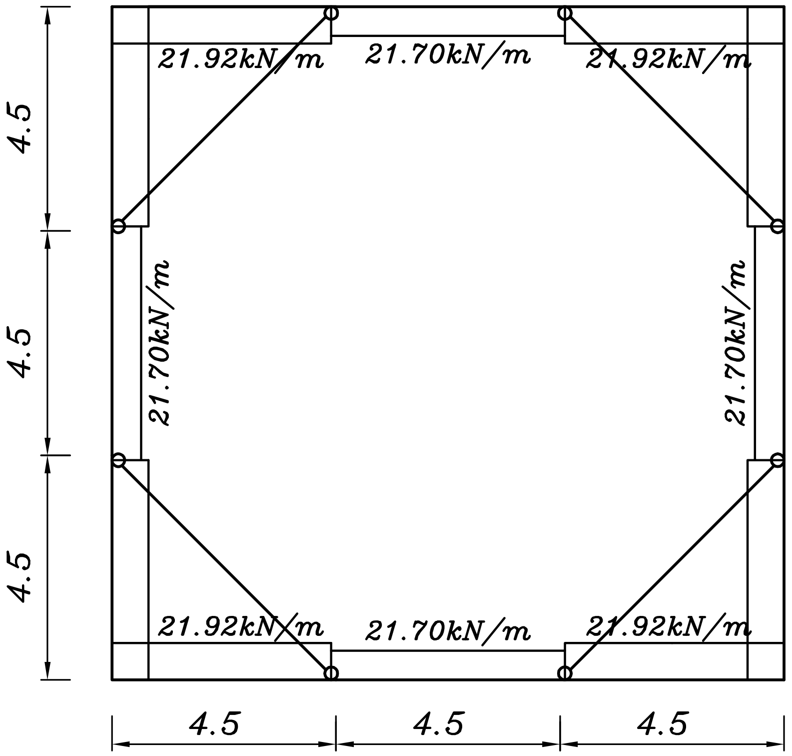
- HZ. strip (3) at h=1.125 sec (C-C)

$$\frac{\gamma_w h}{4} = \frac{10*4.5}{4} = 11.25kN/m$$

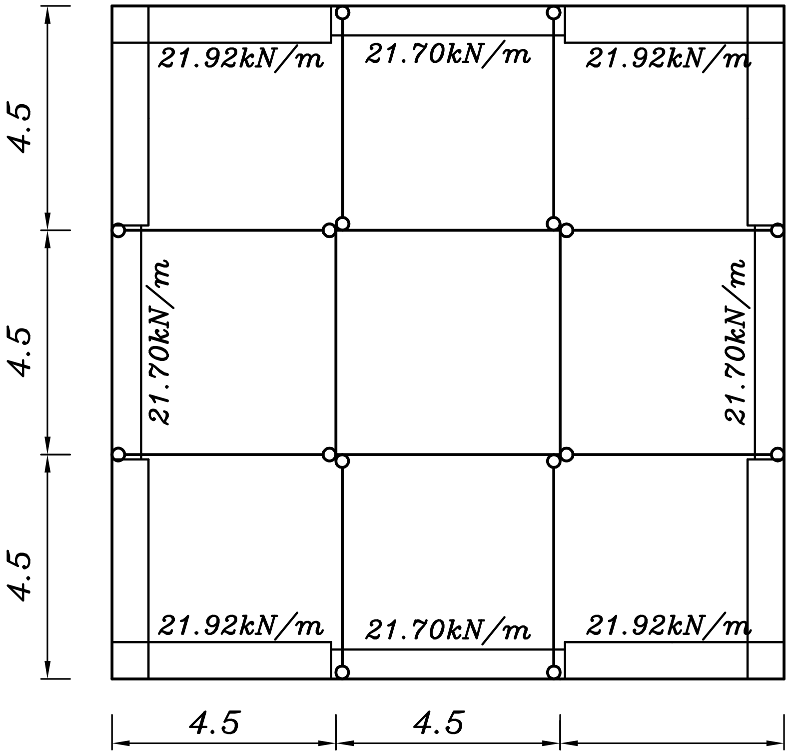




– Loads on top hz. beam



–Alternative solution



5- Design of sections

Sec (1-1) water section

$M_{working}=54.22\ kN.m$, $T_{working}=79.55\ kN$, $b=1000mm$

Stage (I)

$$t_{(mm)}=\sqrt{\frac{M*10^3}{factor}}+40mm=\sqrt{\frac{54.22*10^3}{0.28}}+40mm=480.05mm$$

$\Longrightarrow$ Take $t\ =500mm$

Check stresses

$$f_t=+\frac{T}{A}+\frac{M}{Z}=+\frac{79.55*10^3}{1000*500}+\frac{54.22*10^6}{1000*(500)^2/6}$$

$$=0.16+1.30=1.46\ N/mm^2$$

$\Longrightarrow f_{ct}=\frac{0.6\sqrt{25}}{1.7}=1.76N/mm^2 \quad \Longrightarrow f_t < f_{ct}$ (safe)

Stage (II)

$M_{u.l.}=1.5*54.22=81.33\ kN.m$, $T_{u.l.}=1.5*79.55=119.33\ kN$

$$e=\frac{M_{u.l.}}{T_{u.l.}}=\frac{81.33}{119.33}=0.68m > \frac{t}{2}-cover$$

$$e_s=e-\frac{t}{2}+c=0.68-\frac{0.50}{2}+0.04=0.47m$$

$$M_{us}=119.33*0.47=56.09kN.m$$

$$460=C_1\sqrt{\frac{56.09*10^6}{1000*25}} \qquad C_1=9.71 \quad \& \quad J=0.826$$

$$A_s=\frac{1}{\beta_{cr}}*[\frac{M_{us}}{J*d*f_y}+\frac{T_{u.l.}}{f_y/\gamma_s}]$$

assume $\phi 16$ used $\Longrightarrow$ $\beta_{cr}=0.75$

$$A_s=\frac{1}{0.75}\left[\frac{56.09*10^6}{0.826*460*360}+\frac{119.33*10^3}{360/1.15}\right]$$

$A_s=1055.00mm^2/m' \Longrightarrow 6\phi 16/m'$

Sec (2-2) water section

$M_{working}=35.80$ kN.m , $T_{working}=79.55$ kN , b=1000mm

t=400mm , $A_s=5\phi 16/m'$

Sec (3-3) air section , t=250mm

$M_{working}=30.14$ kN.m , $T_{working}=28.55$ kN , b=1000mm

$A_s=8\phi 12/m'$

Sec (4-4) air section , t=250mm

$M_{working}=19.87$ kN.m , $T_{working}=79.55$ kN , b=1000mm

$A_s=7\phi 12/m'$

Sec (5-5) water section

$M_{working}=53.22$ kN.m , $T_{working}=79.33$ kN , b=1000mm

t=500mm , $A_s=6\phi 16/m'$

Sec (6-6) water section

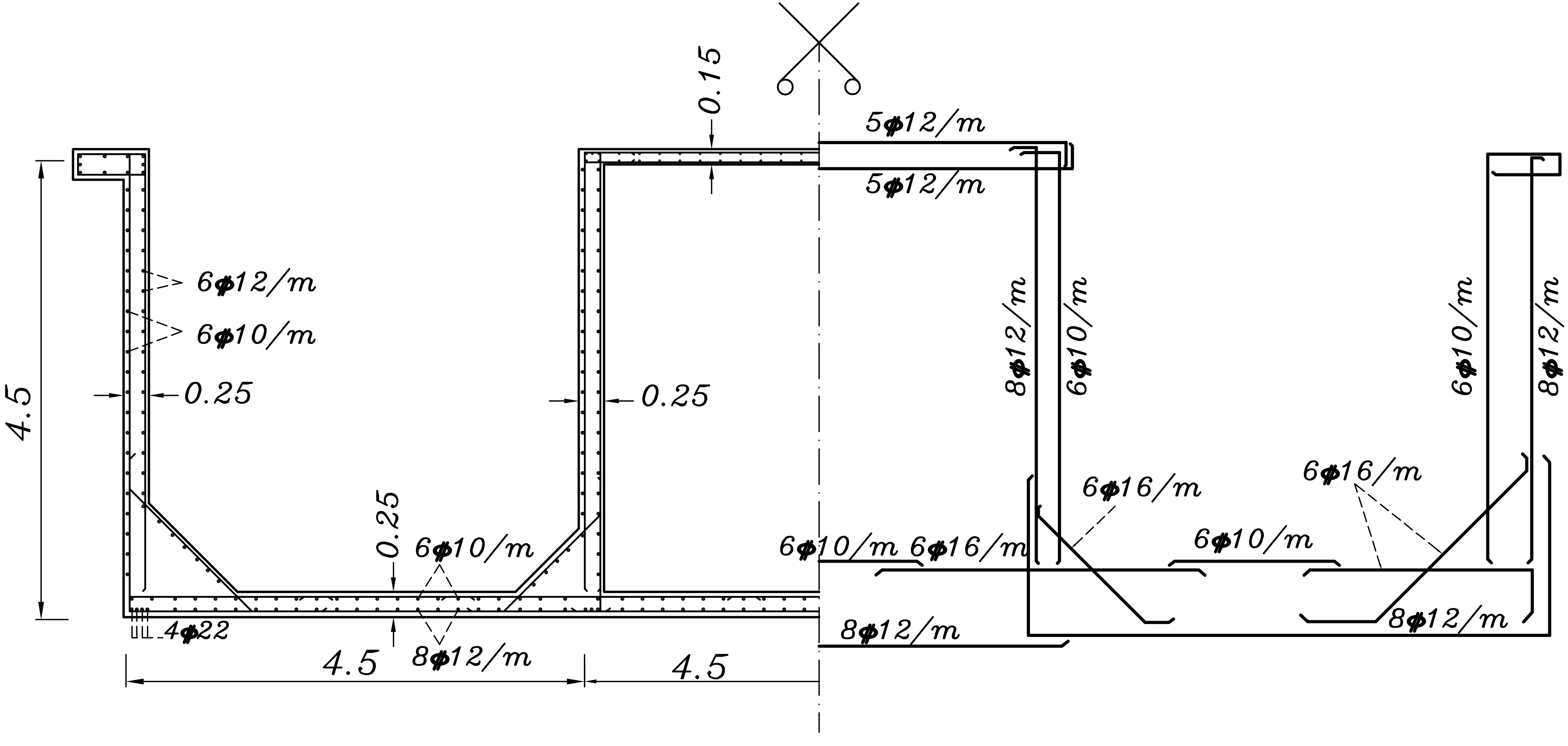
$M_{working}=41.60$ kN.m , $T_{working}=79.33$ kN , b=1000mm

t=400mm , $A_s=6\phi 16/m'$

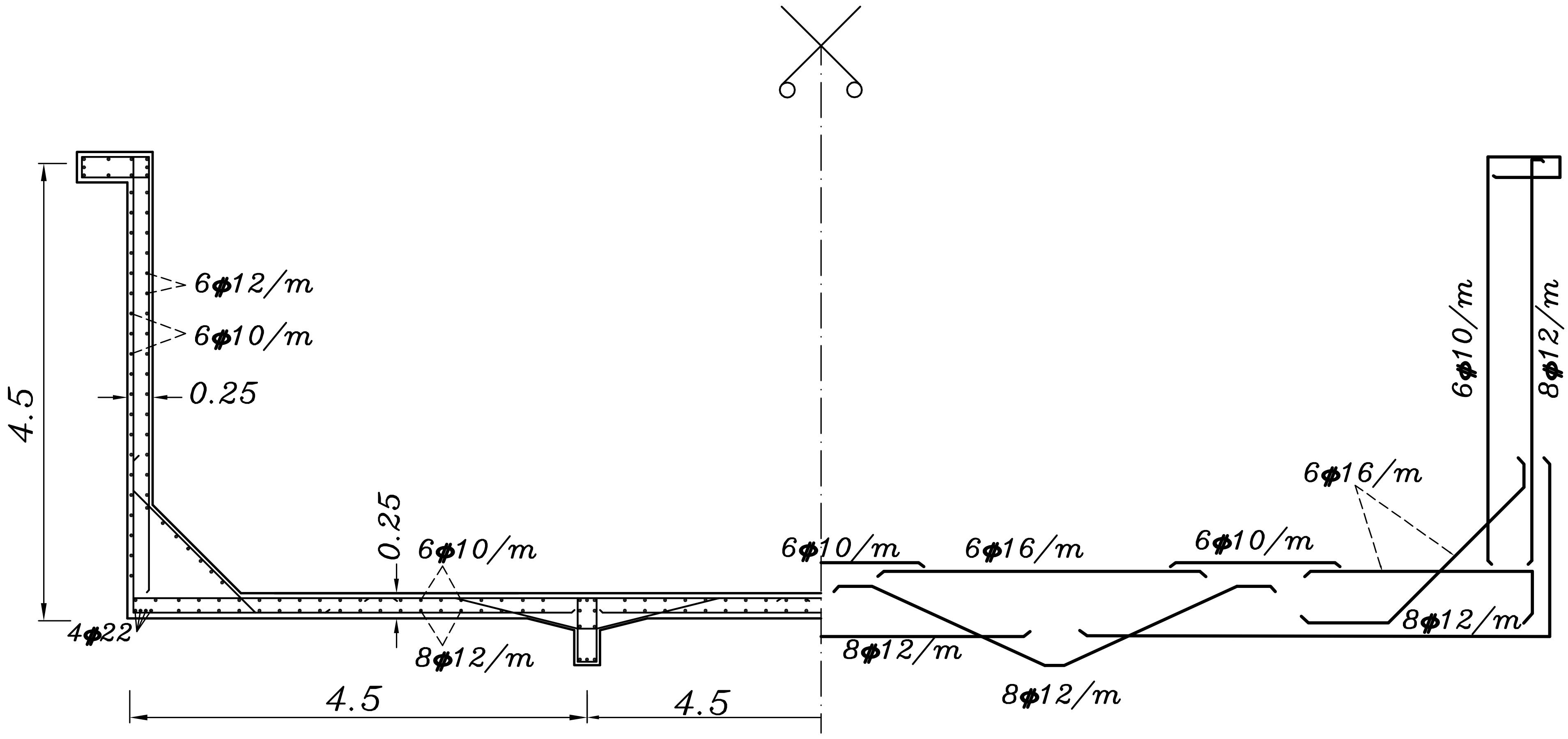
Sec (7-7) water section

t=350mm , $A_s=6\phi 12/m'$

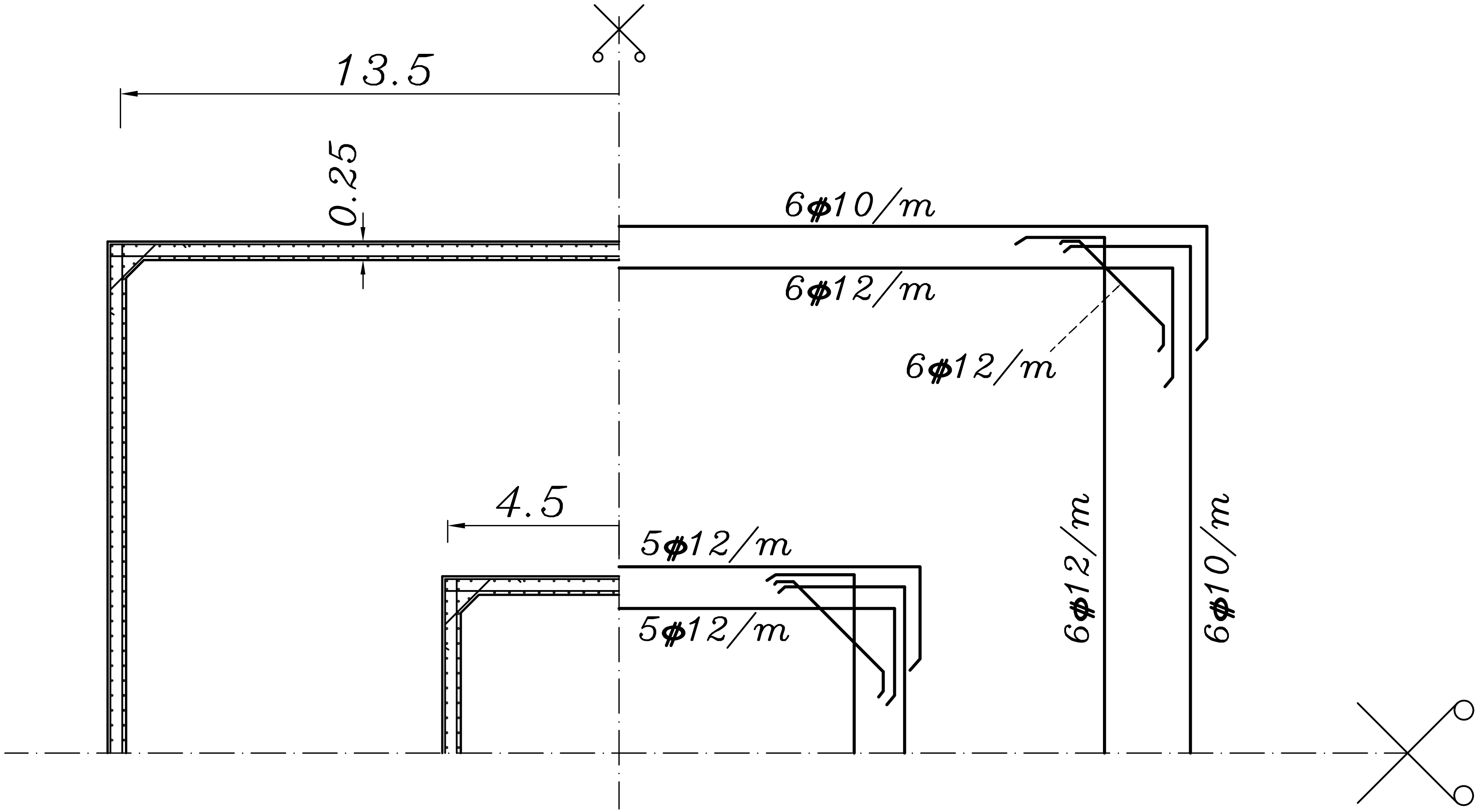
Details of RFT.



VL. strip (1)


6ϕ12/m
6ϕ10/m
0.25
4.5
4ϕ22
0.25
6ϕ10/m
8ϕ12/m
4.5
4.5
6ϕ10/m
6ϕ16/m
6ϕ10/m
6ϕ16/m
8ϕ12/m
8ϕ12/m
8ϕ12/m
6ϕ10/m
8ϕ12/m

VL. strip (2)



Hz. strip (3)

Example(7) *(M.T. public works 2004)*

Given:

$f_{cu}=25\ N/mm^2$ &

steel used is 360/520

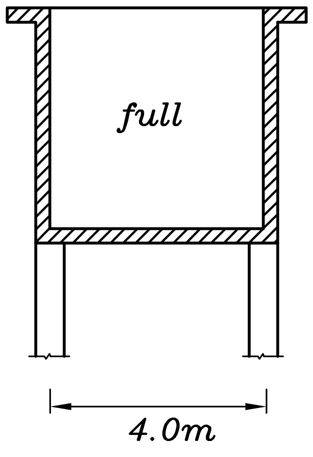
Required

1–*Draw the load diagram for the vertical sections (A–A) , (B–B) & hz. section (C–C)*

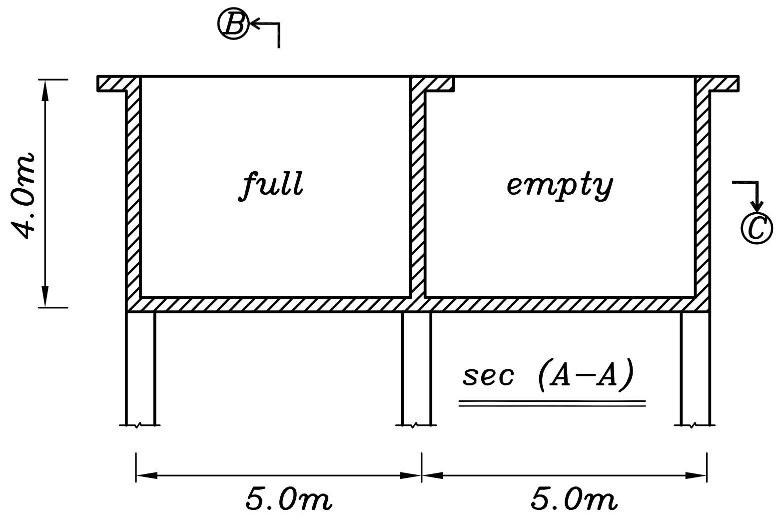
2–*Calculate the internal forces and design section (A–A) , (C–C)*

3–*Draw the load diagram for the top hz. beam.*

4–*Draw to a convenient scale details of RFT for sections (A–A) & (C–C)*

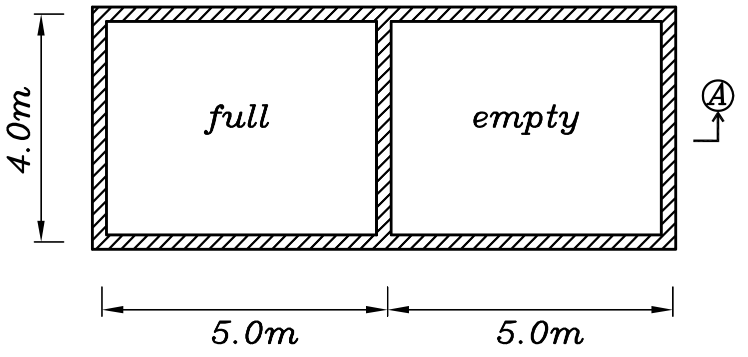


sec (B–B)



sec (A–A)

sec (C–C)



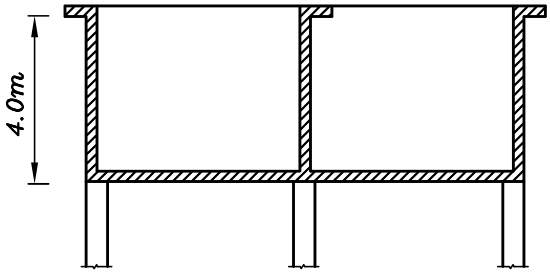
Solution

1- Concrete dimensions

$$t_w = t_f = \frac{L}{16} = \frac{400}{16} = 25cm$$

$\Longrightarrow$ Take $t_w = t_f = 25cm$

2- Loads on floor

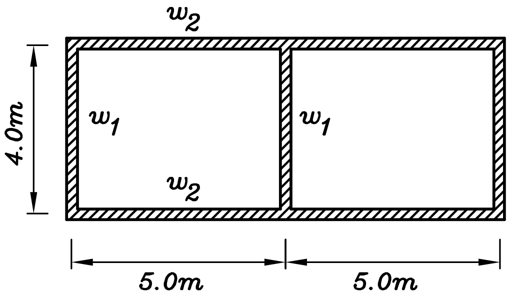


for floor (full of water)

$$w_f = 0.25*25+10*4.0=46.25 \ kN/m^2$$

for empty floor

$$w_f = 0.25*25=6.25 \ kN/m^2$$



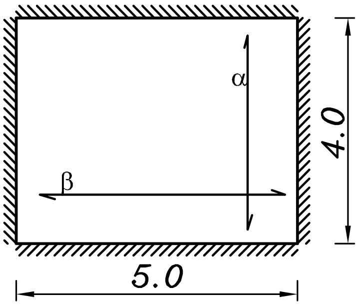
3- Load distribution

- for floor (4.0*5.0)

$$r = \frac{0.76*5.0}{0.76*4.0} = 1.25$$

$$\alpha = \frac{r^4}{1+r^4} = 0.71$$

$$\beta = \frac{1}{1+r^4} = 0.29$$

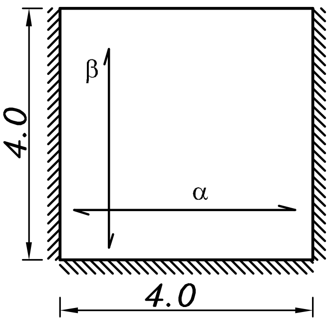


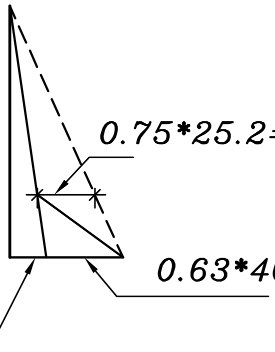
- Wall (1) (4.0*4.0)

$$r = \frac{0.87*4.0}{0.76*4.0} = 1.14$$

$$\alpha = \frac{r^4}{1+r^4} = 0.63$$

$$\beta = \frac{1}{1+r^4} = 0.37$$





$0.75*25.2=18.9 \ kN/m$

$0.63*40=25.2 \ kN/m$

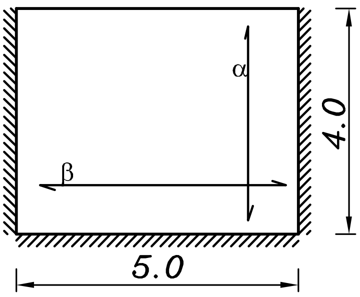
$0.37*40=14.8 \ kN/m$

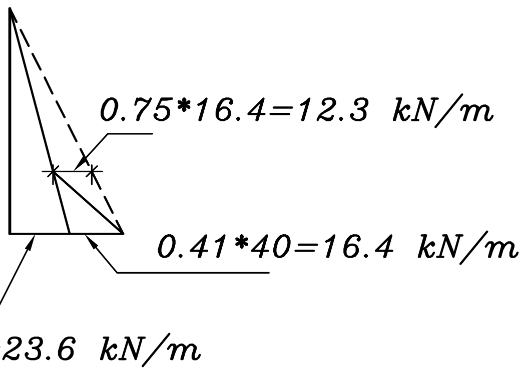
– Wall (2) (5.0*4.0)

$$r=\frac{0.76*5.0}{0.87*4.0}=1.09$$

$$\alpha=\frac{r4}{1+r^4}=0.59$$

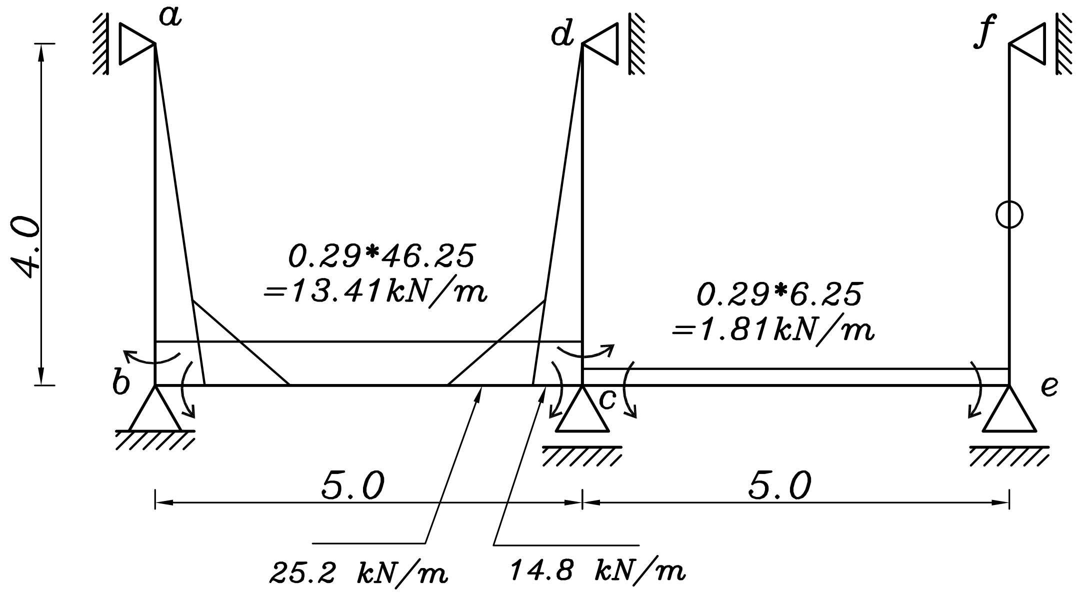
$$\beta=\frac{1}{1+r^4}=0.41$$





4– Analysis of strips

– VL. strip (1) sec (A–A)



For Joint b , e

$$D.f_{ba}=D.f_{ef}=\frac{0.75(I/4.0)}{0.75(I/4.0)+(I/5.0)}=0.48$$

$$D.f_{bc}=D.f_{ec}=\frac{(I/5.0)}{0.75(I/4.0)+(I/5.0)}=0.52$$

For Joint c

$$D.f_{\substack{cb\\ce}}=\frac{(I/5.0)}{(I/5.0)+0.75(I/4.0)+(I/5.0)}=0.34$$

$$D.f_{cd}=\frac{0.75(I/4.0)}{(I/5.0)+0.75(I/4.0)+(I/5.0)}=0.32$$

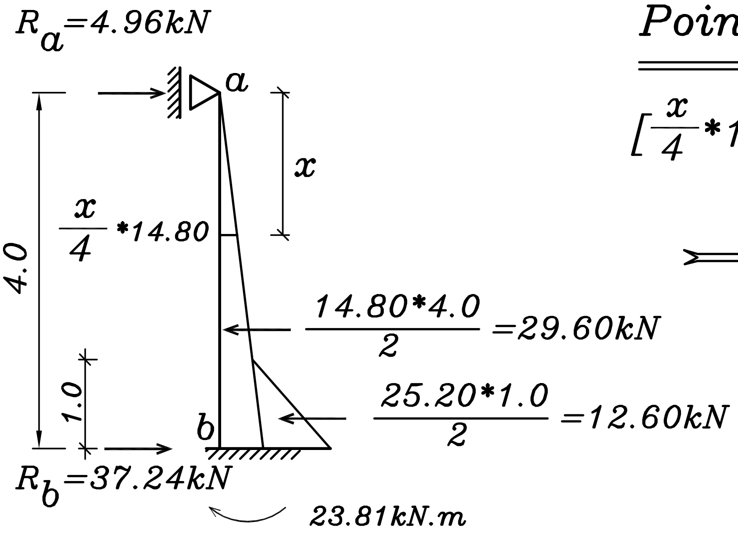
$$F.E.M._{ba}=\frac{14.80*(4)^2}{15}+\frac{25.20*(4)^2}{117}=19.23kN.m$$

$$F.E.M._{cd}=-19.23kN.m$$

$$F.E.M._{bc}=\frac{-13.41*(5)^2}{12}=-27.94kN.m \quad \& \quad F.E.M._{cb}=27.94kN.m$$

$$F.E.M._{ce}=\frac{-1.81*(5)^2}{12}=-3.77kN.m \quad \& \quad F.E.M._{ec}=3.77kN.m$$

Joint	b		c			e	
member	ba	bc	cb	cd	ce	ec	ef
D.f.	0.48	0.52	0.34	0.32	0.34	0.52	0.48
F.E.M.	19.23	−27.94	27.94	−19.23	−3.77	3.77	0
Bal.M.	4.18	4.53	−1.68	−1.58	−1.68	−1.96	−1.81
C.O.M.	0	−0.84	2.27	0	−0.98	−0.84	0
Bal.M.	0.40	0.44	−0.44	−0.41	−0.44	0.44	0.40
M_f	23.81	−23.81	28.09	−21.22	−6.87	1.41	−1.41



Point of zero shear

$$[\frac{x}{4}*14.80]*\frac{x}{2}=4.96 \Longrightarrow x=1.64m$$

$$\Longrightarrow M_{+ve}=4.96x-(\frac{x}{4}*14.80)*(\frac{x^2}{6})$$

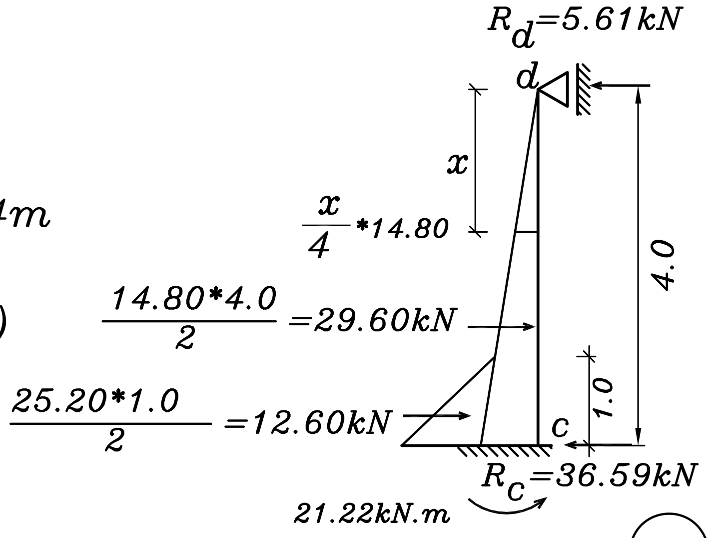
$$M_{+ve}=5.41 \quad kN.m$$

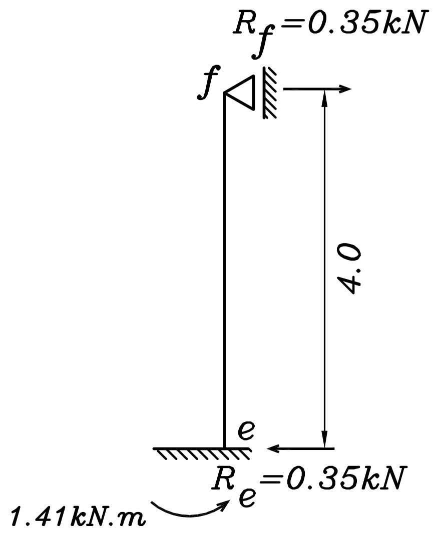
Point of zero shear

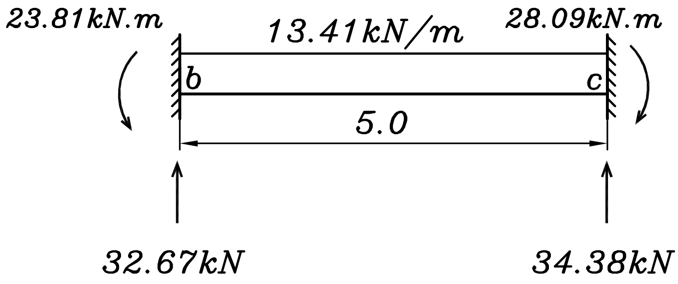
$$[\frac{x}{4}*14.80]*\frac{x}{2}=5.61 \Longrightarrow x=1.74m$$

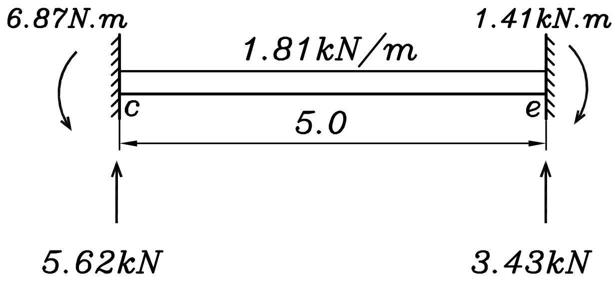
$$\Longrightarrow M_{+ve}=5.61x-(\frac{x}{4}*14.80)*(\frac{x^2}{6})$$

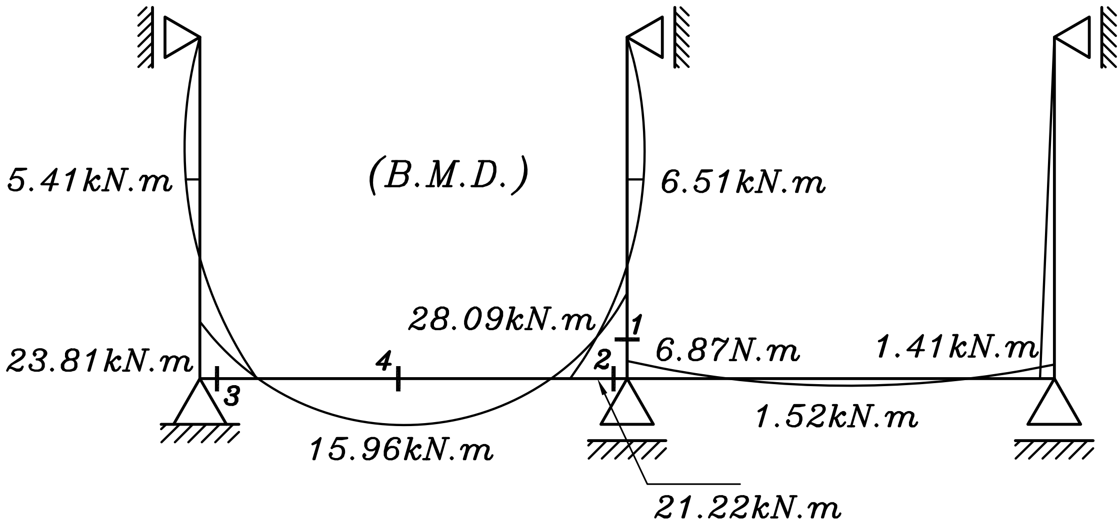
$$M_{+ve}=6.51 \quad kN.m$$

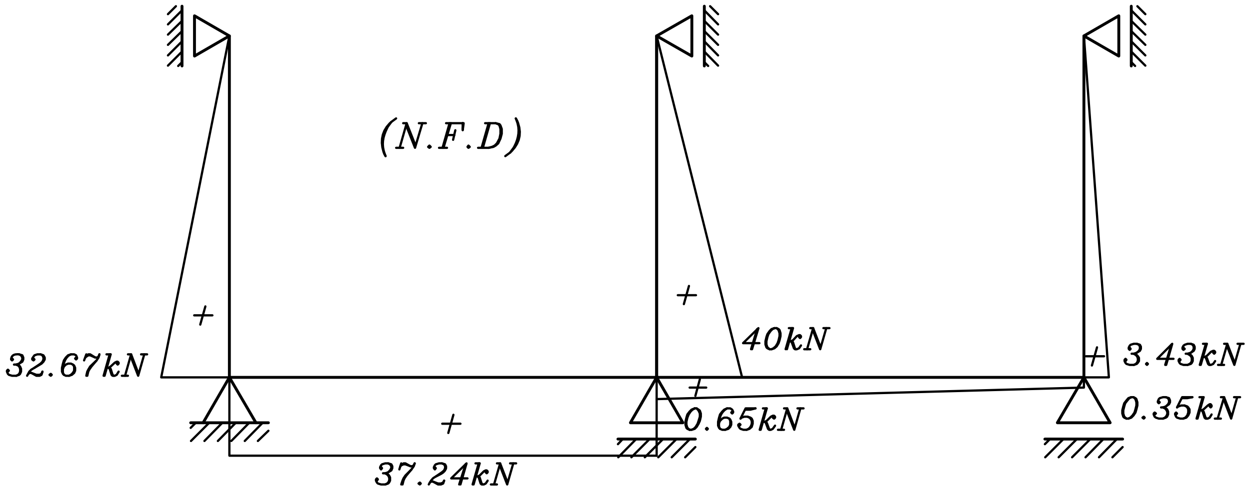



R_f=0.35kN
f
4.0
e
R_e=0.35kN
1.41kN.m


23.81kN.m
13.41kN/m
28.09kN.m
b
c
5.0
32.67kN
34.38kN

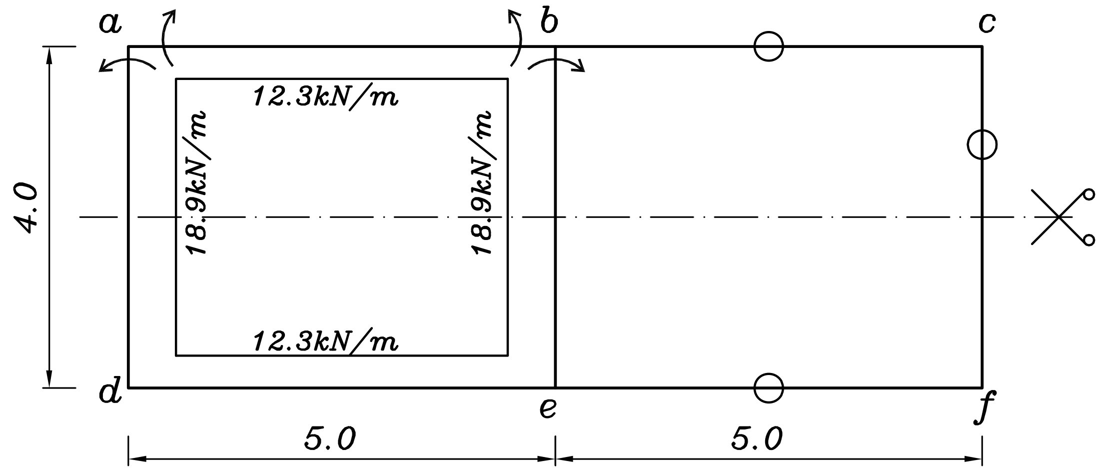

6.87N.m
1.81kN/m
1.41kN.m
c
e
5.0
5.62kN
3.43kN


(B.M.D.)
5.41kN.m
6.51kN.m
28.09kN.m
1
23.81kN.m
4
2
6.87N.m
1.41kN.m
3
15.96kN.m
1.52kN.m
21.22kN.m


(N.F.D)
+
+
32.67kN
40kN
+
3.43kN
+
0.35kN
+
0.65kN
37.24kN

– HZ. strip (2) at h=1.0

sec (C–C)



For Joint a , c

$$D.f_{ad}=D.f_{cf}=\frac{0.5(I/4.0)}{0.5(I/4.0)+(I/5.0)}=0.38$$

$$D.f_{ab}=D.f_{cb}=\frac{(I/5.0)}{0.5(I/4.0)+(I/5.0)}=0.62$$

For Joint b

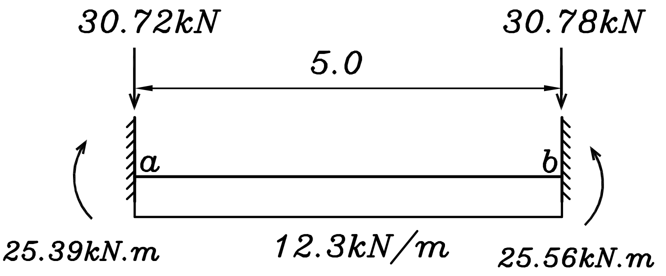
$$D.f_{\substack{ba\\bc}}=\frac{(I/5.0)}{(I/5.0)+0.5(I/4.0)+(I/5.0)}=0.38$$

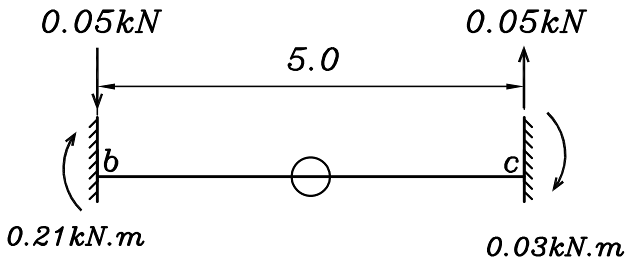
$$D.f_{be}=\frac{0.5(I/4.0)}{(I/5.0)+0.5(I/4.0)+(I/5.0)}=0.24$$

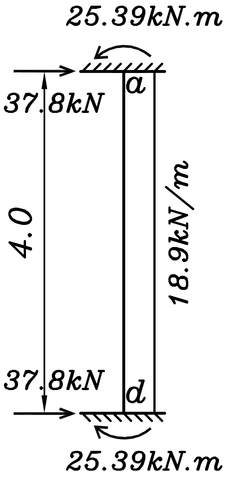
$$F.E.M._{ad}=\frac{-18.90*(4)^2}{12}=-25.20kN.m \quad \& \quad F.E.M._{be}=25.20kN.m$$

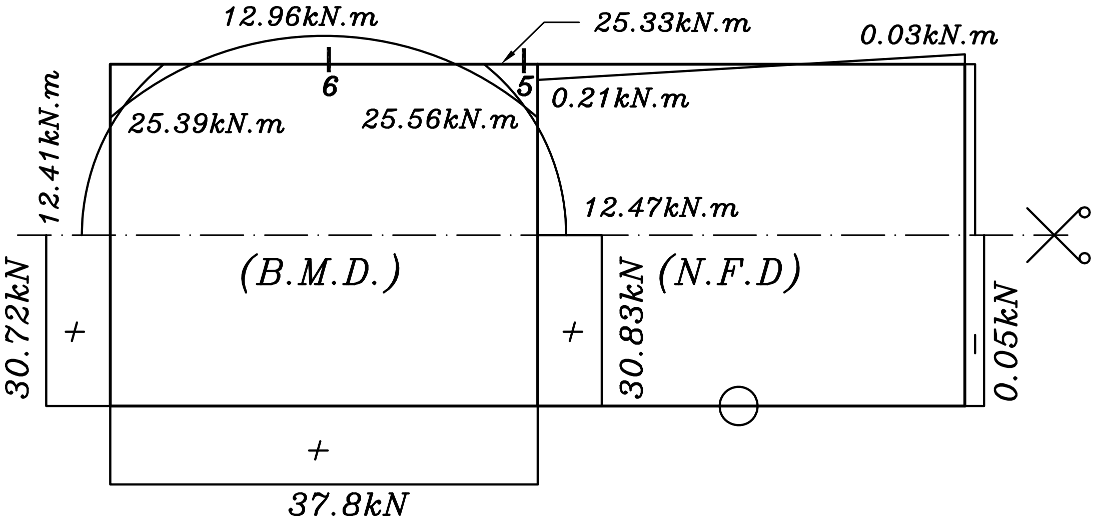
$$F.E.M._{ab}=\frac{12.30*(5)^2}{12}=25.63kN.m \quad \& \quad F.E.M._{ba}=-25.63kN.m$$

Joint	a		b			c	
member	ad	ab	ba	be	bc	cb	cf
D.f.	0.38	0.62	0.38	0.24	0.38	0.62	0.38
F.E.M.	–25.20	25.63	–25.63	25.20	0	0	0
Bal.M.	–0.16	–0.27	0.16	0.10	0.16	0	0
C.O.M.	0	0.08	–0.14	0	0	0.08	0
Bal.M.	–0.03	–0.05	0.05	0.03	0.05	–0.05	–0.03
M_f	–25.39	25.39	–25.56	25.33	0.21	0.03	–0.03

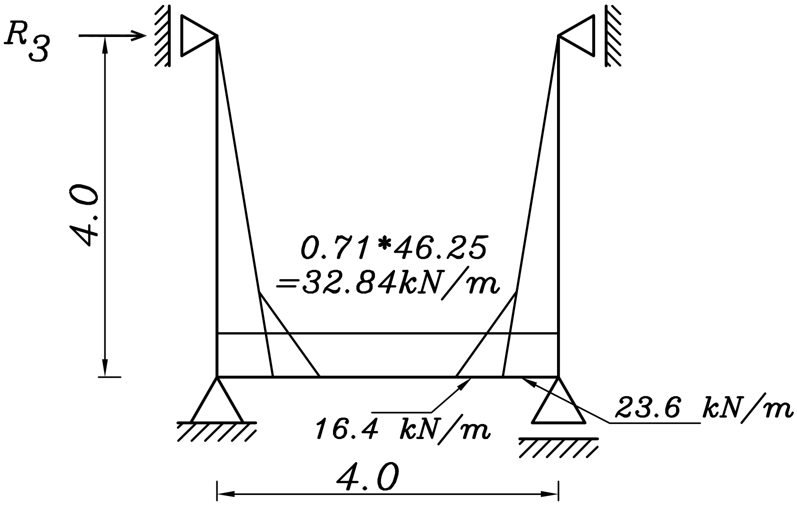




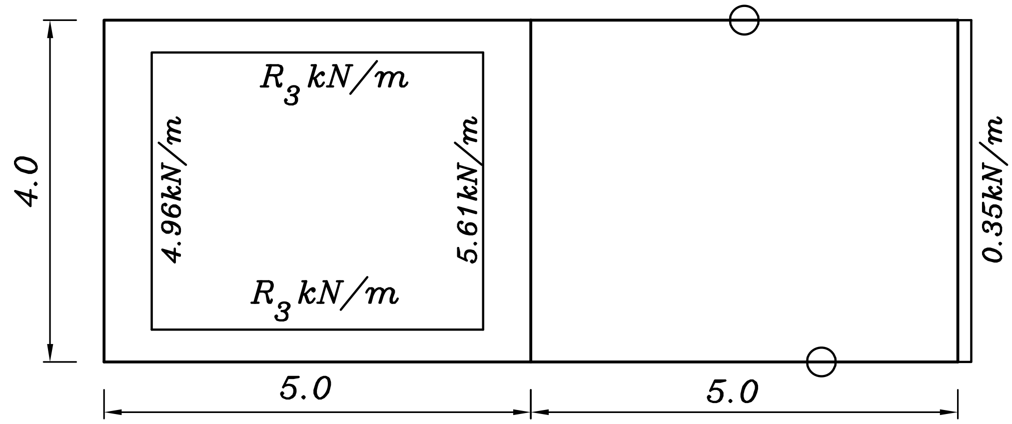




− VL. strip (3) sec (B−B)



− Loads on top hz. beam



5- Design of sections

Sec (1-1) water section

$M_{working}=21.22\ kN.m$, $T_{working}=40.00\ kN$, $b=1000mm$

Stage (I)

$$t_{(mm)}=\sqrt{\frac{M*10^3}{factor}}+40mm=\sqrt{\frac{21.22*10^3}{0.30}}+40mm=305.96mm$$

$\Longrightarrow$ Take $t\ =300mm$

Check stresses

$$f_t=+\frac{T}{A}+\frac{M}{Z}=+\frac{40.00*10^3}{1000*300}+\frac{21.22*10^6}{1000*(300)^2/6}$$

$$=0.13+1.41=1.54\ N/mm^2$$

$\Longrightarrow f_{ct}=\frac{0.6\sqrt{25}}{1.6}=1.88N/mm^2$ $\Longrightarrow f_t < f_{ct}$ (safe)

Stage (II)

$M_{u.l.}=1.5*21.22=31.83\ kN.m$, $T_{u.l.}=1.5*40.00=60.00\ kN$

$$e=\frac{M_{u.l.}}{T_{u.l.}}=\frac{31.83}{60.00}=0.53m>\frac{t}{2}-cover$$

$$e_s=e-\frac{t}{2}+c=0.53-\frac{0.30}{2}+0.04=0.42m$$

$M_{us}=60*0.42=25.2\ kN.m$

$$260=C_1\sqrt{\frac{25.20*10^6}{1000*25}}\qquad C_1=8.19\quad \&\quad J=0.826$$

$$A_s=\frac{1}{\beta_{cr}}*[\frac{M_{us}}{J*d*f_y}+\frac{T_{u.l.}}{f_y/\gamma_s}]$$

assume $\phi 12$ used $\Longrightarrow$ $\beta_{cr}=0.85$

$$A_s=\frac{1}{0.85}\left[\frac{25.20*10^6}{0.826*260*360}+\frac{60.00*10^3}{360/1.15}\right]$$

$A_s=608.96mm^2/m' \Longrightarrow 6\phi 12/m'$

Sec (2−2) water section

$M_{working}=28.09$ kN.m , $T_{working}=37.24$ kN , $b=1000mm$

$t=350mm$, $A_s=6\phi 12/m'$

Sec (3−3) water section

$M_{working}=23.81$ kN.m , $T_{working}=37.24$ kN , $b=1000mm$

$t=350mm$, $A_s=6\phi 12/m'$

Sec (4−4) air section , t=250mm

$M_{working}=15.96$ kN.m , $T_{working}=37.24$ kN , $b=1000mm$

$A_s=5\phi 12/m'$

Sec (5−5) water section

$M_{working}=25.56$ kN.m , $T_{working}=37.80$ kN , $b=1000mm$

$t=350mm$, $A_s=6\phi 12/m'$

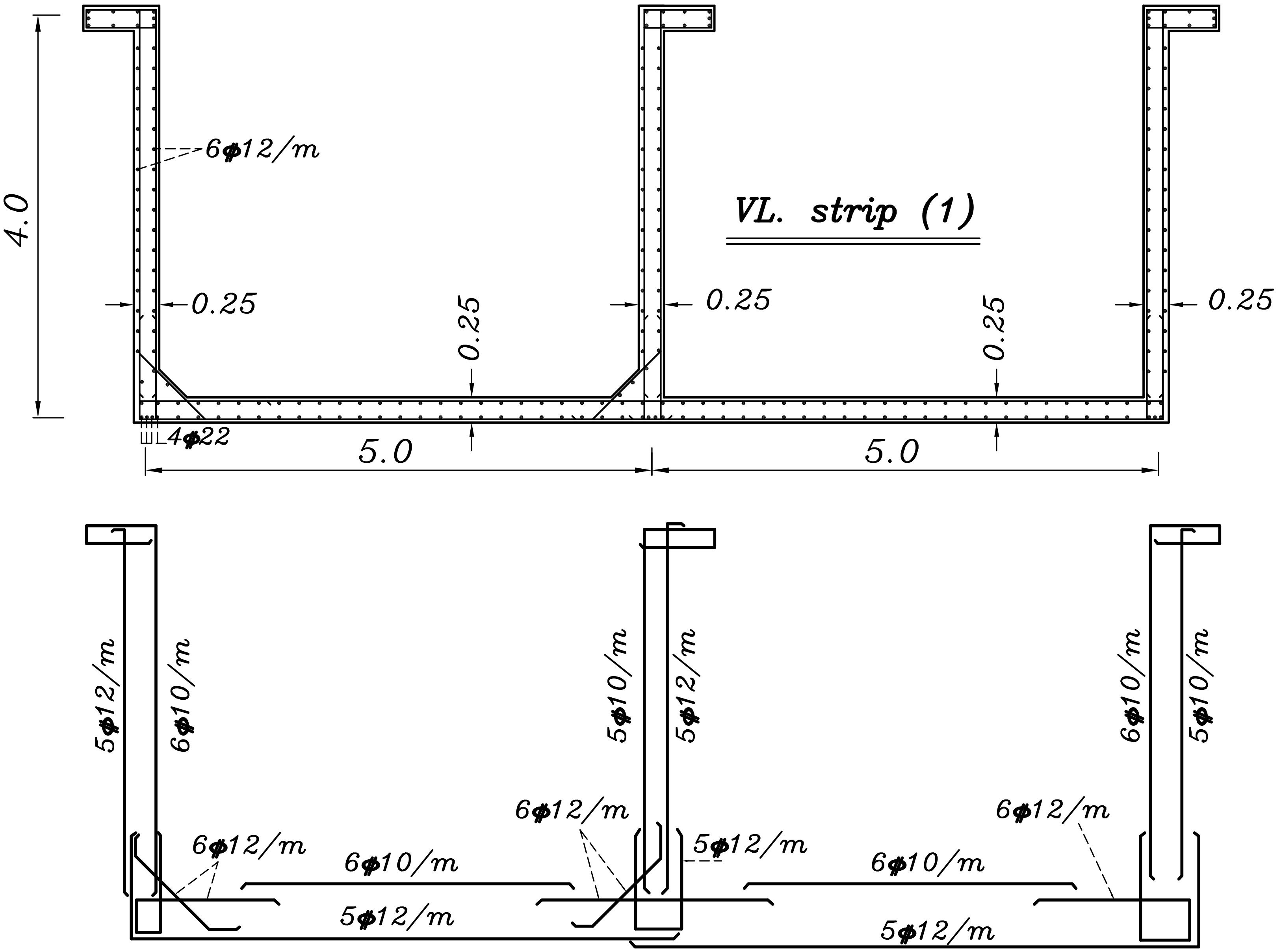
Sec (6−6) air section , t=250mm

$M_{working}=12.96$ kN.m , $T_{working}=37.80$ kN , $b=1000mm$

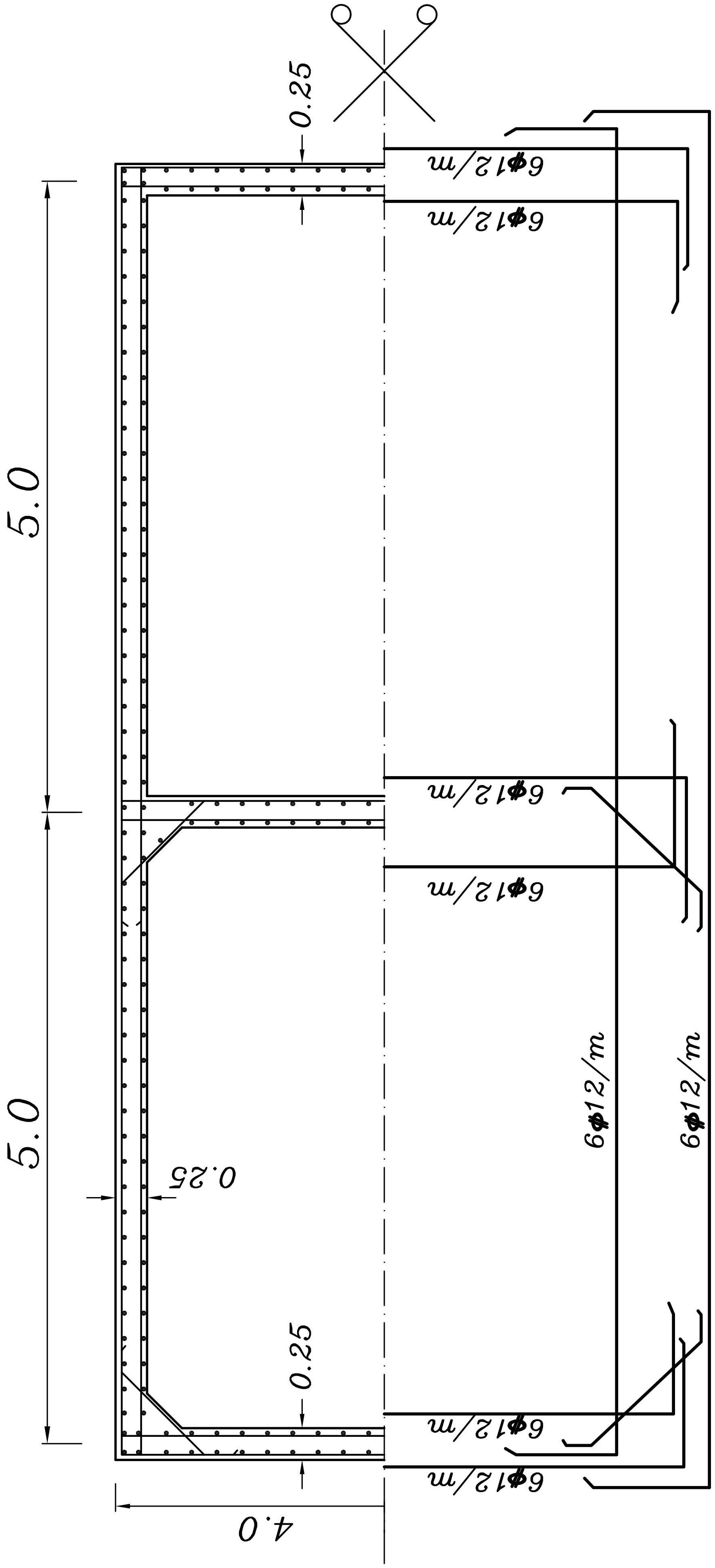
$A_s=5\phi 12/m'$

Details of RFT.

VL. strip (1)



Hz. strip (2)


0.25
6φ12/m
6φ12/m
5.0
6φ12/m
6φ12/m
5.0
6φ12/m
6φ12/m
0.25
0.25
6φ12/m
6φ12/m
4.0

Example(8) (M.T. str. 2001)

Given:

$f_{cu}=25\ N/mm^2$ &

steel used is 360/520

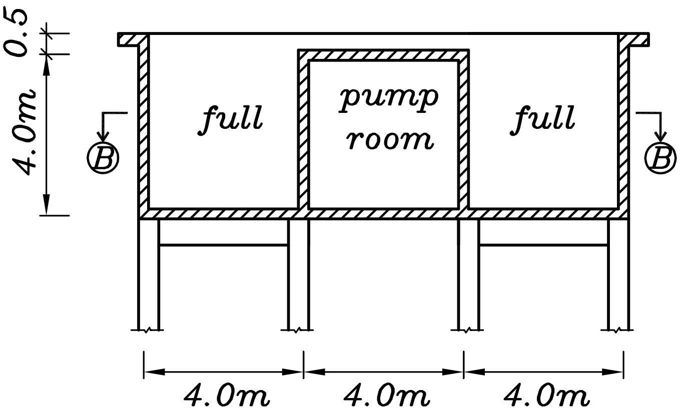
Required

1–Draw the load diagram for the vertical section (A–A) , hz. section (B–B)

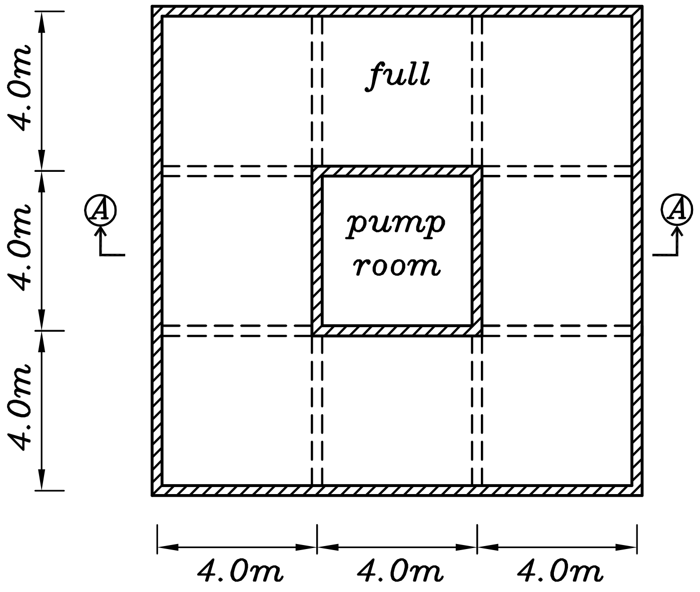
2–Calculate the internal forces and design section (A–A) , (B–B)

3–Draw the load diagram for the top hz. beam.

4–Draw to a convenient scale details of RFT for sections (A–A) & (C–C)



sec (A–A)



sec (B–B)

Solution

1- Concrete dimensions

$$t_w = t_f = \frac{L}{16} = \frac{400}{16} = 25cm$$

$\Longrightarrow$ Take $t_w = t_f = 25cm$

2- Loads on floor

for outer floor (full of water)

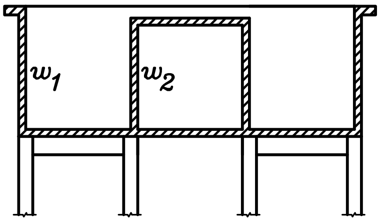
$$w_f = 0.25*25+10*4.5 = 51.25 \ kN/m^2$$

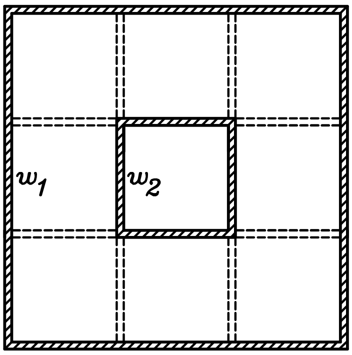
for inner floor of pump room

$$w_f = 0.25*25 = 6.25 \ kN/m^2$$

for cover of pump room

$$w_f = 0.25*25+10*0.5 = 11.25 \ kN/m^2$$



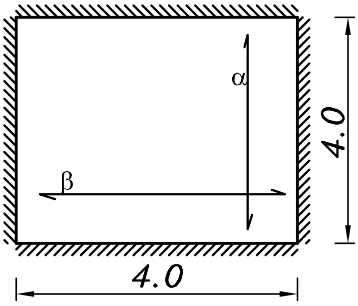


3- Load distribution

- for floor (4.0*4.0)

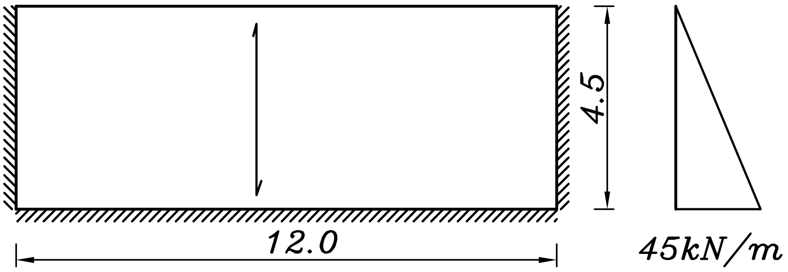
$$r = \frac{0.76*4.0}{0.76*4.0} = 1.00$$

$\alpha = \beta = 0.50$



- Wall (1) (12.0*4.5)

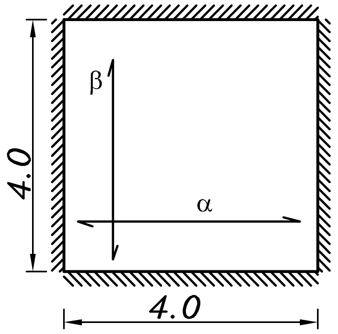
one way in vl. direction

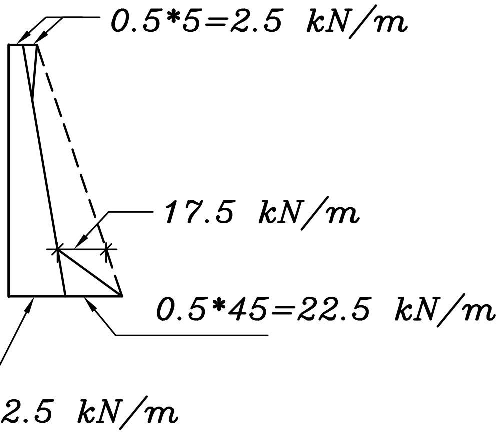


- Wall (2) (4.0*4.0)

$$r=\frac{0.76*4.0}{0.76*4.0}=1.00$$

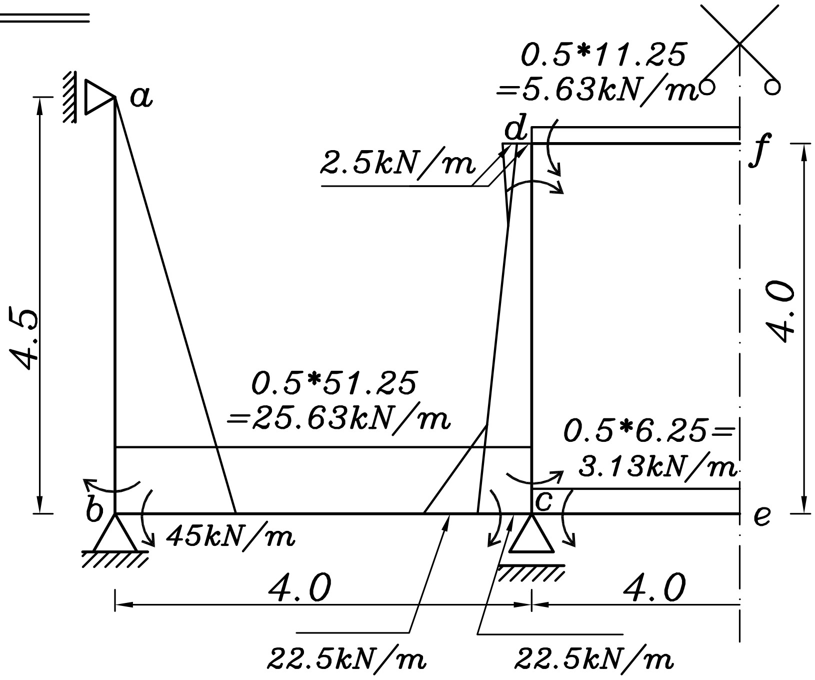
$\alpha=\beta=0.50$





4- Analysis of strips

- VL. strip (1) sec (A-A)



For Joint b

$$D.f_{ba}=\frac{0.75(I/4.5)}{0.75(I/4.5)+(I/4.0)}$$

$$D.f_{ba}=0.4$$

$$D.f_{bc}=0.6$$

For Joint c

$$D.f_{\substack{cb\\cd}}=\frac{(I/4.0)}{(I/4.0)+(I/4.0)+0.5(I/4.0)}=0.40$$

$$D.f_{ce}=\frac{0.5(I/4.0)}{(I/4.0)+(I/4.0)+0.5(I/4.0)}=0.20$$

For Joint d

$$D.f_{dc}=\frac{(I/4.0)}{(I/4.0)+0.5(I/4.0)}=0.67$$

$$D.f_{df}=\frac{0.5(I/4.0)}{(I/4.0)+0.5(I/4.0)}=0.33$$

$$F.E.M._{ba}=\frac{45*(4.5)^2}{15}=60.75kN.m$$

$$F.E.M._{bc}=\frac{-25.63*(4)^2}{12}=-34.17kN.m \quad \& \quad F.E.M._{cb}=34.17kN.m$$

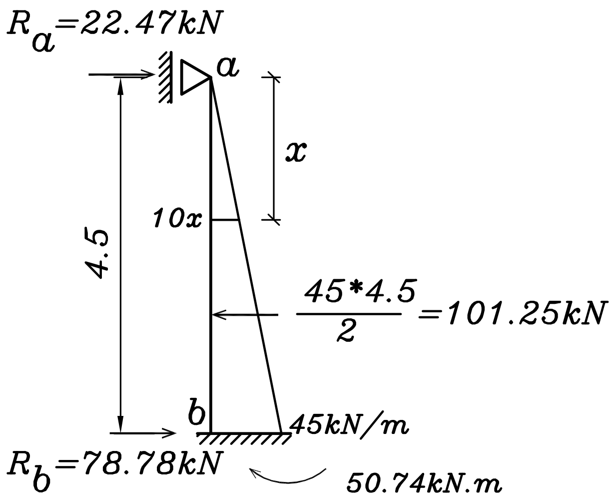
$$F.E.M._{ce}=\frac{-3.13*(4)^2}{12}=-4.17kN.m$$

$$F.E.M._{df}=\frac{-5.63*(4)^2}{12}=-7.51kN.m$$

$$F.E.M._{cd}=-\frac{2.5*(4)^2}{12}-\frac{20*(4)^2}{20}-\frac{22.5*(4)^2}{124}-\frac{2.5*(4)^2}{904}=-22.28kN.m$$

$$F.E.M._{dc}=\frac{2.5*(4)^2}{12}+\frac{20*(4)^2}{30}+\frac{22.5*(4)^2}{904}+\frac{2.5*(4)^2}{124}=14.72kN.m$$

Joint	b		c			d	
member	ba	bc	cb	ce	cd	dc	df
D.f.	0.40	0.60	0.40	0.20	0.40	0.67	0.33
F.E.M.	60.75	−34.17	34.17	−4.17	−22.28	14.72	−7.51
Bal.M.	−10.63	−15.95	−3.09	−1.54	−3.09	−4.83	−2.38
C.O.M.	0	−1.55	−7.98	0	−2.42	−1.55	0
Bal.M.	0.62	0.93	4.16	2.08	4.16	1.04	0.51
M_f	50.74	−50.74	27.26	−3.63	−23.63	9.38	−9.38



Point of zero shear

$$(10x)*\frac{x}{2}=22.47 \Longrightarrow x=2.12m$$

$$\Longrightarrow M_{+ve}=22.47x-(10x)*(\frac{x^2}{6})$$

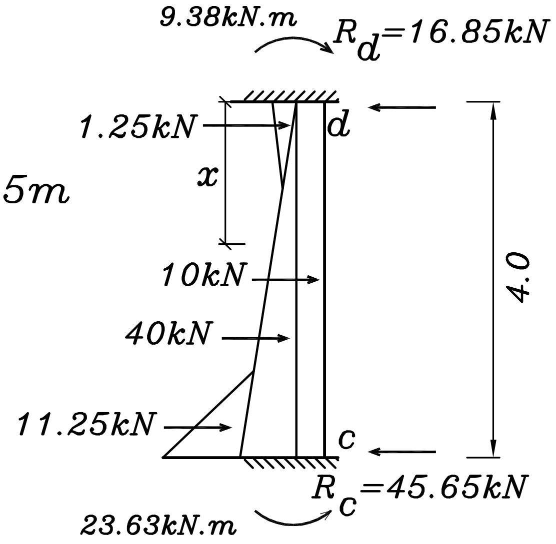
$$M_{+ve}=31.76 \ kN.m$$

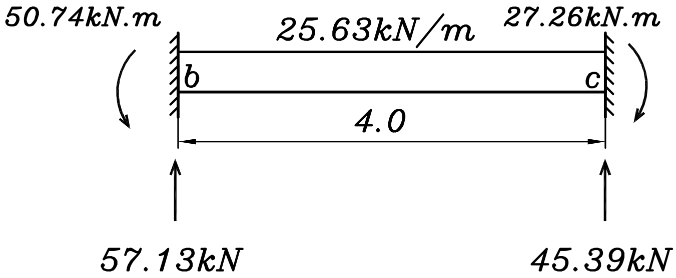
Point of zero shear

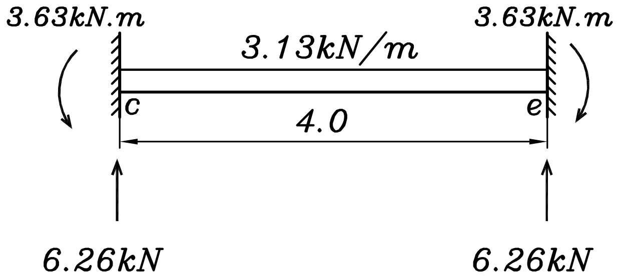
$$2.5x+\left[\frac{x}{4}*20\right]*\frac{x}{2}+1.25=16.85 \Longrightarrow x=2.05m$$

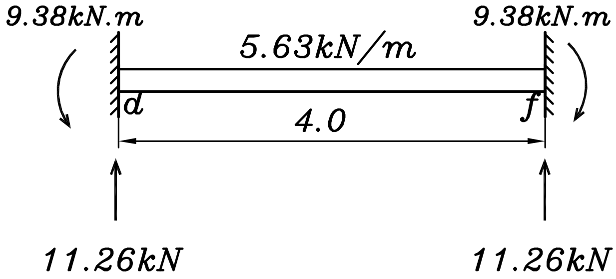
$$\Longrightarrow M_{+ve}=16.85x-2.5x\frac{x}{2}-\left(\frac{x}{4}*20\right)*\left(\frac{x^2}{6}\right)$$

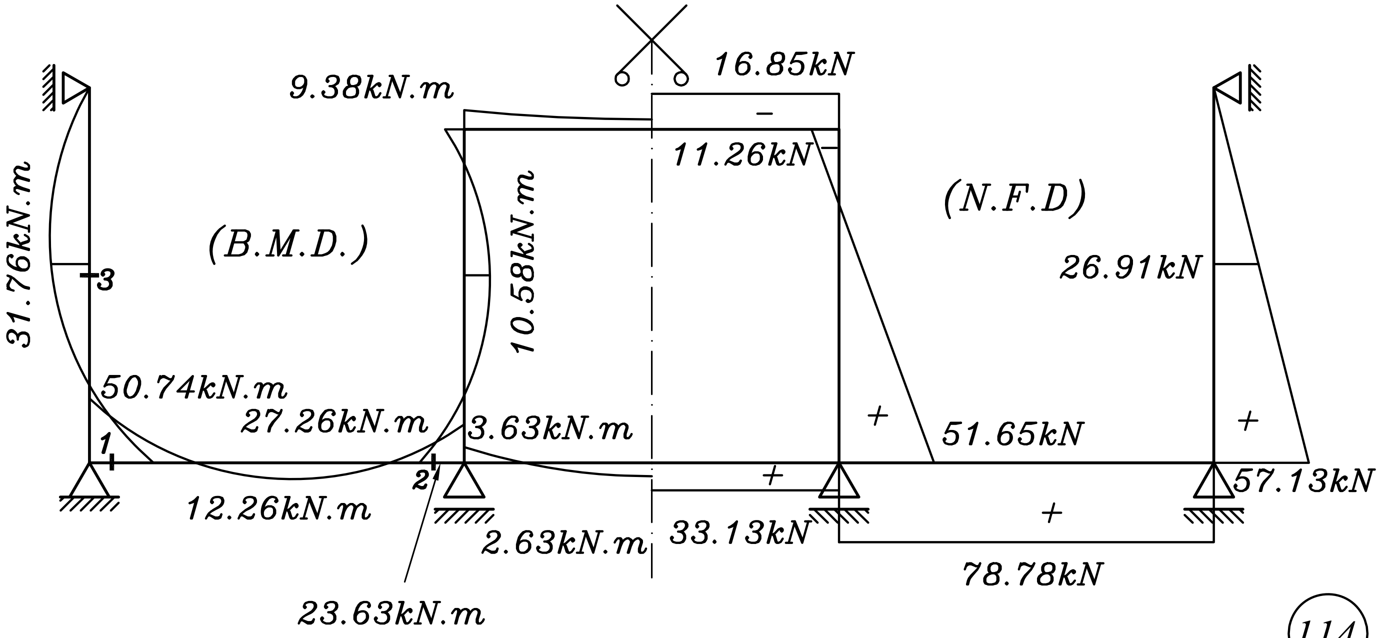
$$-1.25*(x-1/3)-9.38=10.58\ \ kN.m$$





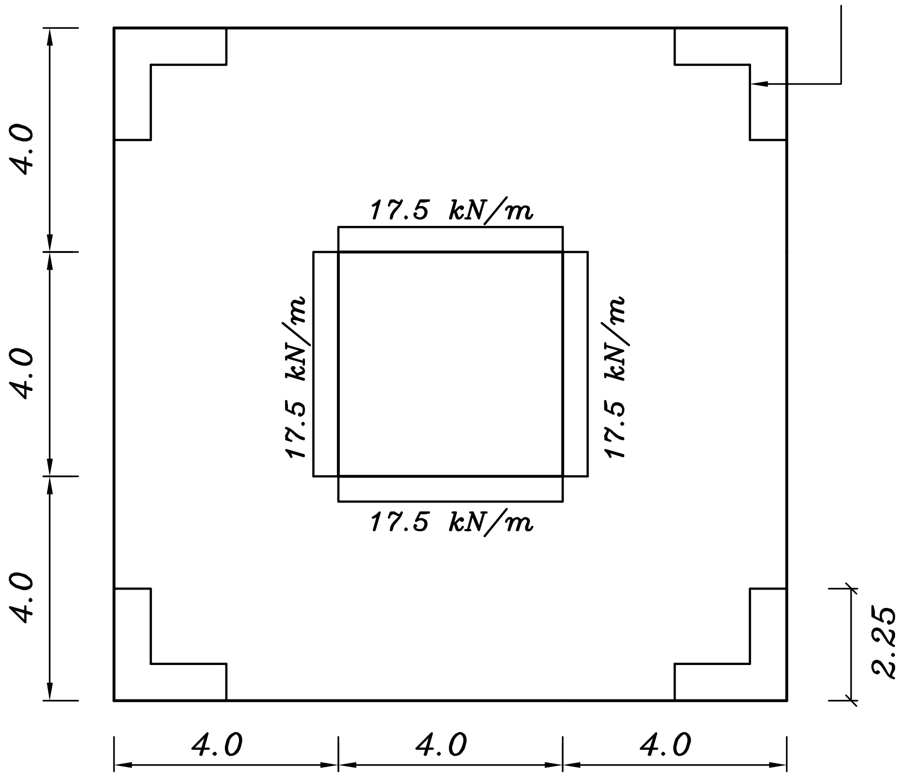


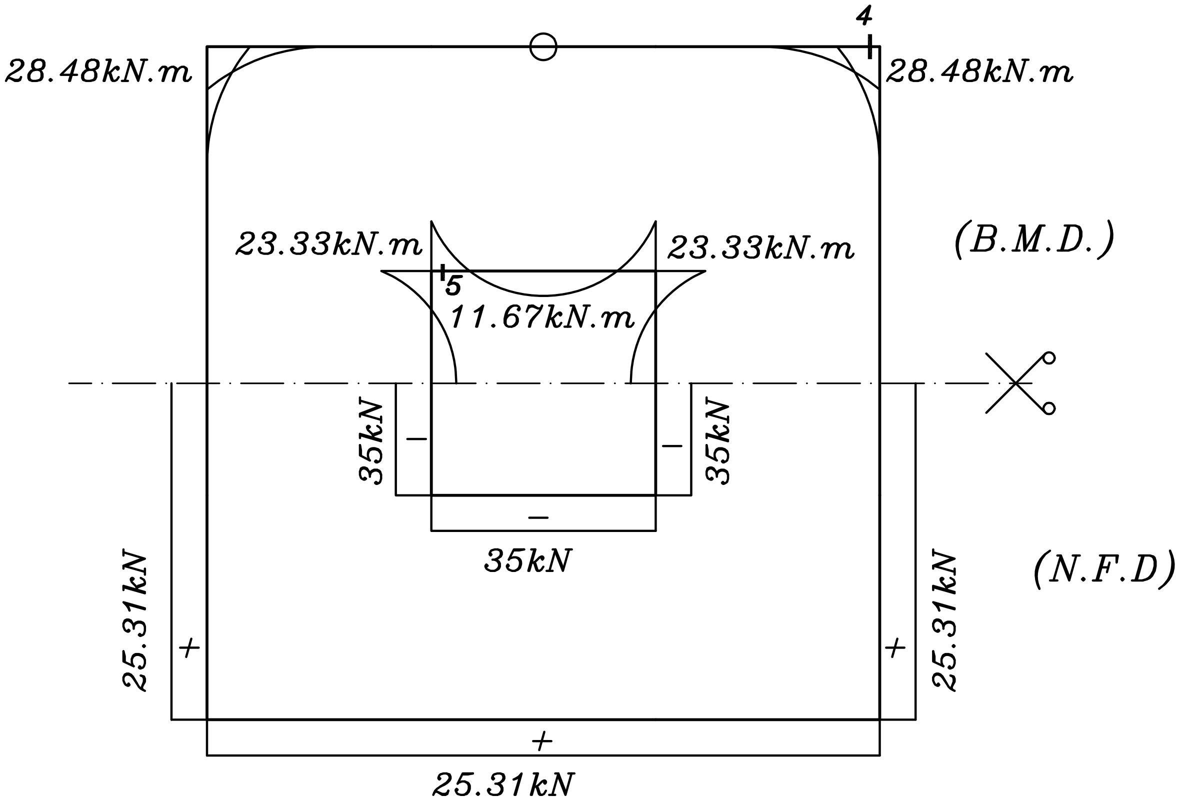




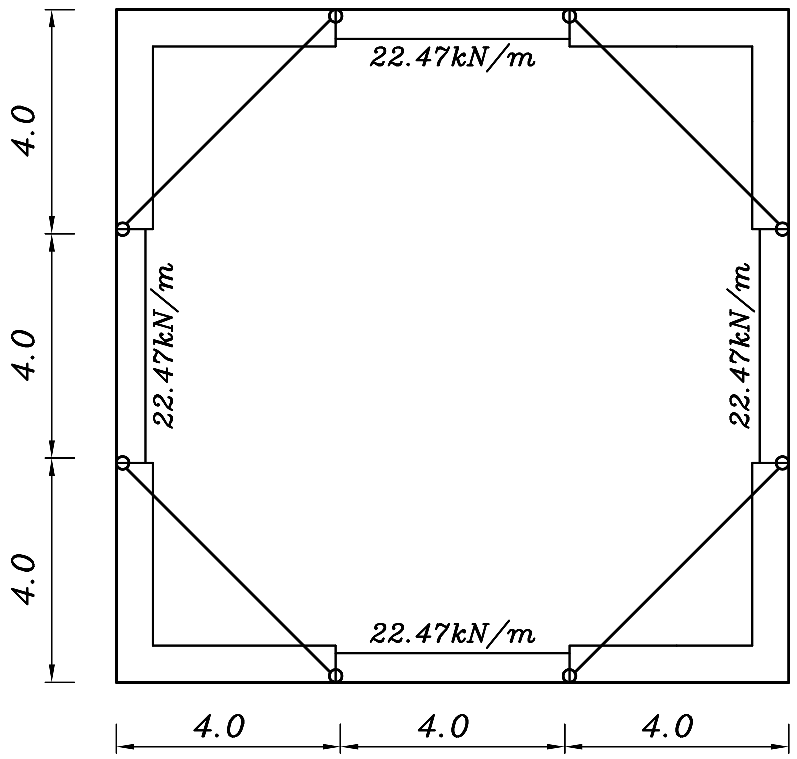
– HZ. strip (2) at h=1.00 sec (B–B)

$$\frac{\gamma_w\,h}{4}=\frac{10*4.5}{4}=11.25kN/m$$





– Loads on top hz. beam



5– Design of sections

Sec (1–1) water section

$M_{working}=50.74$ kN.m , $T_{working}=78.78$ kN , b=1000mm

Stage (I)

$$t_{(mm)}=\sqrt{\frac{M*10^3}{factor}}+40mm=\sqrt{\frac{50.74*10^3}{0.28}}+40mm=465.69mm$$

$\Rrightarrow$ Take t =500mm

Check stresses

$$f_t=+\frac{T}{A}+\frac{M}{Z}=+\frac{78.78*10^3}{1000*500}+\frac{50.74*10^6}{1000*(500)^2/6}$$

$$=0.16+1.22=1.38\ N/mm^2$$

$$\Longrightarrow f_{ct}=\frac{0.6\sqrt{25}}{1.7}=1.76N/mm^2 \quad \Longrightarrow f_t < f_{ct} \quad (safe)$$

Stage (II)

$$M_{u.l.}=1.5*50.74=76.11 \ kN.m \quad , \quad T_{u.l.}=1.5*78.78=118.17 \ kN$$

$$e=\frac{M_{u.l.}}{T_{u.l.}}=\frac{76.11}{118.17}=0.64m > \frac{t}{2} - cover$$

$$e_s=e-\frac{t}{2}+c=0.64-\frac{0.50}{2}+0.04=0.43m$$

$$M_{us}=118.17*0.43=50.81kN.m$$

$$460=C_1\sqrt{\frac{50.81*10^6}{1000*25}} \qquad C_1=10.2 \quad \& \quad J=0.826$$

$$A_s=\frac{1}{\beta_{cr}}*[\frac{M_{us}}{J*d*f_y}+\frac{T_{u.l.}}{f_y/\gamma_s}]$$

assume $\phi 16$ used $\Longrightarrow$ $\beta_{cr}=0.75$

$$A_s=\frac{1}{0.75}[\frac{50.81*10^6}{0.826*460*360}+\frac{118.17*10^3}{360/1.15}]$$

$$A_s=998.59mm^2/m' \Longrightarrow 5\phi 16/m'$$

Sec (2-2) water section

$$M_{working}=27.26 \ kN.m \ , \quad T_{working}=78.78 \ kN \quad , \quad b=1000mm$$

$$t=350mm \quad , \quad A_s=7\phi 12/m'$$

Sec (3–3) air section , t=250mm

$M_{working}=31.76$ kN.m , $T_{working}=26.91$ kN , b=1000mm

$A_s=8\phi 12/m'$

Sec (4–4) water section

$M_{working}=28.48$ kN.m , $T_{working}=25.31$ kN , b=1000mm

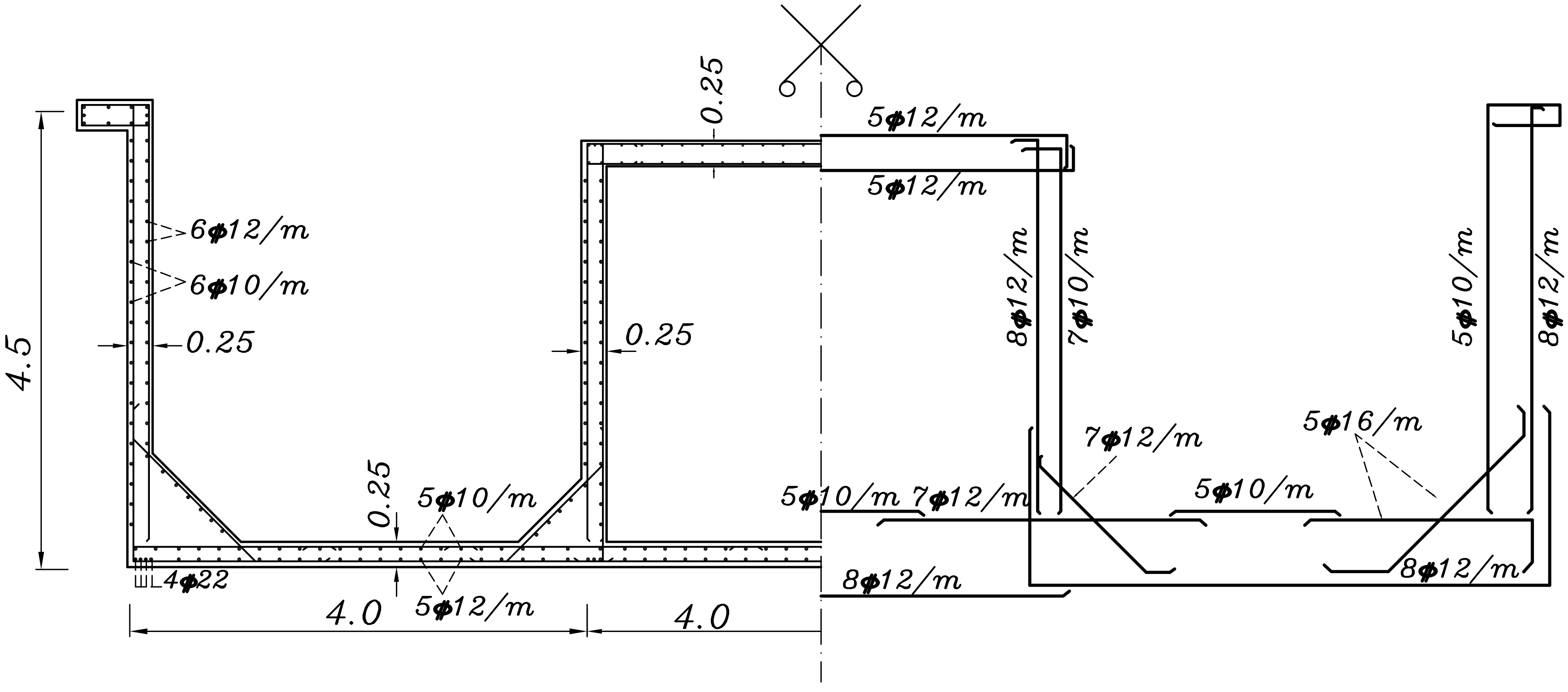
t=350mm , $A_s=6\phi 12/m'$

Sec (5–5) water section

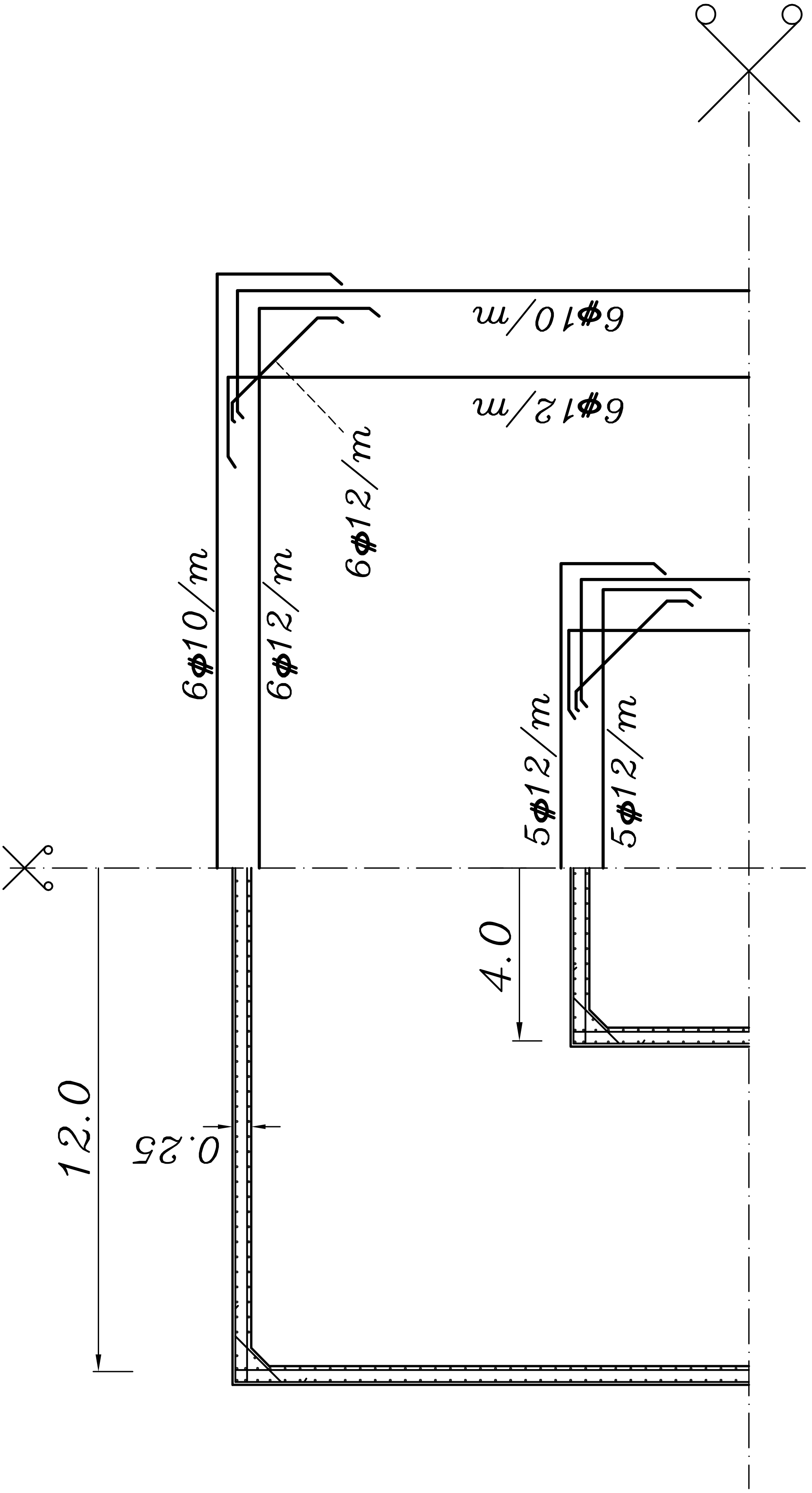
$M_{working}=23.33$ kN.m , $N_{working}=35.00$ kN , b=1000mm

t=300mm , $A_s=5\phi 12/m'$

Details of RFT.



VL. strip (1)



Hz. strip (2)

Example(9)

Given:

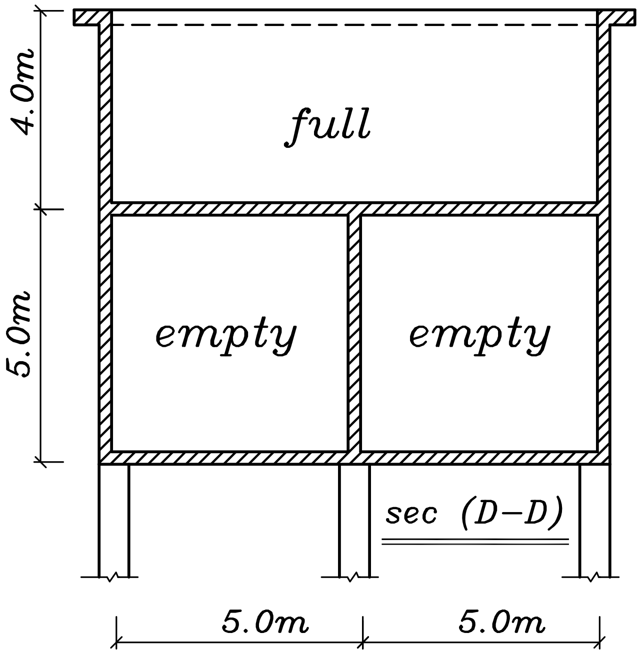
$f_{cu}=25\ N/mm^2$ &

steel used is 360/520

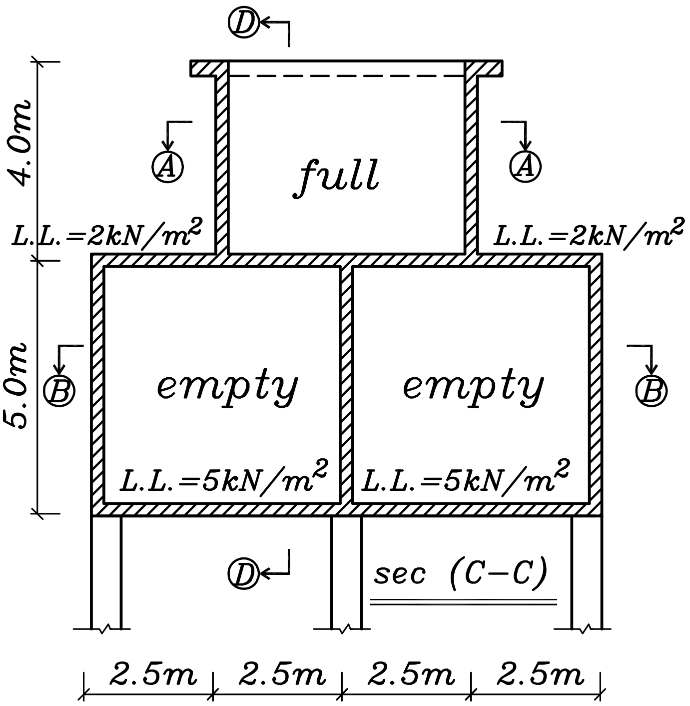
Required

1-Design the given tank.

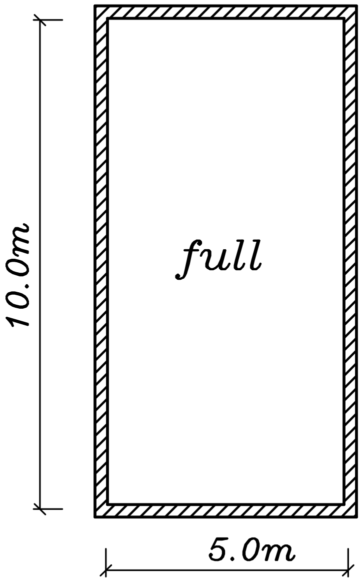
2-Calculate the loads acting on the top hz. beam.



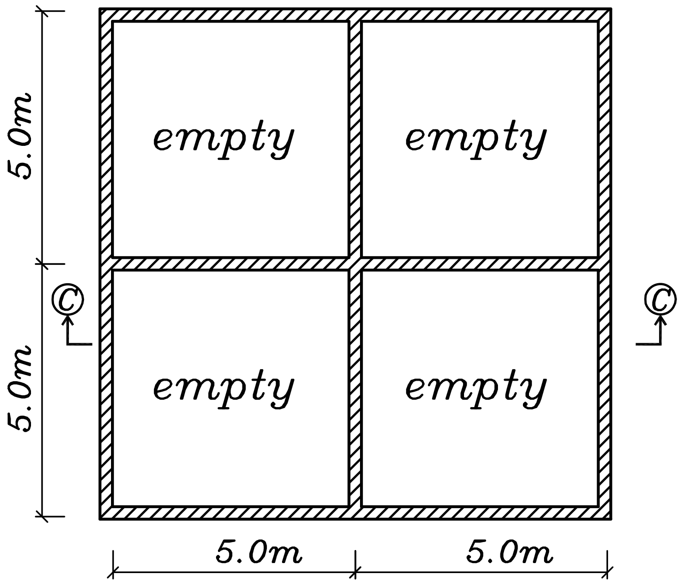
sec (D-D)



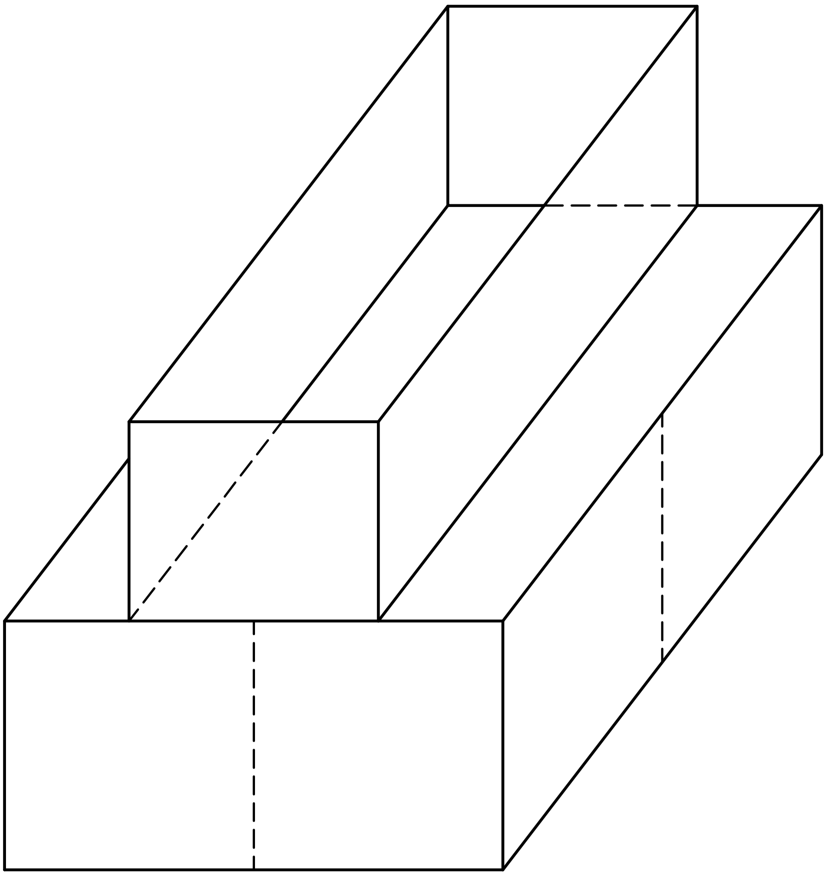
sec (C-C)

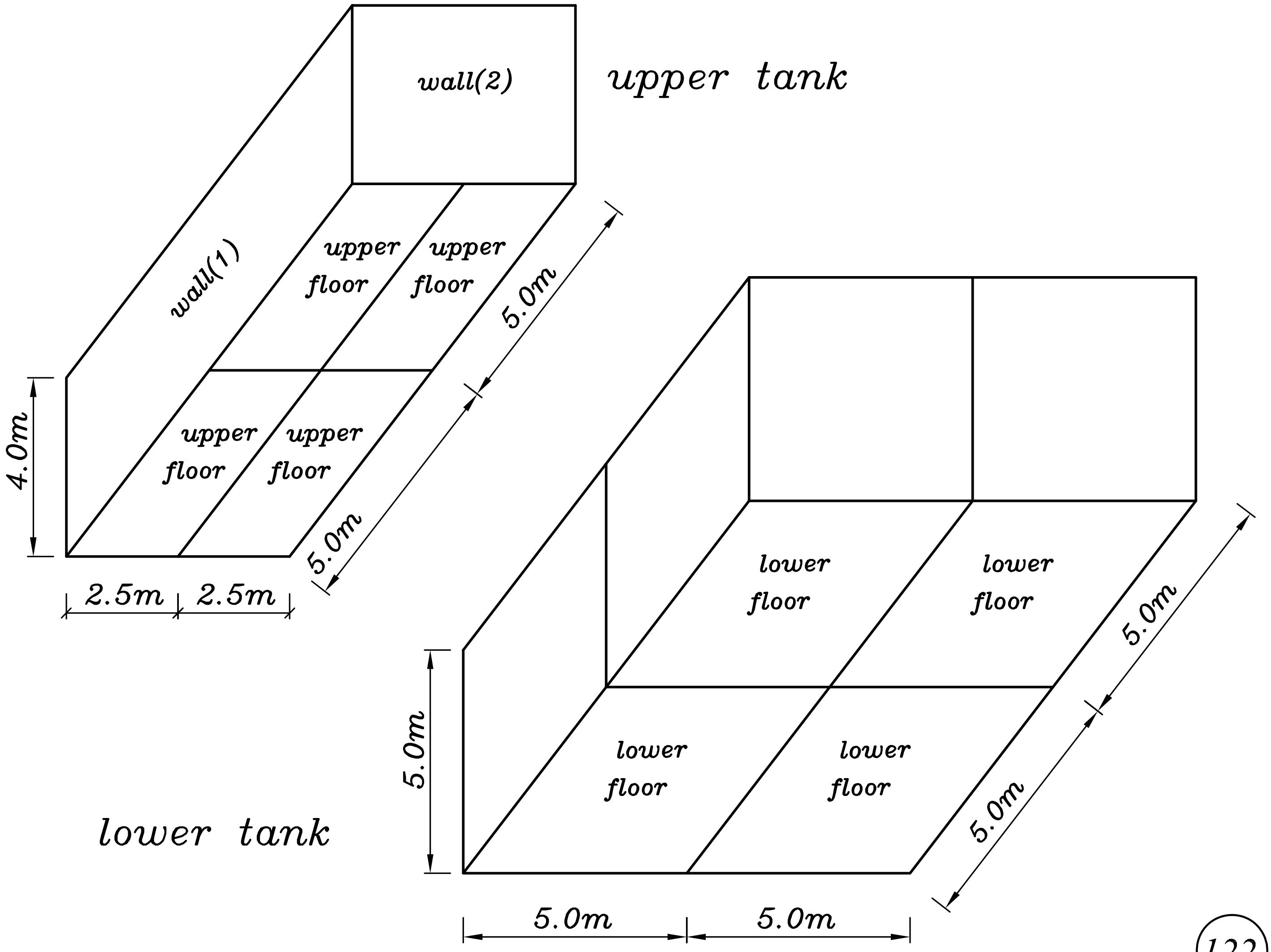


sec (A-A)



sec (B-B)




wall(2)
upper tank
wall(1)
upper floor
upper floor
upper floor
upper floor
5.0m
5.0m
4.0m
2.5m
2.5m
lower floor
lower floor
lower floor
lower floor
5.0m
5.0m
5.0m
lower tank
5.0m
5.0m

Solution

1- Concrete dimensions

$$t_w = t_f = \frac{L}{16} = \frac{500}{16} = 31.25cm$$

$\Longrightarrow$ Take $t_w = t_f = 30cm$

2- Loads on floor

for inner upper floor (full of water)

$$w_f = 0.30*25+10*4=47.50 \ kN/m^2$$

for outer upper floor (of $L.L. = 2.0kN/m^2$)

$$w_f = 0.30*25+2.0=9.50 \ kN/m^2$$

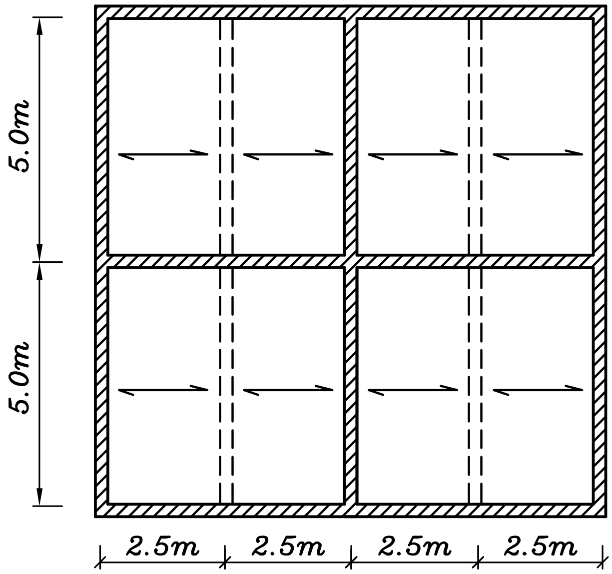
for lower floor (of $L.L. = 5.0kN/m^2$)

$$w_f = 0.30*25+5.0=12.50 \ kN/m^2$$

3- Load distribution

- Upper floor (2.5*5.0)

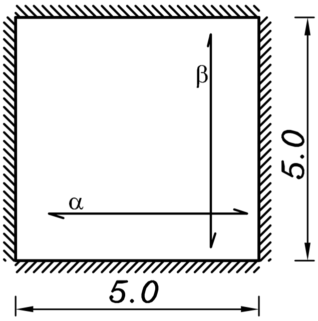
one way slabs



– Lower floor

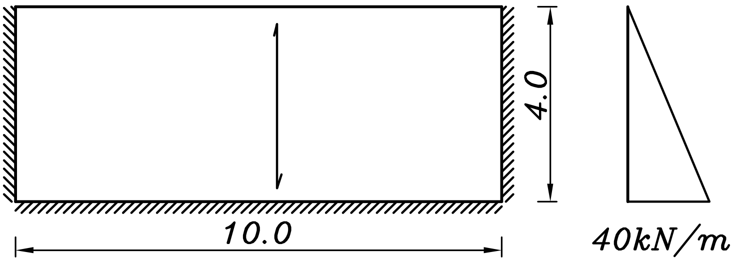
$$r=\frac{0.76*5}{0.76*5}=1.0$$

$$\alpha=\beta=0.5$$



– Wall (1) (10.0*4.0)

one way in vl. direction

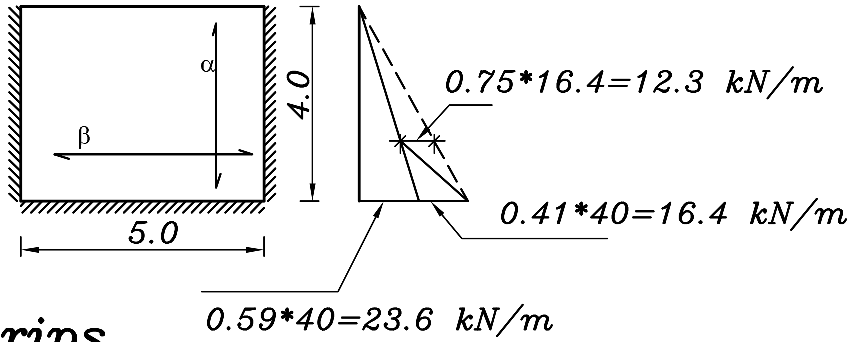


– Wall (2) (5.0*4.0)

$$r=\frac{0.76*5}{0.87*4}=1.09$$

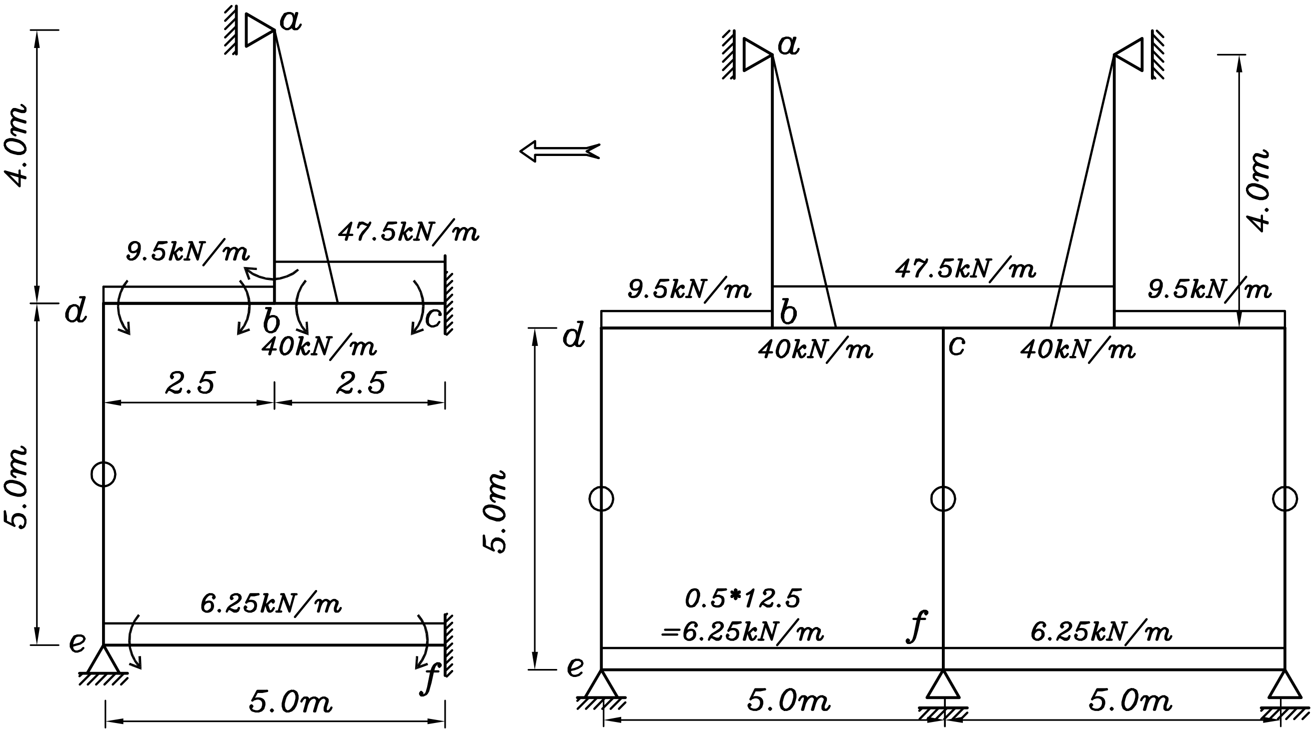
$$\alpha=\frac{r^4}{1+r^4}=0.59$$

$$\beta=\frac{1}{1+r^4}=0.41$$



4– Analysis of strips

– VL. strip (1) sec (C–C)



For Joint b

$$D.f_{ba}=\frac{0.75(I/4.0)}{0.75(I/4.0)+(I/2.5)+(I/2.5)}=0.18$$

$$D.f_{bd}=D.f_{bc}=\frac{(I/2.5)}{0.75(I/4.0)+(I/2.5)+(I/2.5)}=0.41$$

For Joint d

$$D.f_{db}=\frac{(I/2.5)}{(I/2.5)+(I/5.0)}=0.67 \quad \& \quad D.f_{de}=0.33$$

For Joint e

$$D.f_{ed}=D.f_{ef}=\frac{(I/5.0)}{(I/5.0)+(I/5.0)}=0.5$$

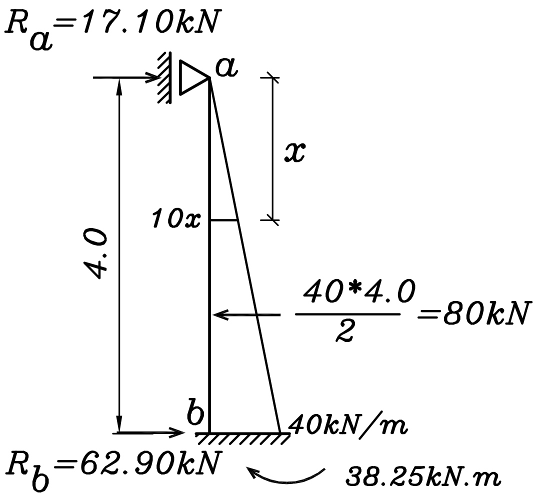
$$F.E.M._{ba}=\frac{40*(4.0)^2}{15}=42.67kN.m$$

$$F.E.M._{bc}=\frac{-47.5*(2.5)^2}{12}=-24.74kN.m \quad \& \quad F.E.M._{cb}=24.74kN.m$$

$$F.E.M._{db}=\frac{-9.5*(2.5)^2}{12}=-4.95kN.m \quad \& \quad F.E.M._{bd}=4.95kN.m$$

$$F.E.M._{ef}=\frac{-6.25*(5.0)^2}{12}=-13.02kN.m \quad \& \quad F.E.M._{fe}=13.02kN.m$$

Joint	c	b			d		e		f
member	cb	bc	ba	bd	db	de	ed	ef	fe
D.f.	0	0.41	0.18	0.41	0.67	0.33	0.50	0.50	0
F.E.M.	24.74	−24.74	42.67	4.95	−4.95	0	0	−13.02	13.02
Bal.M.	0	−9.38	−4.12	−9.38	3.32	1.63	6.51	6.51	0
C.O.M.	−4.69	0	0	1.66	4.69	3.26	0.82	0	3.26
Bal.M.	0	−0.68	−0.30	−0.68	−5.33	−2.62	−0.41	−0.41	0
Mf	20.05	−34.80	38.25	−3.45	−2.27	2.27	6.92	−6.92	16.28

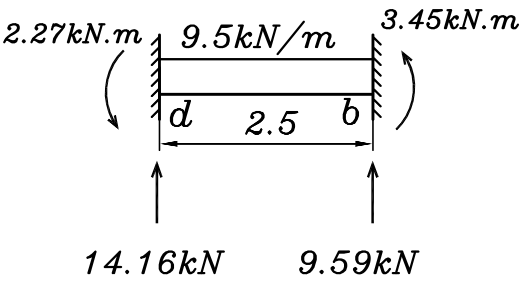


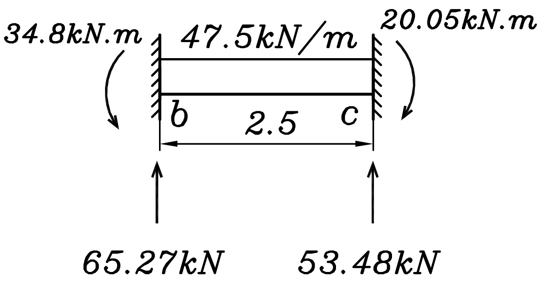
Point of zero shear

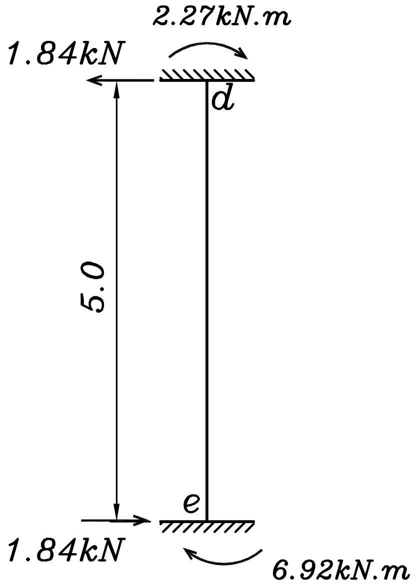
$$(10x)*\frac{x}{2}=17.10 \Longrightarrow x=1.85m$$

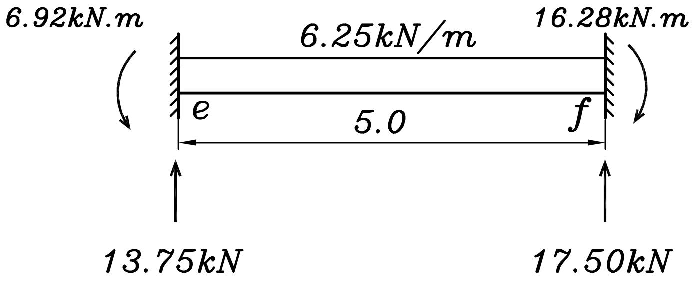
$$\Longrightarrow M_{+ve}=17.10x-(10x)*(\frac{x^2}{6})$$

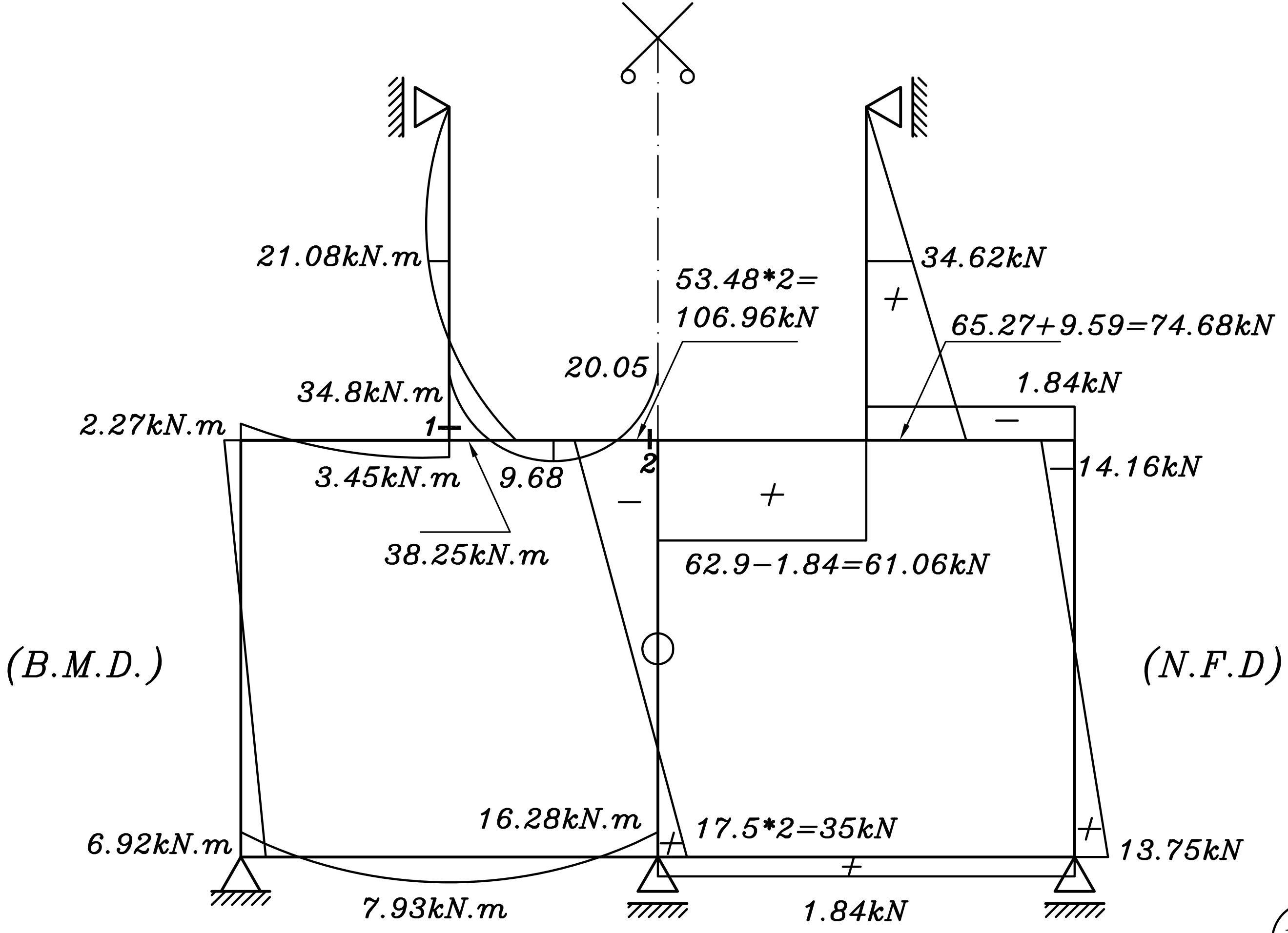
$$M_{+ve}=21.08\ kN.m$$


2.27kN.m
9.5kN/m
3.45kN.m
d
2.5
b
14.16kN
9.59kN

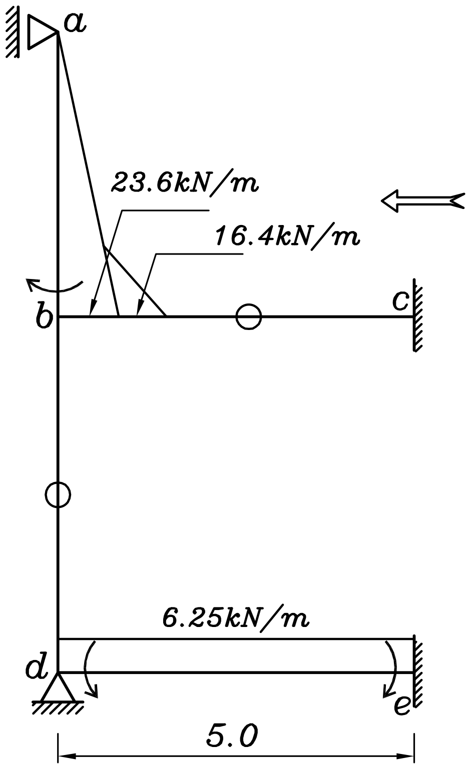

34.8kN.m
47.5kN/m
20.05kN.m
b
2.5
c
65.27kN
53.48kN

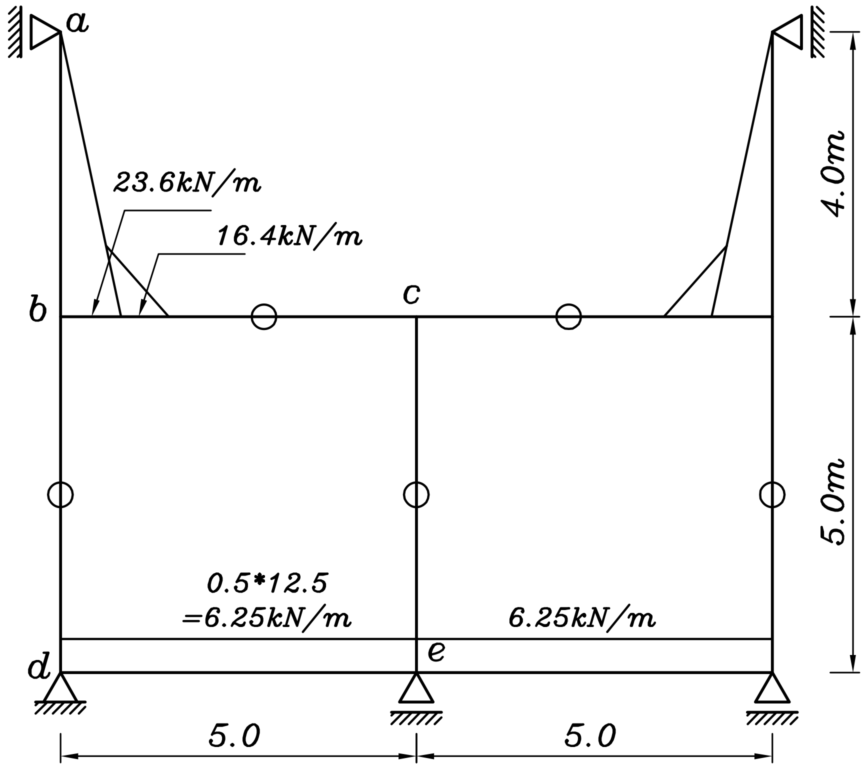

2.27kN.m
1.84kN
d
5.0
e
1.84kN
6.92kN.m


6.92kN.m
6.25kN/m
16.28kN.m
e
5.0
f
13.75kN
17.50kN


21.08kN.m
53.48*2=
106.96kN
34.62kN
+
65.27+9.59=74.68kN
20.05
34.8kN.m
1.84kN
2.27kN.m
1
−
2
3.45kN.m
9.68
14.16kN
−
+
38.25kN.m
62.9−1.84=61.06kN
(B.M.D.)
(N.F.D)
16.28kN.m
6.92kN.m
17.5*2=35kN
+
+
13.75kN
+
7.93kN.m
1.84kN

– VL. strip (2) sec (D–D)





For Joint b

$$D.f_{bd}=D.f_{bc}=\frac{(I/5.0)}{0.75(I/4.0)+(I/5.0)+(I/5.0)}=0.34\ ,\ D.f._{ba}=0.32$$

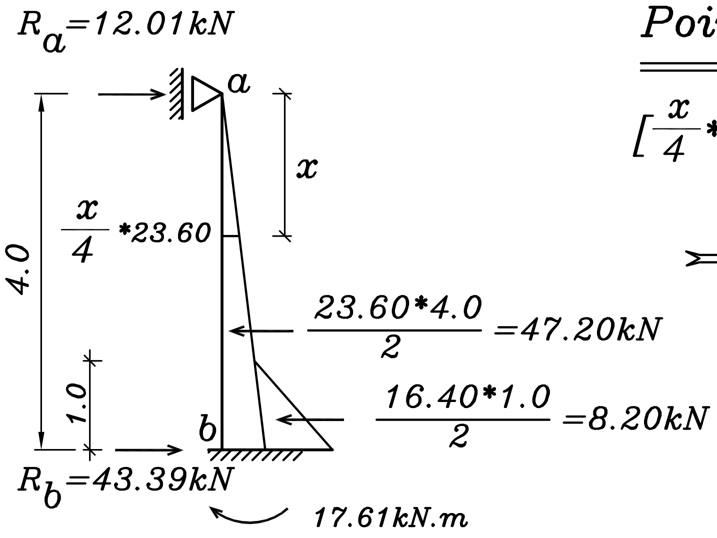
For Joint d

$$D.f_{db}=D.f_{de}=\frac{(I/5.0)}{(I/5.0)+(I/5.0)}=0.5$$

$$F.E.M._{ba}=\frac{23.60*(4)^2}{15}+\frac{16.40*(4)^2}{117}=27.42kN.m$$

$$F.E.M._{de}=\frac{-6.25*(5.0)^2}{12}=-13.02kN.m\quad \&\quad F.E.M._{ed}=13.02kN.m$$

Joint	c	b			d		e
member	cb	bc	ba	bd	db	de	ed
D.f.	0	0.34	0.32	0.34	0.50	0.50	0
F.E.M.	0	0	27.42	0	0	−13.02	13.02
Bal.M.	0	−9.32	−8.77	−9.32	6.51	6.51	0
C.O.M.	−4.66	0	0	3.26	−4.66	0	3.26
Bal.M.	0	−1.11	−1.04	−1.11	2.33	2.33	0
M_f	−4.66	−10.43	17.61	−7.17	4.18	−4.18	16.28

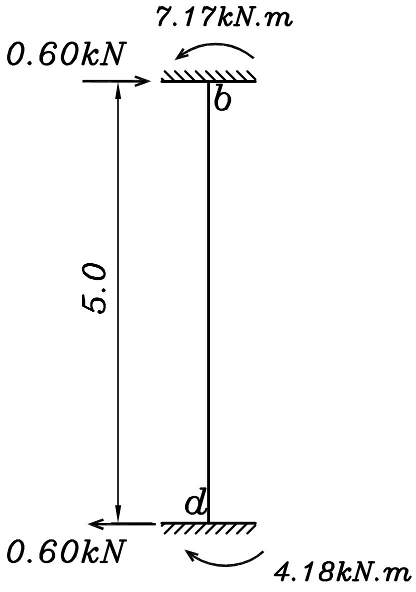


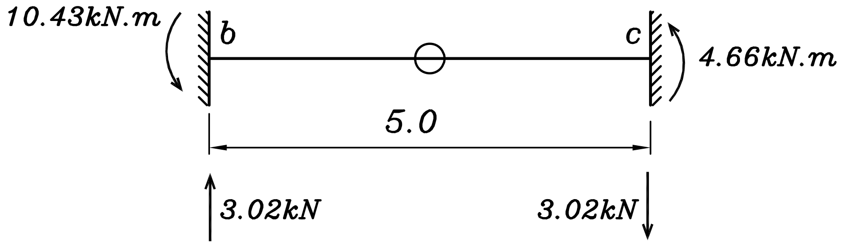
Point of zero shear

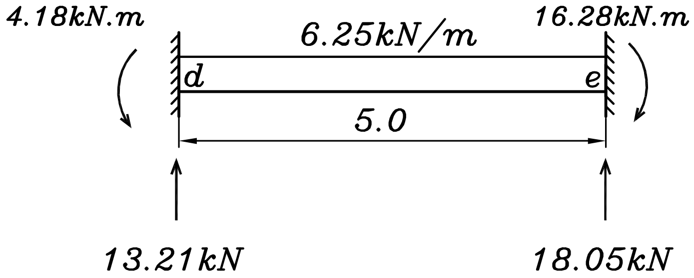
$$[\frac{x}{4}*23.60]*\frac{x}{2}=12.01 \Longrightarrow x=2.02m$$

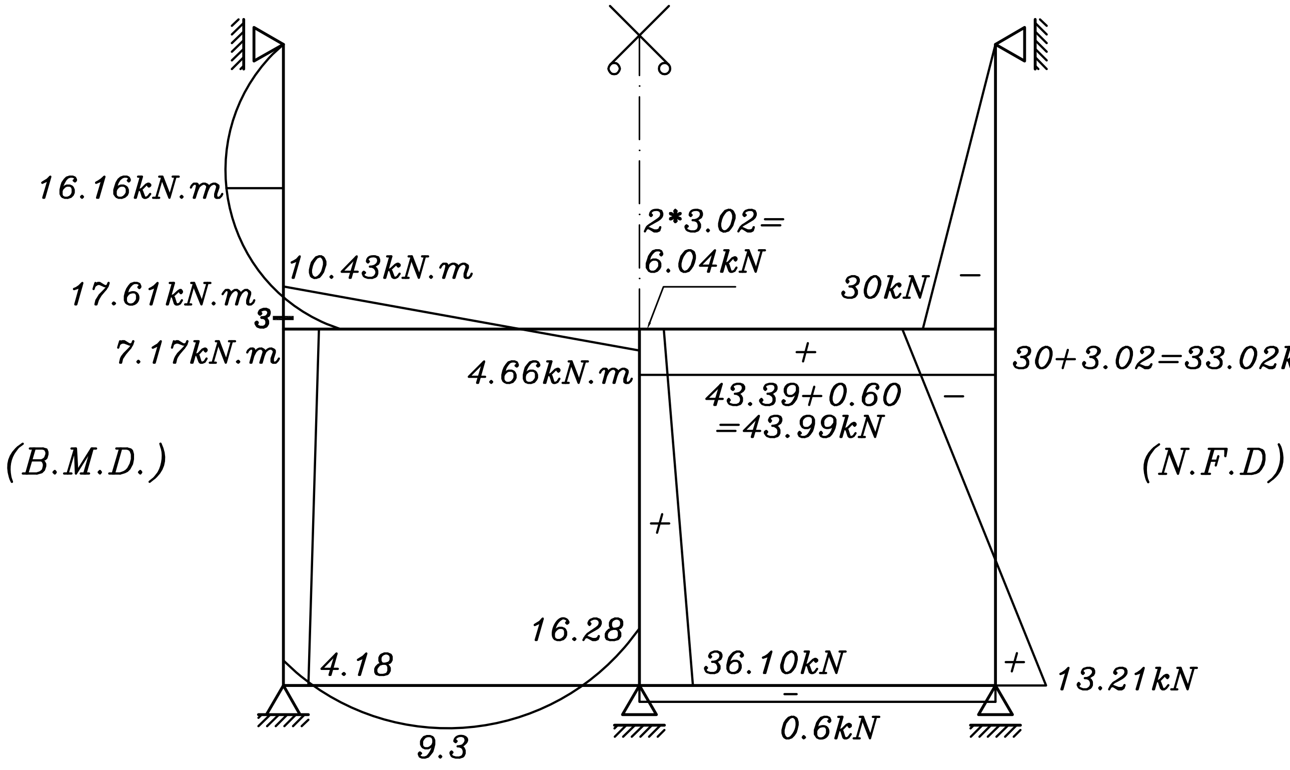
$$\Longrightarrow M_{+ve}=12.01x-(\frac{x}{4}*23.60)*(\frac{x^2}{6})$$

$$M_{+ve}=16.16\ \ kN.m$$

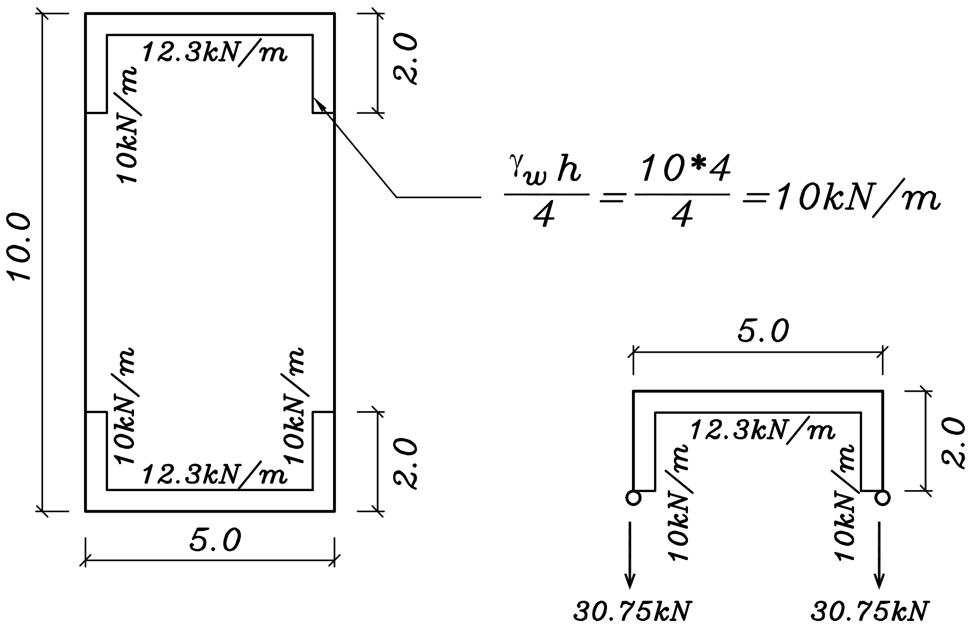


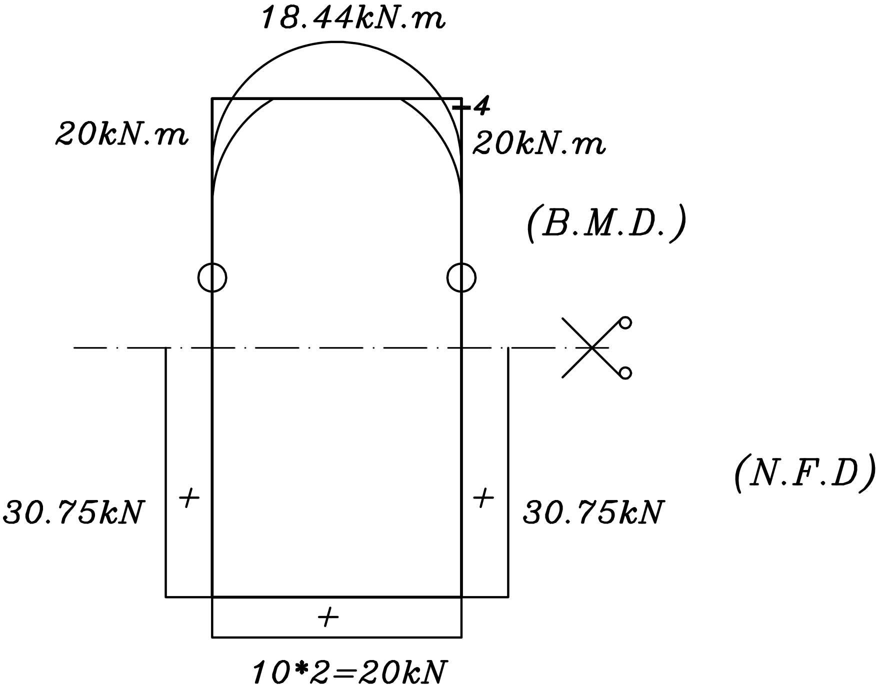




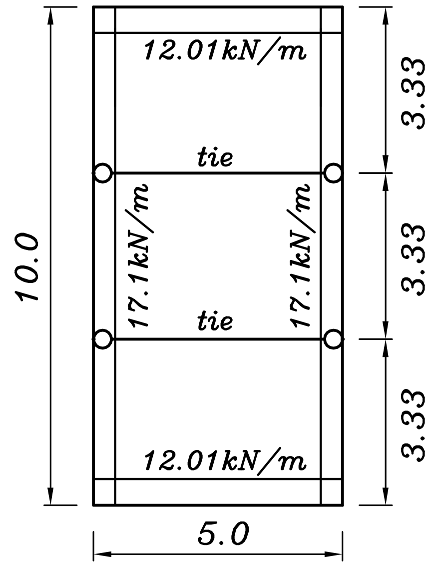


– HZ. strip (3) at h=6.00 sec (A–A)





– Loads on top hz. beam



5– Design of sections

Sec (1–1) water section

$M_{working}=38.25$ kN.m , $T_{working}=74.68$ kN , $b=1000mm$

Stage (I)

$$t_{(mm)}=\sqrt{\frac{M*10^3}{factor}}+40mm=\sqrt{\frac{38.25*10^3}{0.30}}+40mm=397.07mm$$

$\Longrightarrow$ Take $t=400mm$

Check stresses

$$f_t=+\frac{T}{A}+\frac{M}{Z}=+\frac{74.68*10^3}{1000*400}+\frac{38.25*10^6}{1000*(400)^2/6}$$

$$=0.19+1.43=1.62\ N/mm^2$$

$\Longrightarrow f_{ct}=\frac{0.6\sqrt{25}}{1.7}=1.76N/mm^2 \quad \Longrightarrow f_t < f_{ct}$ (safe)

Stage (II)

$M_{u.l.}=1.5*38.25=57.38\ kN.m$, $T_{u.l.}=1.5*74.68=112.02\ kN$

$$e=\frac{M_{u.l.}}{T_{u.l.}}=\frac{57.38}{112.02}=0.51m>\frac{t}{2}-cover$$

$$e_s=e-\frac{t}{2}+c=0.51-\frac{0.40}{2}+0.04=0.35m$$

$$M_{us}=112.02*0.35=39.46kN.m$$

$$360=C_1\sqrt{\frac{39.46*10^6}{1000*25}}\qquad C_1=9.06\quad \&\quad J=0.826$$

$$A_s=\frac{1}{\beta_{cr}}*[\frac{M_{us}}{J*d*f_y}+\frac{T_{u.l.}}{f_y/\gamma_s}]$$

assume $\phi 16$ used $\Longrightarrow$ $\beta_{cr}=0.75$

$$A_s=\frac{1}{0.75}[\frac{39.46*10^6}{0.826*360*360}+\frac{112.02*10^3}{360/1.15}]$$

$A_s=968.61mm^2/m' \Longrightarrow 5\phi 16/m'$

Sec (2-2) water section

$M_{working}=20.05\ kN.m$, $T_{working}=61.06\ kN$, $b=1000mm$

$t=300mm$, $A_s=6\phi 12/m'$

Sec (3-3) water section

$M_{working}=17.61\ kN.m$, $N_{working}=30.00\ kN$, $b=1000mm$

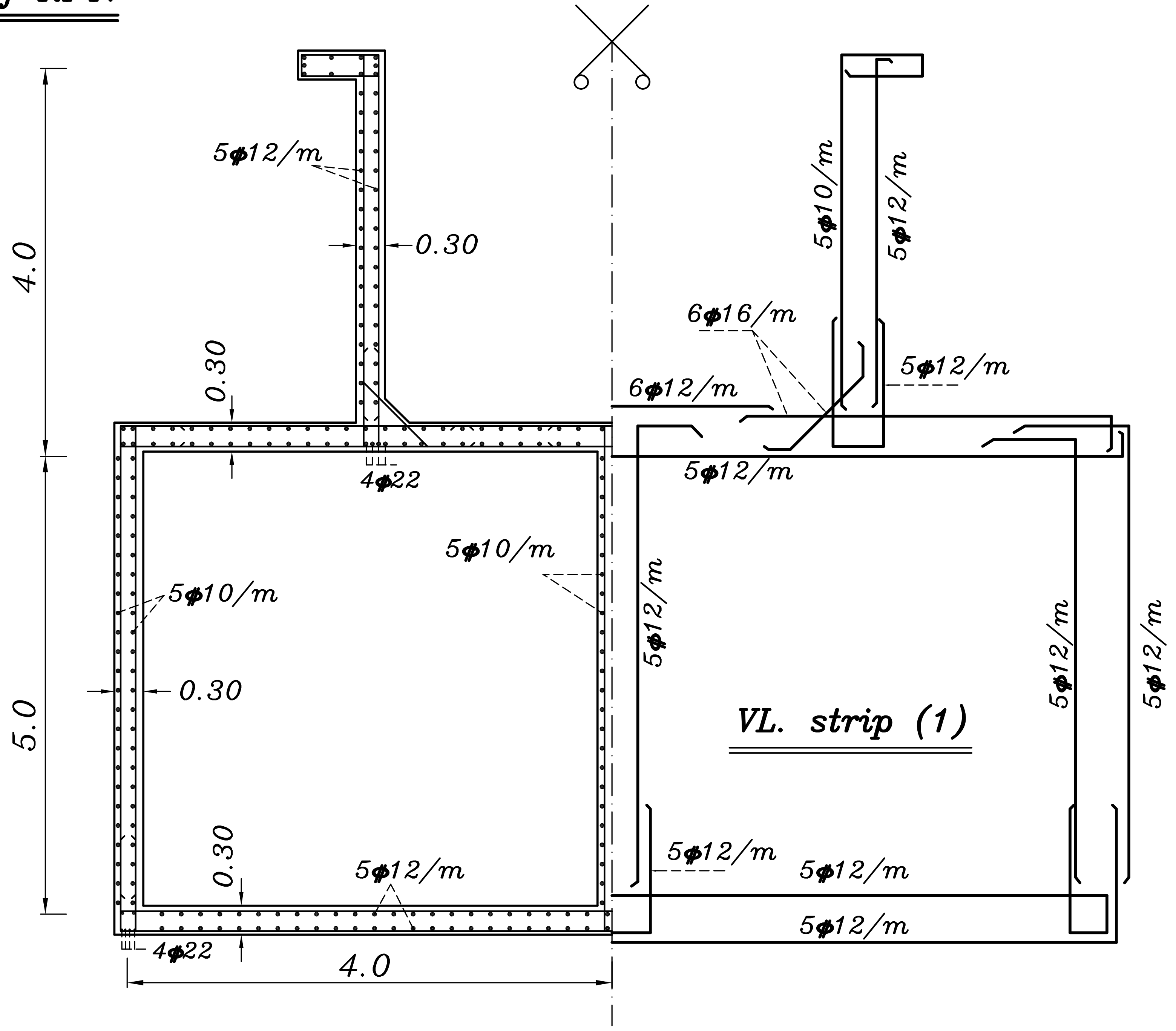
$t=300mm$, $A_s=5\phi 12/m'$

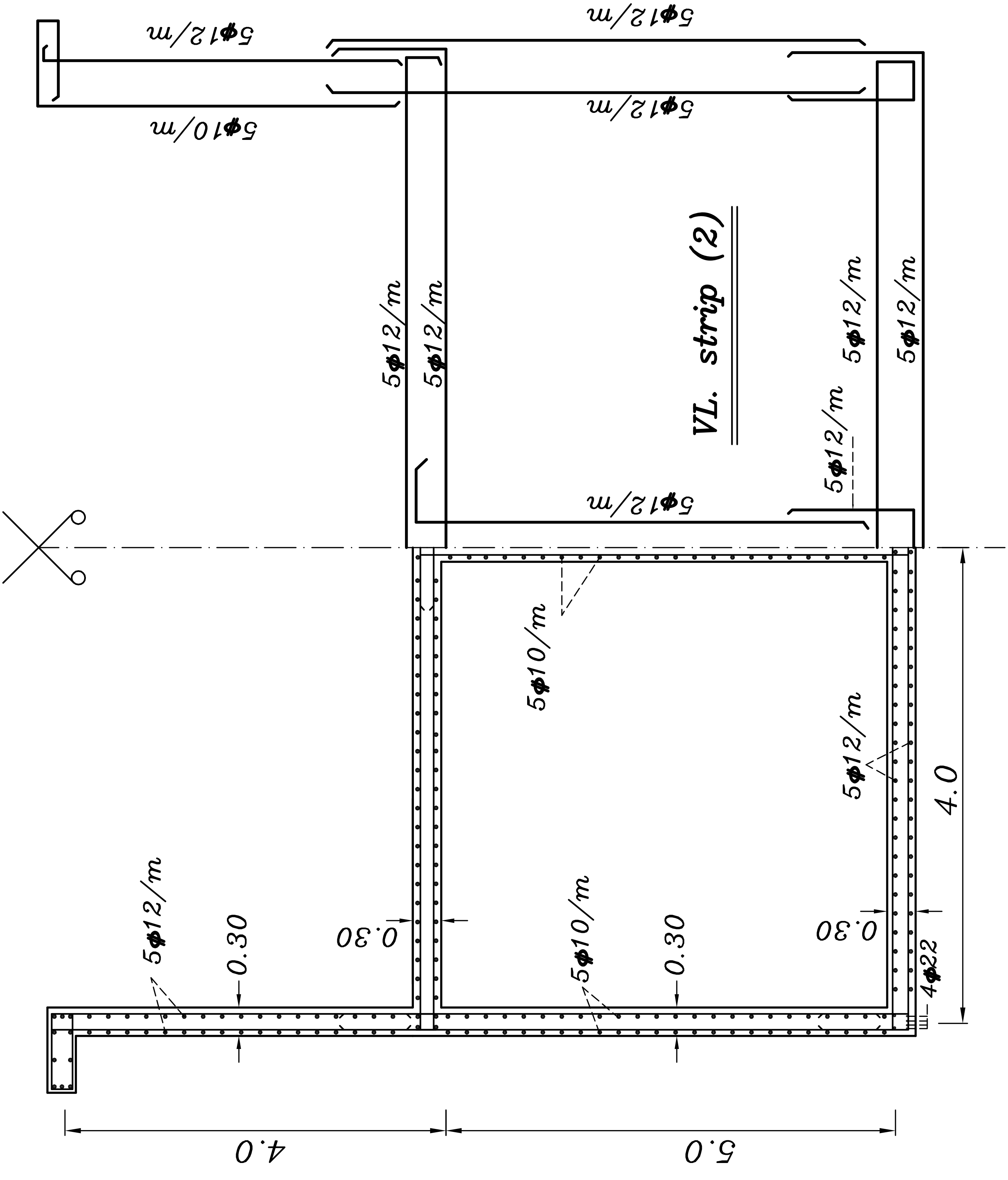
Sec (4-4) water section

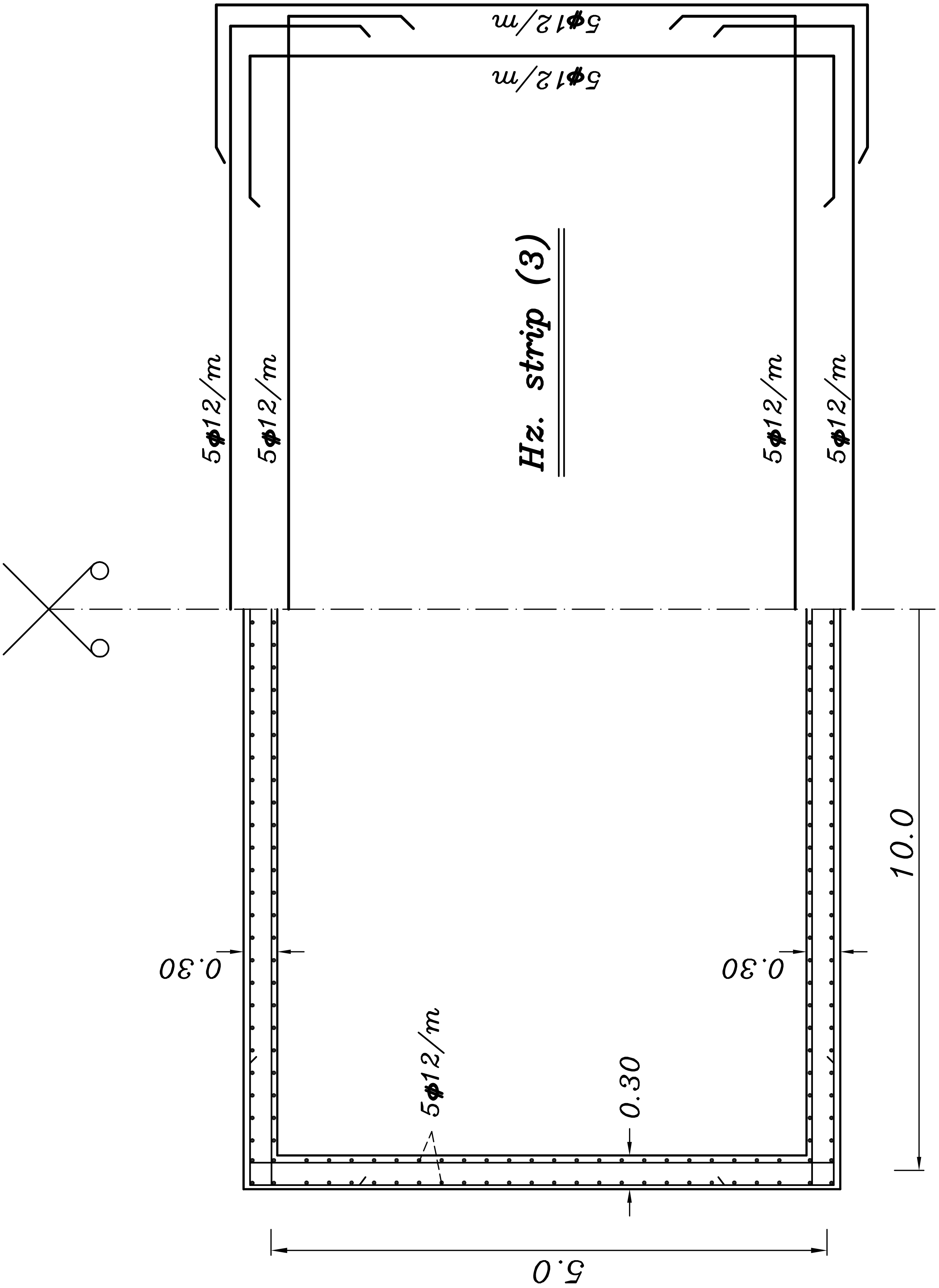
$M_{working}=20.00\ kN.m$, $T_{working}=30.75\ kN$, $b=1000mm$

$t=300mm$, $A_s=5\phi 12/m'$

Details of RFT.




VL. strip (2)
5φ12/m
5φ12/m
5φ10/m
5φ12/m
5φ12/m
5φ12/m
5φ12/m
5φ12/m
5φ12/m
5φ12/m
5φ10/m
5φ12/m
5φ12/m
5φ10/m
0.30
0.30
0.30
0.30
4φ22
4.0
4.0
5.0


Hz. strip (3)
5ϕ12/m
5ϕ12/m
5ϕ12/m
5ϕ12/m
5ϕ12/m
5ϕ12/m
5ϕ12/m
0.30
0.30
0.30
10.0
5.0

Example(10)

Given:

$f_{cu}=25\ N/mm^2$ &

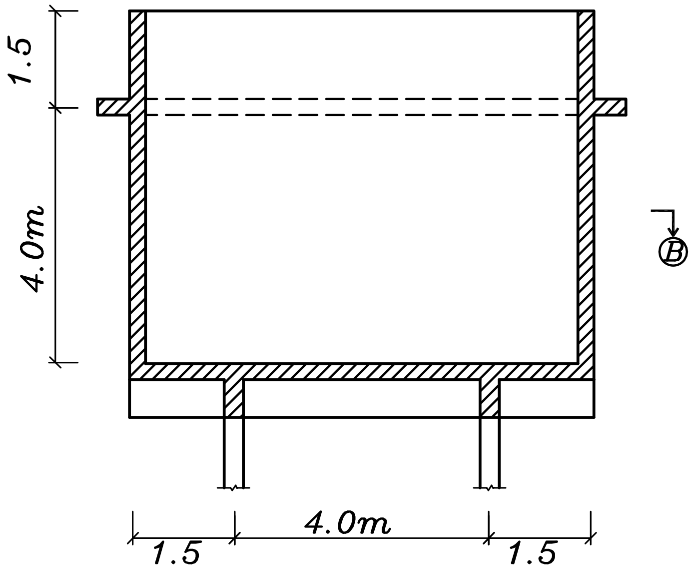
steel used is 360/520

Required

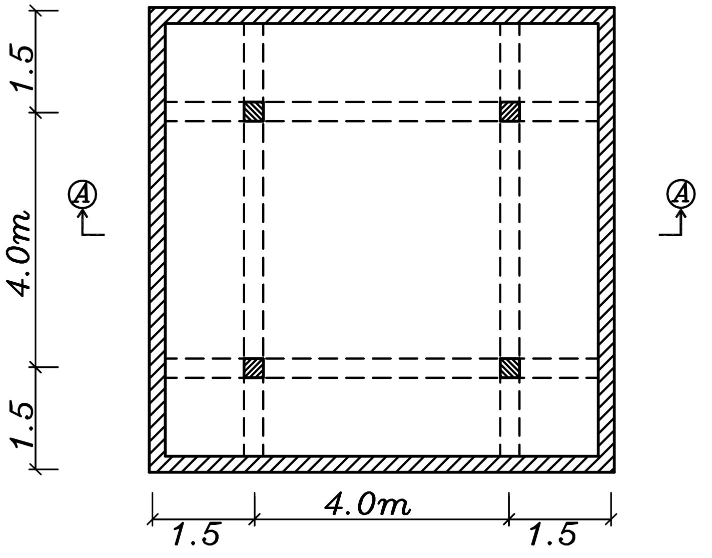
1-Draw the load diagram for the vertical sections (A-A) and hz. section (B-B)

2-Calculate the internal forces and design section (A-A) , (B-B)

3-Draw the load diagram for the top hz. beam.

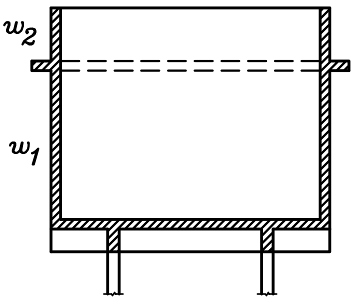


sec (A-A)



sec (B-B)

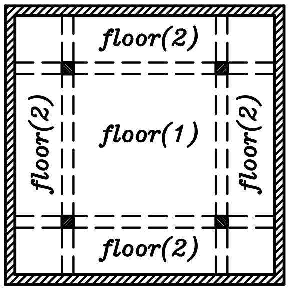
Solution



1- Concrete dimensions

$$t_w = t_f = \frac{L}{16} = \frac{400}{16} = 25cm$$

$\Longrightarrow$ Take $t_w = t_f = 25cm$

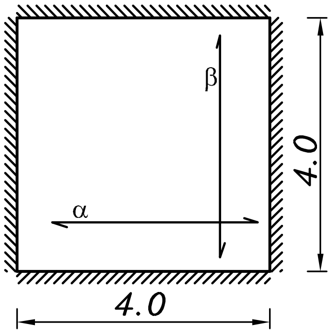


2- Loads on floor

$$w_f = 0.25*25+10*5.5=61.25 \ kN/m^2$$

3- Load distribution

- Floor (1) (4.0*4.0)

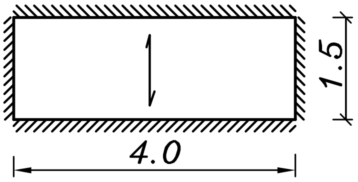


$$r = \frac{0.76*4.0}{0.76*4.0} = 1.00$$

$$\alpha = \beta = 0.50$$

- Floor (2) (1.5*4.0)

one way in short direction

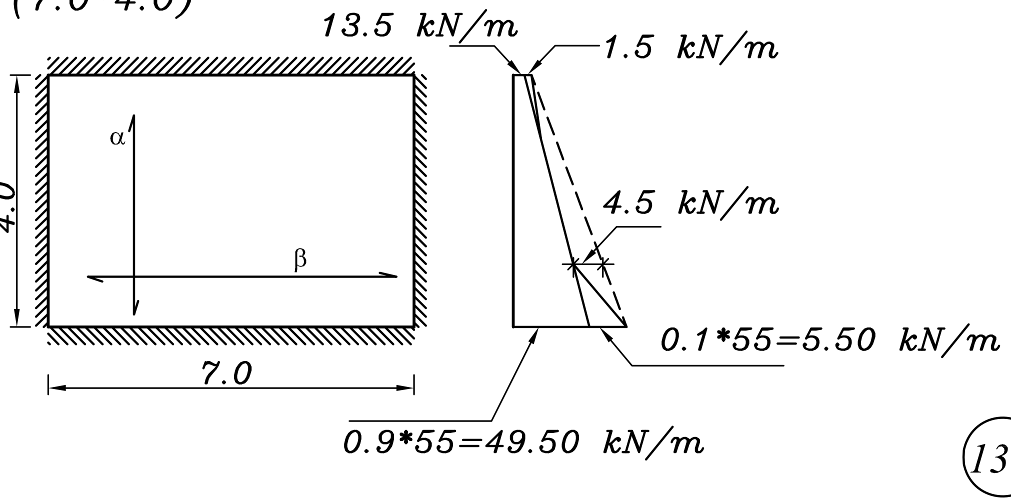


- Wall (1) (7.0*4.0)

$$r = \frac{0.76*7}{0.76*4} = 1.75$$

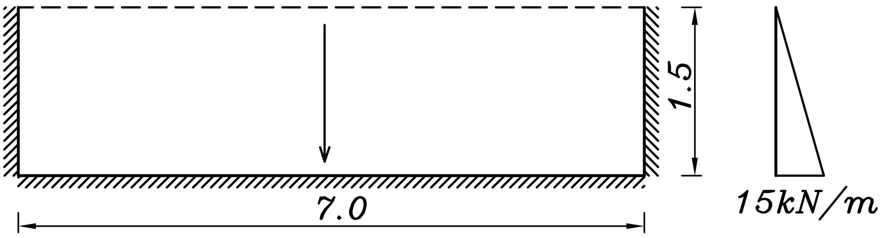
$$\alpha = \frac{r^4}{1+r^4} = 0.90$$

$$\beta = \frac{1}{1+r^4} = 0.10$$



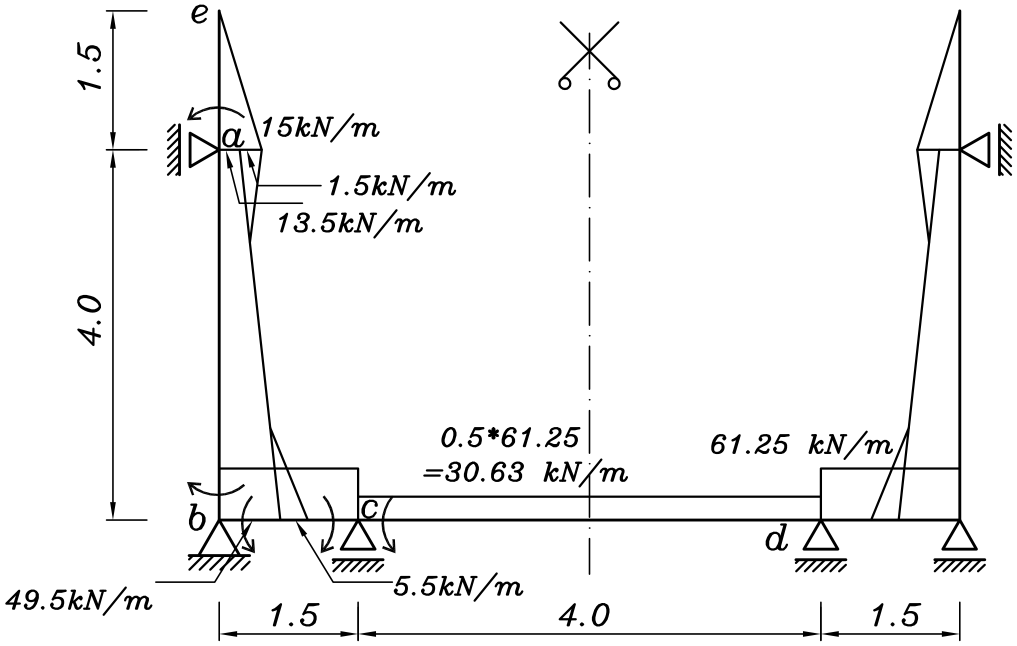
– Wall (2) (7.0*1.5)

cantilever wall



4– Analysis of strips

– VL. strip (1) sec (A–A)



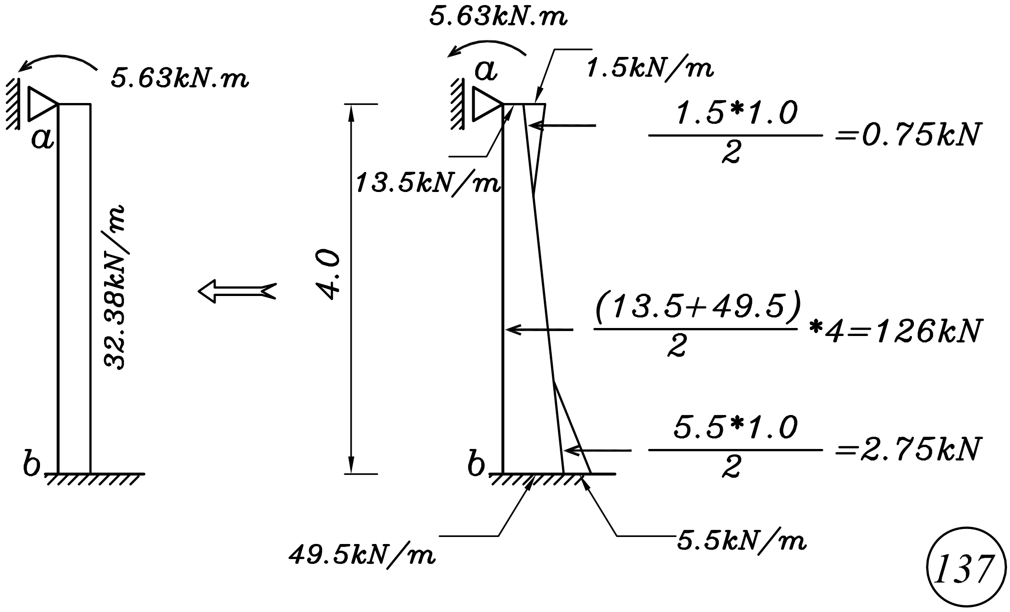
$$F.E.M._{ae} = \frac{15*(1.5)^2}{6} = 5.63\ kN.m$$

for part ab

$w_{eq}=(0.75+126$

$+2.75)/4$

$w_{eq}=32.38kN/m$



$$\Longrightarrow F.E.M._{ba} = \frac{32.38*(4)^2}{8} - \frac{5.63}{2} = 61.95 \ \ kN.m$$

$$F.E.M._{bc} = \frac{-61.25*(1.5)^2}{12} = -11.48kN.m \quad \& \quad F.E.M._{cb} = 11.48kN.m$$

$$F.E.M._{cd} = \frac{-30.63*(4.0)^2}{12} = -40.84kN.m$$

<u>For Joint b</u>

$$D.f_{ba} = \frac{0.75(I/4.0)}{0.75(I/4.0)+(I/1.5)} = 0.22$$

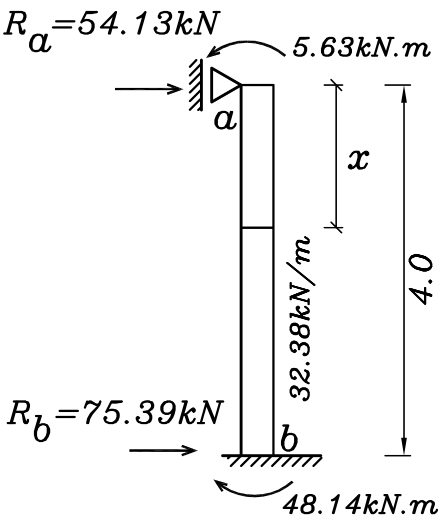
$$D.f_{bc} = \frac{(I/1.5)}{0.75(I/4.0)+(I/1.5)} = 0.78$$

<u>For Joint c</u>

$$D.f_{cb} = \frac{(I/1.5)}{(I/1.5)+0.5(I/4.0)} = 0.84$$

$$D.f_{cd} = \frac{0.5(I/4)}{(I/1.5)+0.5(I/4.0)} = 0.16$$

Joint	b		c	
member	ba	bc	cb	cd
D.f.	0.22	0.78	0.84	0.16
F.E.M.	61.95	−11.48	11.48	−40.84
Bal.M.	−11.10	−39.37	24.66	4.70
C.O.M.	0	12.33	−19.69	0
Bal.M.	−2.71	−9.62	16.54	3.15
M_f	48.14	−48.14	32.99	−32.99

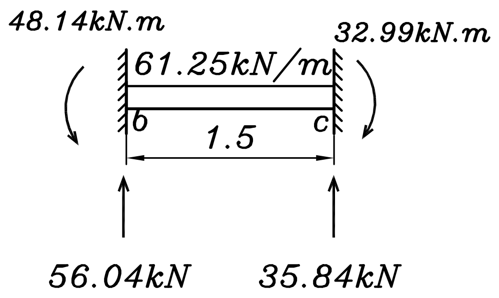


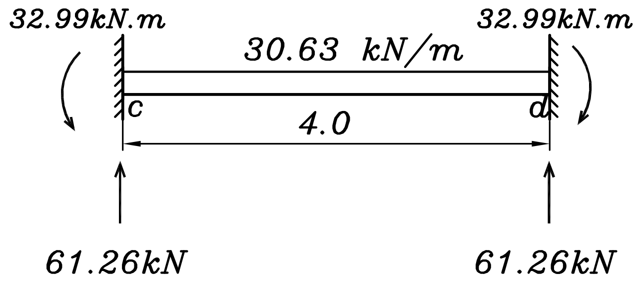
Point of zero shear

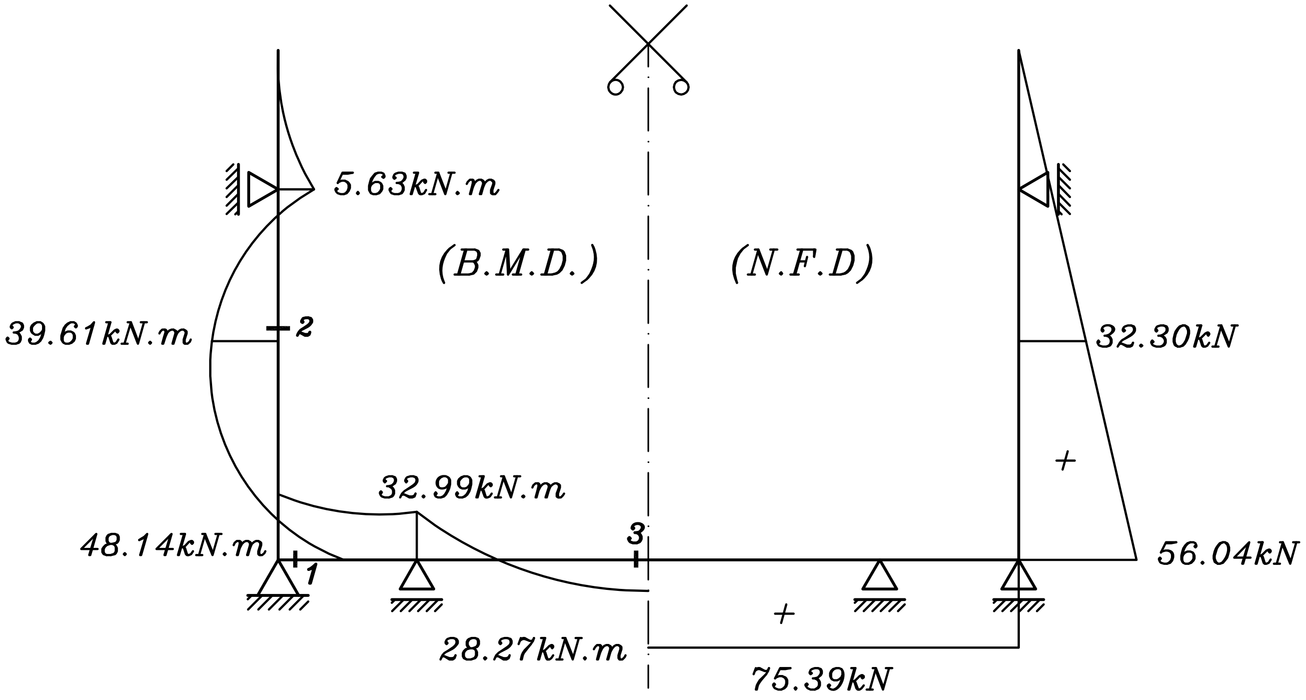
$$32.38x=54.13 \Longrightarrow x=1.67m$$

$$\Longrightarrow M_{+ve}=54.13x-(32.38x)*(\frac{x}{2})$$
$$-5.63$$

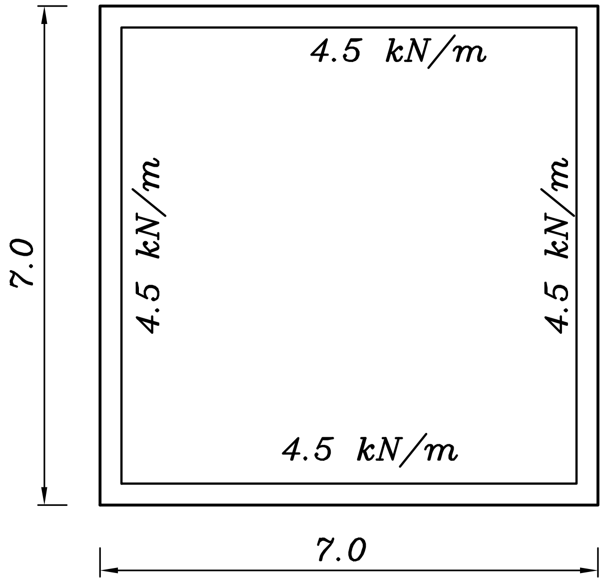
$$M_{+ve}=39.61\ \ kN.m$$

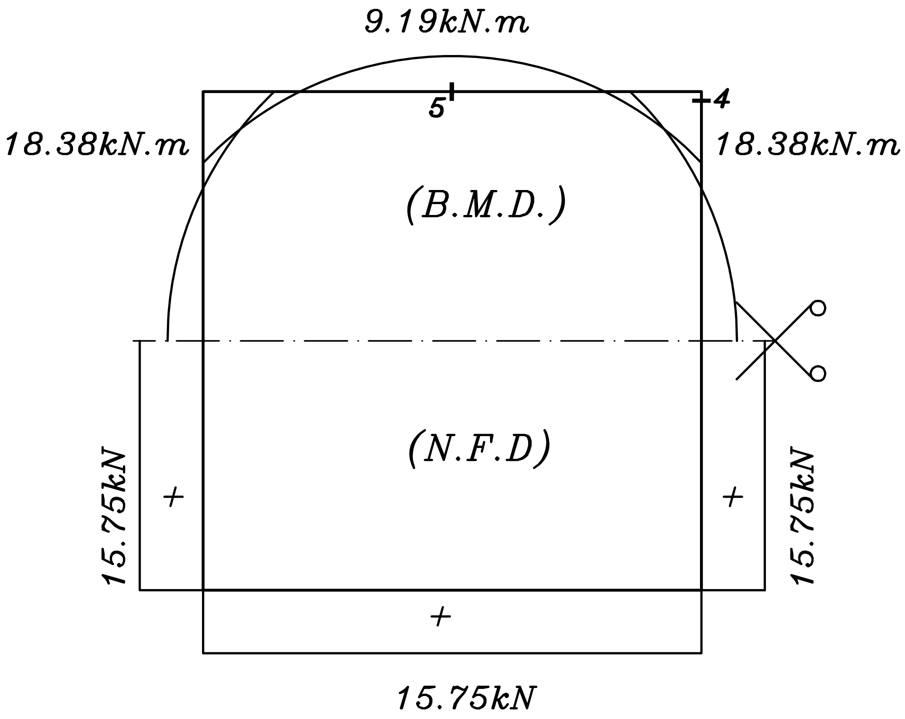




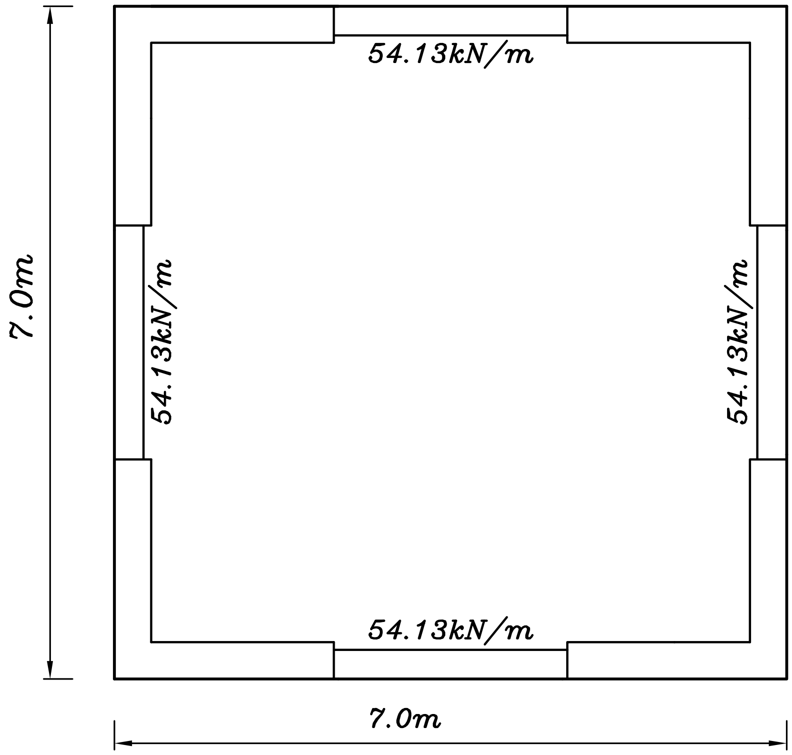


– HZ. strip (2) at h=1.0m sec (B–B)





– Loads on top hz. beam



5– Design of sections

Sec (1–1) water section

$M_{working}=48.14$ kN.m , $T_{working}=75.39$ kN , b=1000mm

Stage (I)

$$t_{(mm)}=\sqrt{\frac{M*10^{3}}{factor}}+40mm=\sqrt{\frac{48.14*10^{3}}{0.28}}+40mm=454.64mm$$

$\Longrightarrow$ Take t =450mm

Check stresses

$$f_t=+\frac{T}{A}+\frac{M}{Z}=+\frac{75.39*10^{3}}{1000*450}+\frac{48.14*10^{6}}{1000*(450)^{2}/6}$$

$$=0.17+1.43=1.60\ N/mm^{2}$$

$$\Longrightarrow f_{ct}=\frac{0.6\sqrt{25}}{1.7}=1.76N/mm^2 \quad \Longrightarrow f_t < f_{ct} \quad (safe)$$

Stage (II)

$$M_{u.l.}=1.5*48.14=72.21 \ kN.m \quad , \quad T_{u.l.}=1.5*75.39=113.09 \ kN$$

$$e=\frac{M_{u.l.}}{T_{u.l.}}=\frac{72.21}{113.09}=0.64m > \frac{t}{2} -cover$$

$$e_s=e-\frac{t}{2}+c=0.64-\frac{0.45}{2}+0.04=0.46m$$

$$M_{us}=113.09*0.46=51.46kN.m$$

$$410=C_1\sqrt{\frac{51.46*10^6}{1000*25}} \qquad C_1=9.04 \quad \& \quad J=0.826$$

$$A_s=\frac{1}{\beta_{cr}}*[\frac{M_{us}}{J*d*f_y}+\frac{T_{u.l.}}{f_y/\gamma_s}]$$

assume $\phi 16$ used $\Longrightarrow$ $\beta_{cr}=0.75$

$$A_s=\frac{1}{0.75}[\frac{51.46*10^6}{0.826*410*360}+\frac{113.09*10^3}{360/1.15}]$$

$$A_s=1044.46mm^2/m' \Longrightarrow 6\phi 16/m'$$

Sec (2−2) air section , t=250mm

$$M_{working}=39.61 \ kN.m \ , \quad T_{working}=32.30 \ kN \quad , \quad b=1000mm$$

$$A_s=6\phi 16/m'$$

Sec (3−3) air section , t=250mm

$$M_{working}=28.27 \ kN.m \ , \quad T_{working}=75.39 \ kN \quad , \quad b=1000mm$$

$$A_s=8\phi 12/m'$$

Sec (4−4) water section

$M_{working}=18.38\ kN.m$, $T_{working}=15.75\ kN$, $b=1000mm$

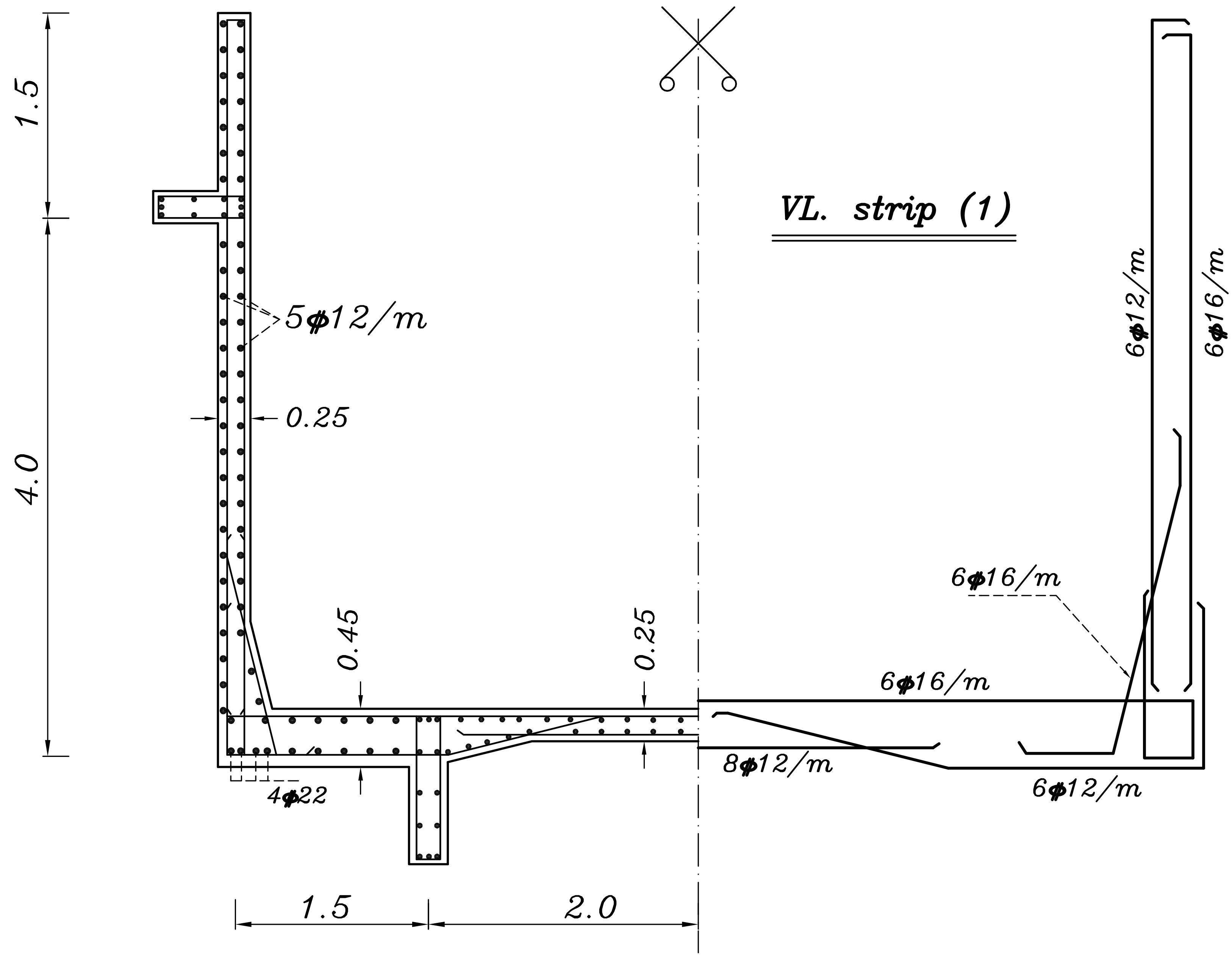
$t=300mm$, $A_s=5\phi12/m'$

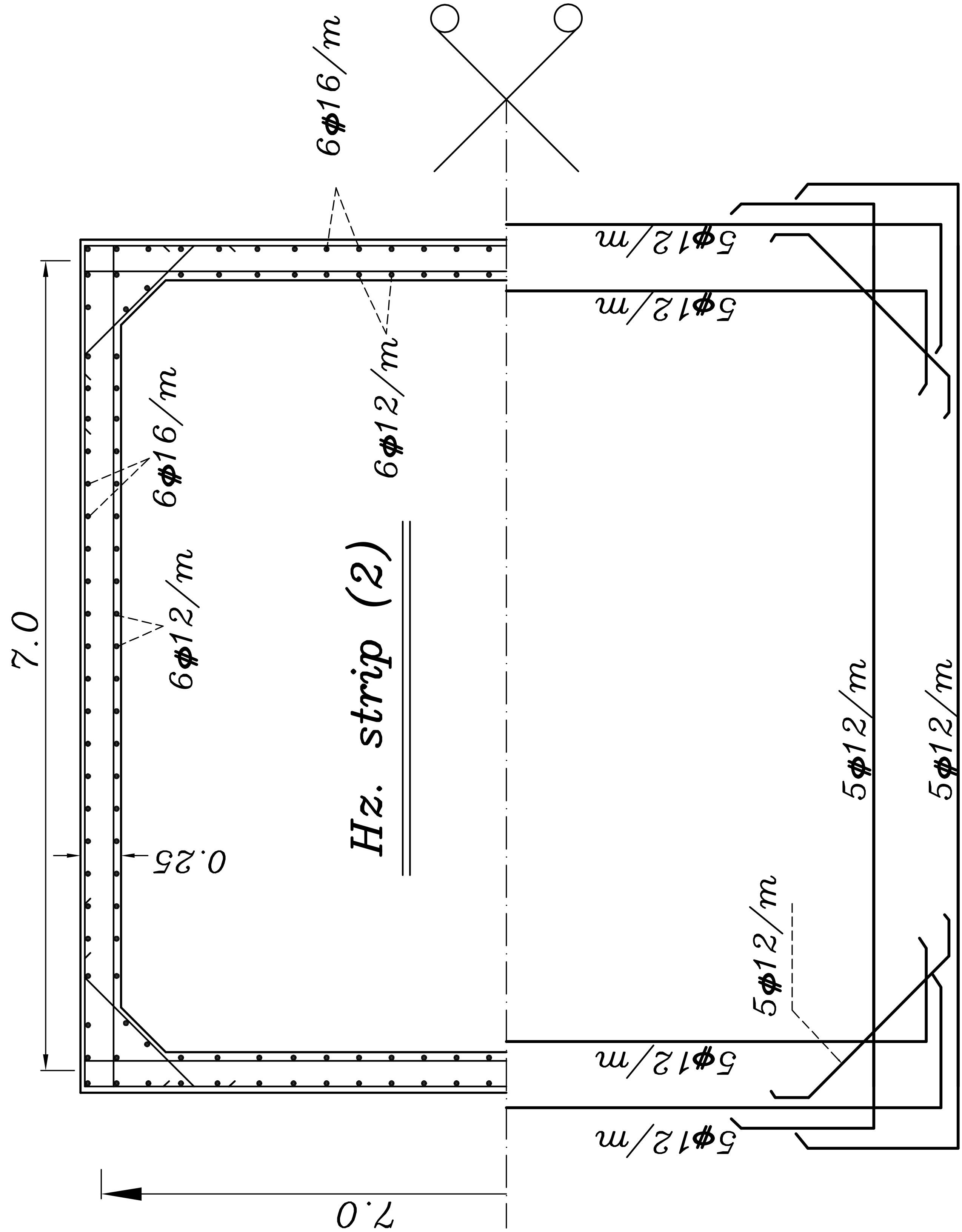
Sec (5−5) air section , t=250mm

$M_{working}=9.19\ kN.m$, $T_{working}=15.75\ kN$, $b=1000mm$

$A_s=5\phi12/m'$

Details of RFT.




Hz. strip (2)
6ϕ16/m
6ϕ12/m
6ϕ16/m
6ϕ12/m
7.0
0.25
7.0
5ϕ12/m
5ϕ12/m
5ϕ12/m
5ϕ12/m
5ϕ12/m
5ϕ12/m
5ϕ12/m

– Design of wall as a deep beam

1– Simple beam

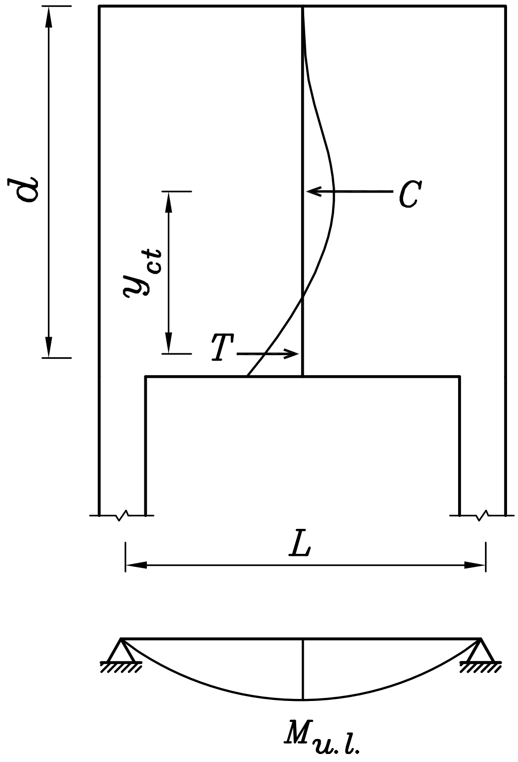
الكمرات العميقة بسيطة الارتكاز (simply supported deep beams)

هى الكمرات التى يزيد عمقها عن بحرها الفعال بنسبة (0.8)

$$\boxed{\frac{d}{L} \geq 0.8}$$

$$y_{ct} = \left[\begin{array}{l} 0.86L \\ 0.87d \end{array}\right.$$

ايهما اقل



$$\Longrightarrow \quad T_{u.l.} = \frac{M_{u.l.}}{y_{ct}}$$

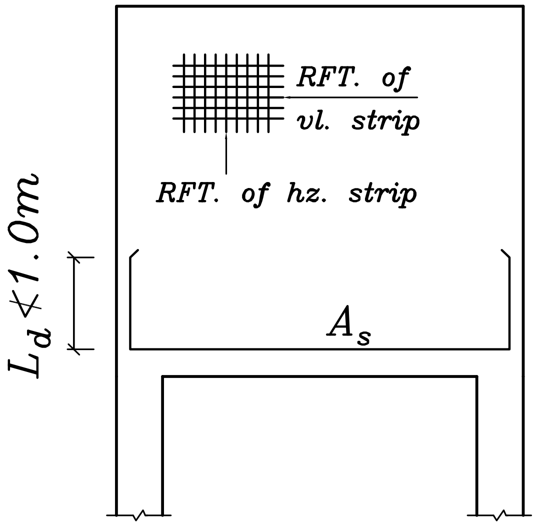
$$\Longrightarrow A_s = \frac{T_{u.l.}}{\beta_{cr} \cdot (f_y / \gamma_s)} > \frac{1.1}{f_y} bd$$

$$If \;\; A_s < \frac{1.1}{f_y} bd \Longrightarrow take \;\; A_{s_{min}}$$

$$A_{s_{min}} = \left[\begin{array}{l} \frac{1.1}{f_y} bd \\ 1.3 A_{s_{req}} \\ \frac{0.15}{100} bd \end{array}\right.$$

الاقل

الاكبر

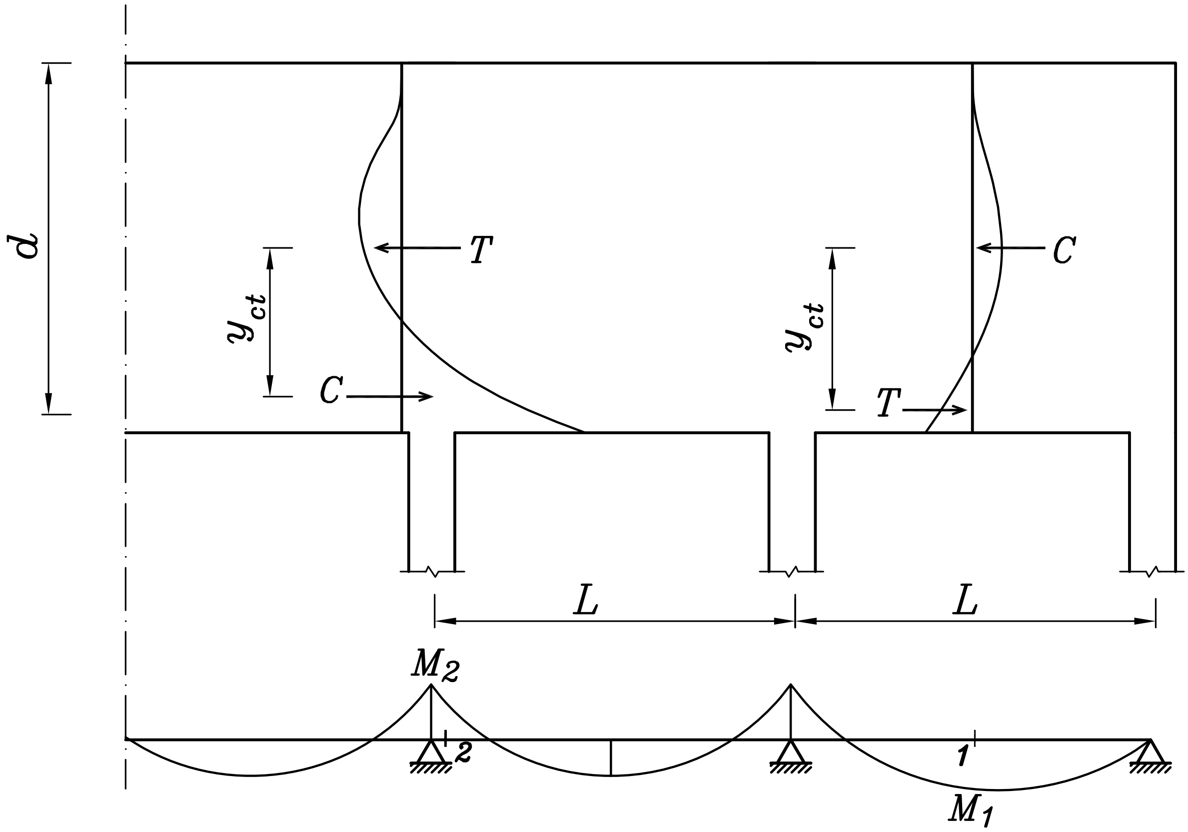


1- Continuous beam

الكمرات العميقة المتصلة (continuous deep beams)

$\boxed{\frac{d}{L} \geq 0.4}$

هى الكمرات التى يزيد عمقها عن بحرها الفعال بنسبة (0.4)



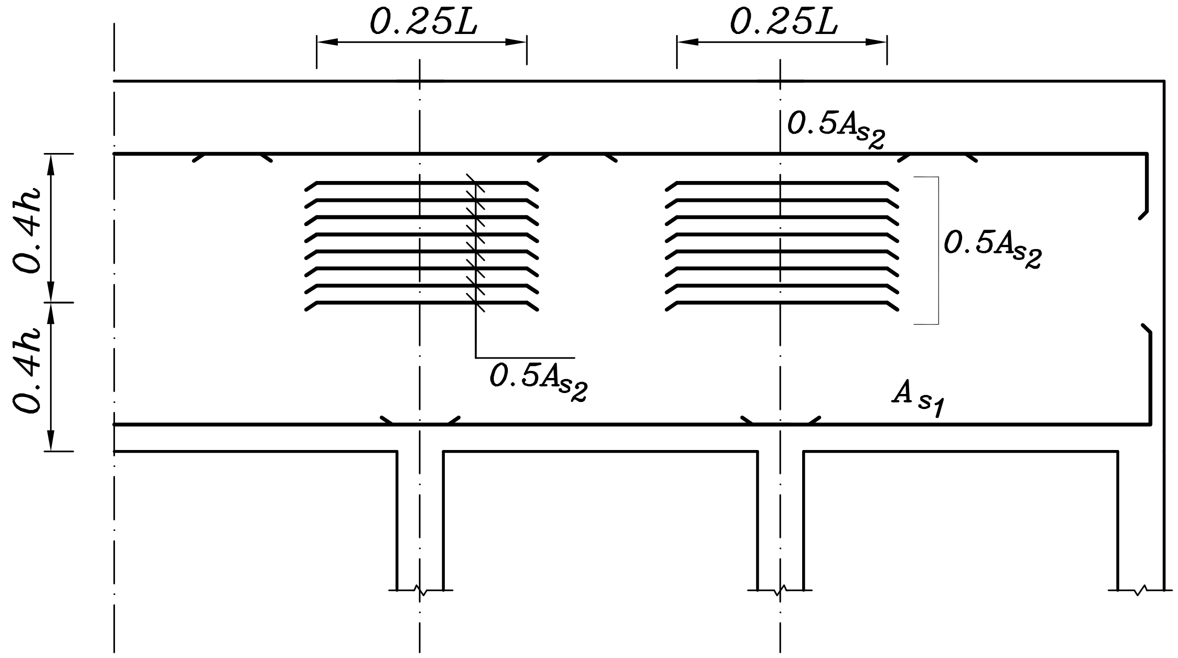
### Sec (1-1)	### Sec (2-2)
$y_{ct} = \left[\begin{array}{l} 0.43L \\ 0.87d \end{array} \right.$ ايهما اقل	$y_{ct} = \left[\begin{array}{l} 0.37L \\ 0.87d \end{array} \right.$ ايهما اقل
$\Longrightarrow T_{u.l.} = \frac{M_1}{y_{ct}}$	$\Longrightarrow T_{u.l.} = \frac{M_2}{y_{ct}}$
$\Longrightarrow A_s = \frac{T_{u.l.}}{\beta_{cr} \cdot (f_y / \gamma_s)} > \frac{1.1}{f_y} bd$	$\Longrightarrow A_s = \frac{T_{u.l.}}{\beta_{cr} \cdot (f_y / \gamma_s)} > \frac{1.1}{f_y} bd$

$$If \ A_s < \frac{1.1}{f_y} bd \Longrightarrow take \ A_{s_{min}}$$

$$A_{s_{min}} = \left[\begin{array}{l} \frac{1.1}{f_y} bd \\ 1.3 A_{s_{req}} \\ \frac{0.15}{100} bd \end{array} \right.$$

الاقل (للأول والثاني)

الاكبر



يتم توزيع الحديد (A_{s_2}) الى نصفين

-نصف يتم وضعه عند $(0.8h)$

-نصف يتم وضعه من $(0.4h)$ الى $(0.8h)$ على مسافات لا تزيد عن $(0.20\ m)$

Example(11) (M.T. str. 2000)

Given:

$f_{cu} = 25\ N/mm^2$ &

steel used is 360/520

Required

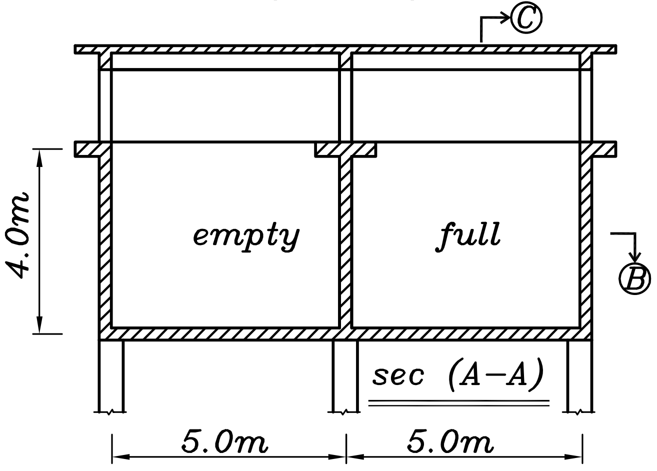
1-Draw the load diagram for the vertical sections (A-A) , (C-C) & hz. section (B-B)

2-Calculate the internal forces and design section (A-A) , (B-B)

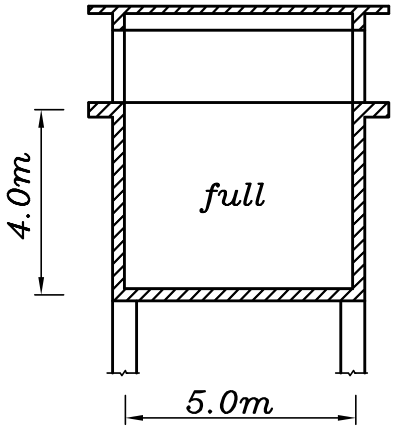
3-Draw the load diagram for the top hz. beam.

4-Draw to a convenient scale details of RFT for sections (A-A) & (B-B)

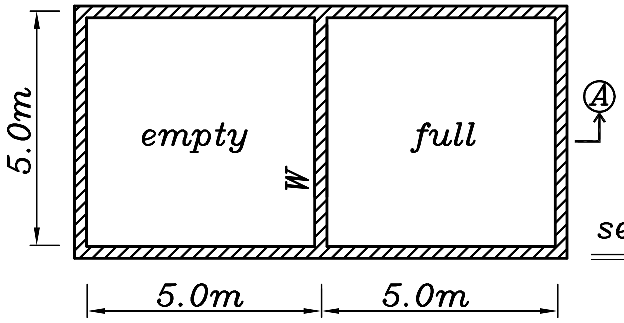
5-Design the wall (W) as a deep beam considering the two vents full of water and draw details of RFT.



sec (A-A)



sec (C-C)



sec (B-B)

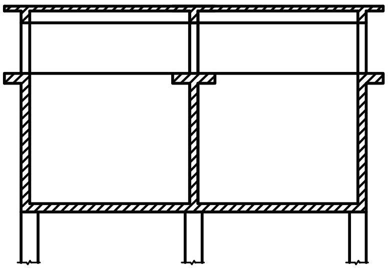
Solution

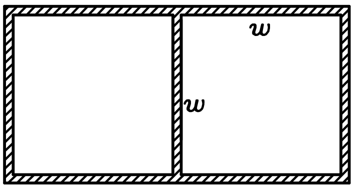
1- Concrete dimensions

$$t_w=t_f=\frac{L}{16}=\frac{500}{16}=31.25cm$$

$\Longrightarrow$ Take $t_w=t_f=30cm$

2- Loads on floor





for floor (full of water)

$$w_f=0.30*25+10*4.0=47.50\ kN/m^2$$

for empty floor

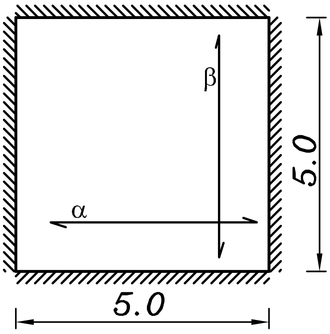
$$w_f=0.30*25=7.50\ kN/m^2$$

3- Load distribution

- for floor (5.0*5.0)

$$r=\frac{0.76*5.0}{0.76*5.0}=1.00$$

$\alpha=\beta=0.50$

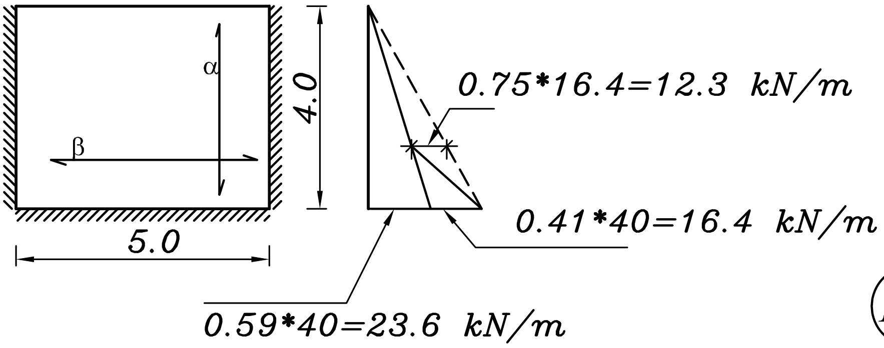


- Wall (5.0*4.0)

$$r=\frac{0.76*5}{0.87*4}=1.09$$

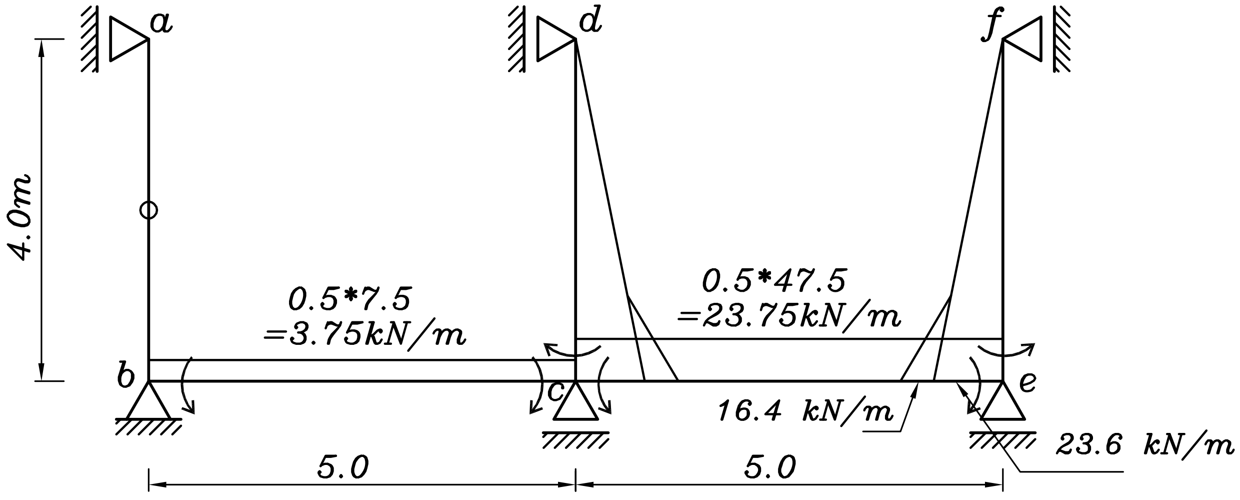
$$\alpha=\frac{r^4}{1+r^4}=0.59$$

$$\beta=\frac{1}{1+r^4}=0.41$$



4- Analysis of strips

- VL. strip (1) sec (A-A)



For Joint b , e

$$D.f_{ba}=D.f_{ef}=\frac{0.75(I/4.0)}{0.75(I/4.0)+(I/5.0)}=0.48$$

$$D.f_{bc}=D.f_{ec}=\frac{(I/5.0)}{0.75(I/4.0)+(I/5.0)}=0.52$$

For Joint c

$$D.f_{cb}=D.f_{ce}=\frac{(I/5.0)}{(I/5.0)+0.75(I/4.0)+(I/5.0)}=0.34$$

$$D.f_{cd}=\frac{0.75(I/4.0)}{(I/5.0)+0.75(I/4.0)+(I/5.0)}=0.32$$

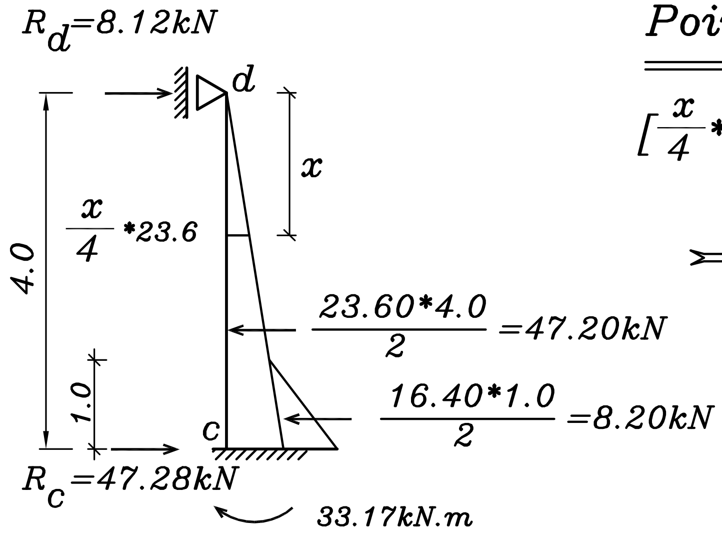
$$F.E.M._{ba}=\frac{23.60*(4)^2}{15}+\frac{16.40*(4)^2}{117}=27.42kN.m$$

$$F.E.M._{ef}=-27.42kN.m$$

$$F.E.M._{bc}=\frac{-3.75*(5)^2}{12}=-7.81kN.m \quad \& \quad F.E.M._{cb}=7.81kN.m$$

$$F.E.M._{ce}=\frac{-23.75*(5)^2}{12}=-49.48kN.m \quad \& \quad F.E.M._{ec}=49.48kN.m$$

Joint	b		c			e	
member	ba	bc	cb	cd	ce	ec	ef
D.f.	0.48	0.52	0.34	0.32	0.34	0.52	0.48
F.E.M.	0	−7.81	7.81	27.42	−49.48	49.48	−27.42
Bal.M.	3.75	4.06	4.85	4.56	4.85	−11.47	−10.59
C.O.M.	0	2.43	2.03	0	−5.74	2.43	0
Bal.M.	−1.17	−1.26	1.26	1.19	1.26	−1.26	−1.17
M_f	2.58	−2.58	15.95	33.17	−49.11	39.18	−39.18



Point of zero shear

$$\left[\frac{x}{4}*23.60\right]*\frac{x}{2}=8.12 \Longrightarrow x=1.66m$$

$$\Longrightarrow M_{+ve}=8.12x-\left(\frac{x}{4}*23.60\right)*\left(\frac{x^2}{6}\right)$$

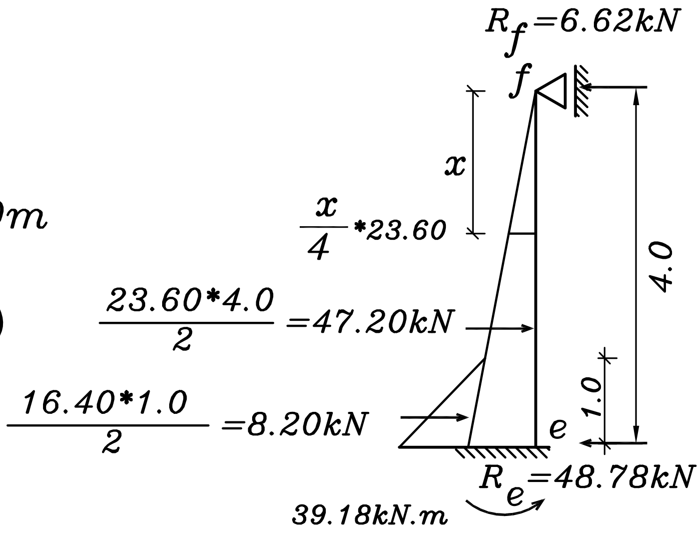
$$M_{+ve}=8.98\ \ kN.m$$

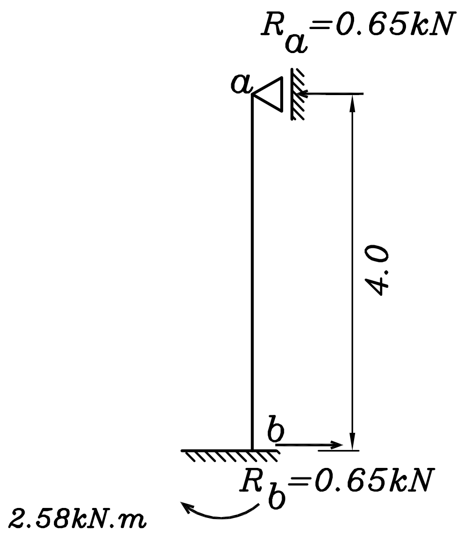
Point of zero shear

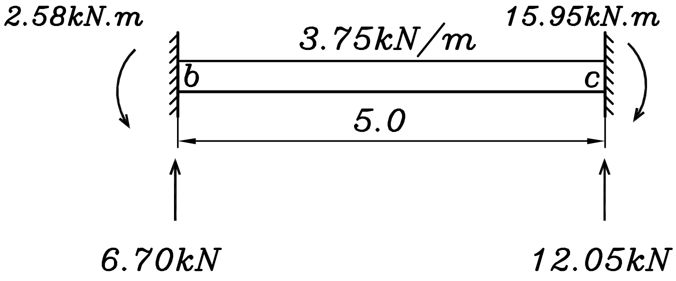
$$\left[\frac{x}{4}*23.60\right]*\frac{x}{2}=6.62 \Longrightarrow x=1.50m$$

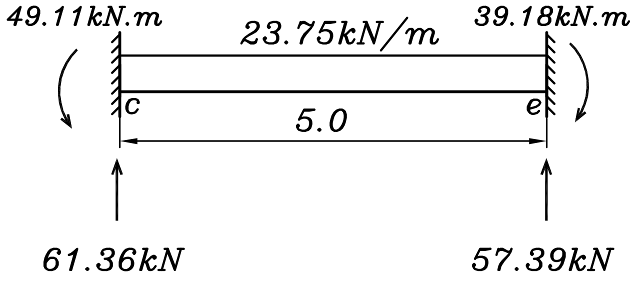
$$\Longrightarrow M_{+ve}=6.62x-\left(\frac{x}{4}*23.60\right)*\left(\frac{x^2}{6}\right)$$

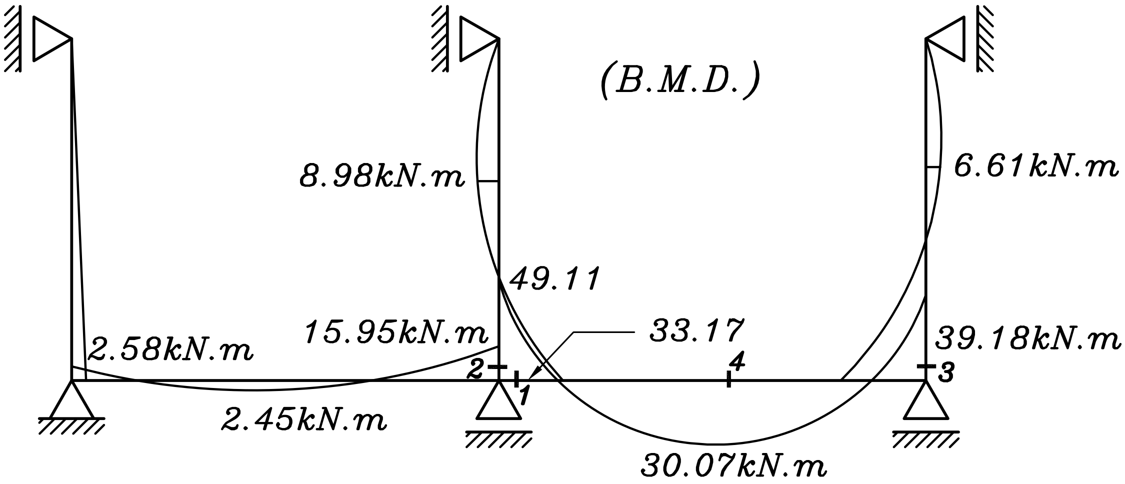
$$M_{+ve}=6.61\ \ kN.m$$

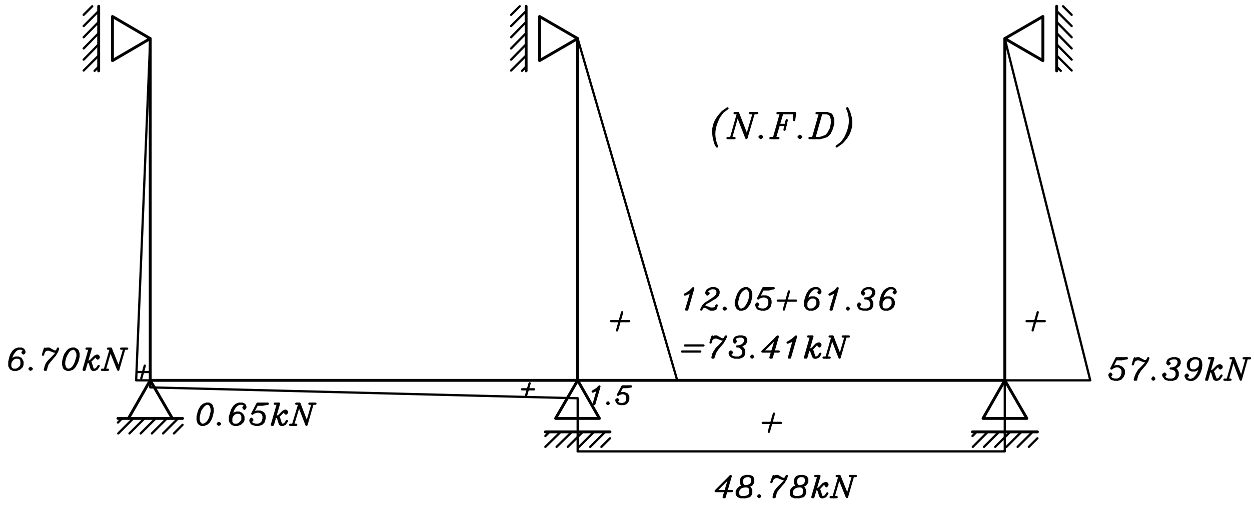




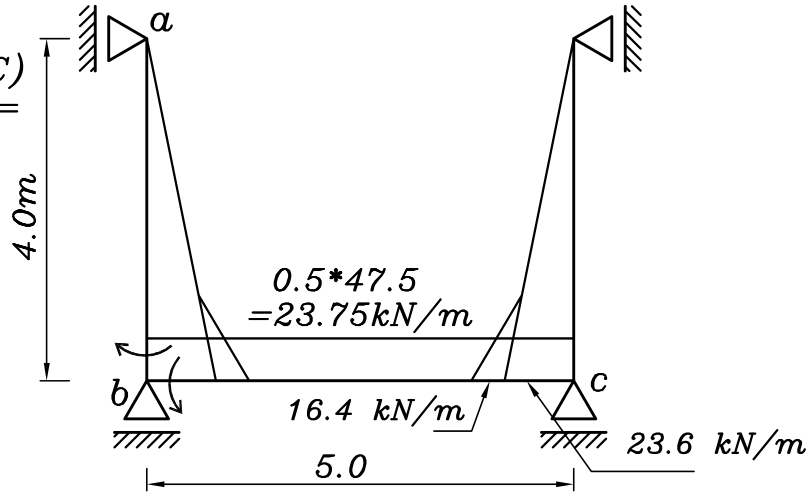








– VL. strip (2) sec (C–C)



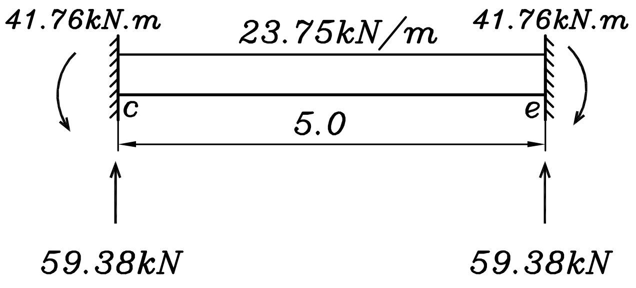
For Joint b

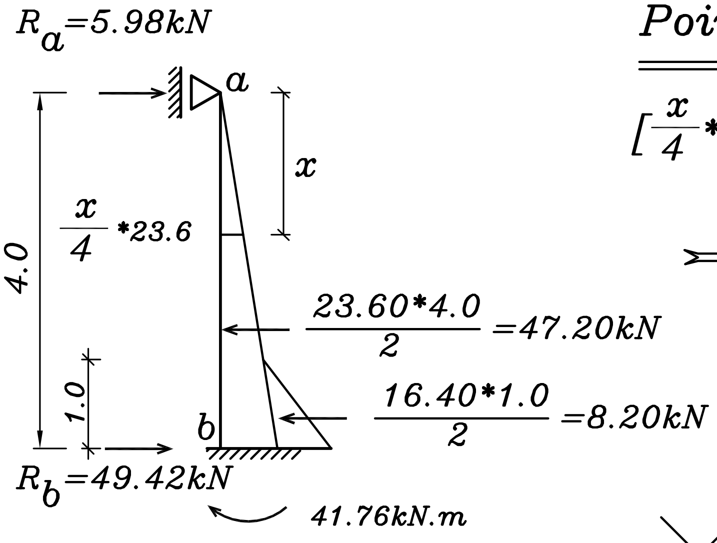
$$D.f_{ba}=\frac{0.75(I/4.0)}{0.75(I/4.0)+0.5(I/5.0)}=0.65\ ,\ D.f_{bc}=1-0.65=0.35$$

$$F.E.M._{ba}=\frac{23.60*(4)^2}{15}+\frac{16.40*(4)^2}{117}=27.42kN.m$$

$$F.E.M._{bc}=\frac{-23.75*(5)^2}{12}=-49.48kN.m$$

Joint	b	
member	ba	bc
D.f.	0.65	0.35
F.E.M.	27.42	−49.48
Bal.M.	14.34	7.72
M_f	41.76	−41.76



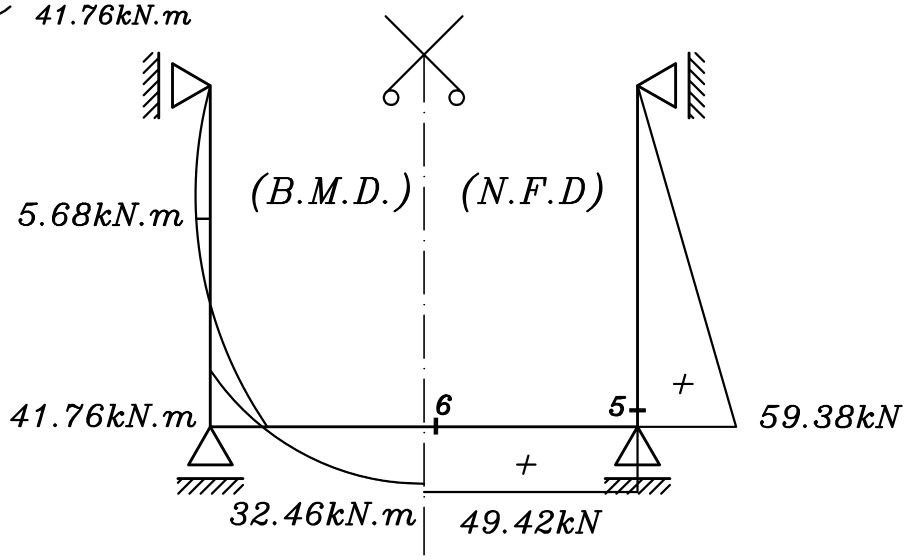


Point of zero shear

$$[\frac{x}{4}*23.60]*\frac{x}{2}=5.98 \Longrightarrow x=1.42m$$

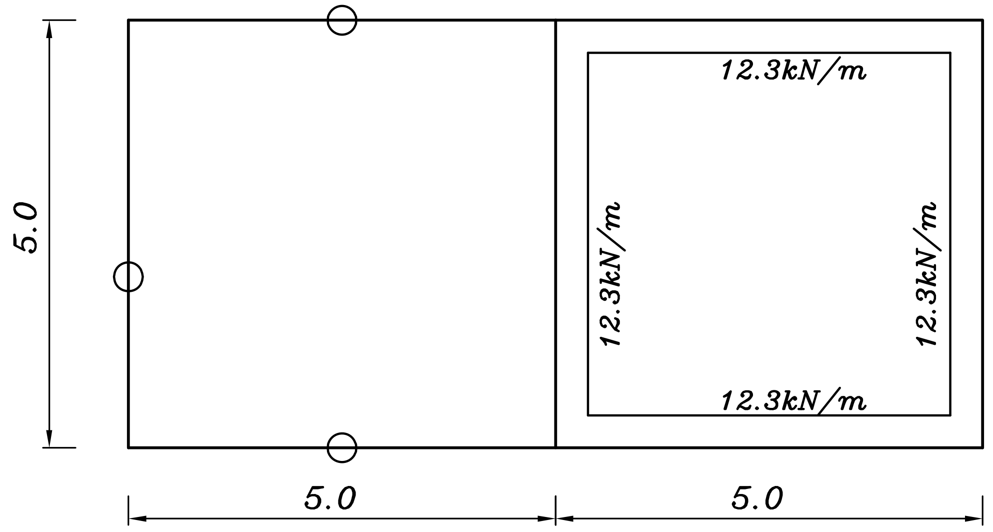
$$\Longrightarrow M_{+ve}=5.98x-(\frac{x}{4}*23.60)*(\frac{x^2}{6})$$

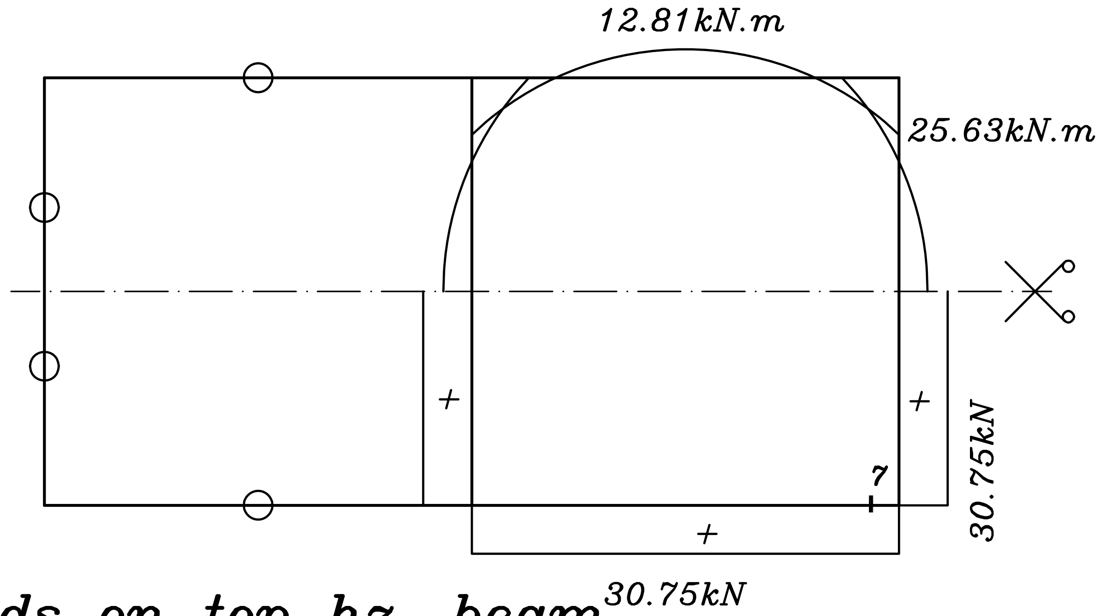
$$M_{+ve}=5.68\ \ kN.m$$



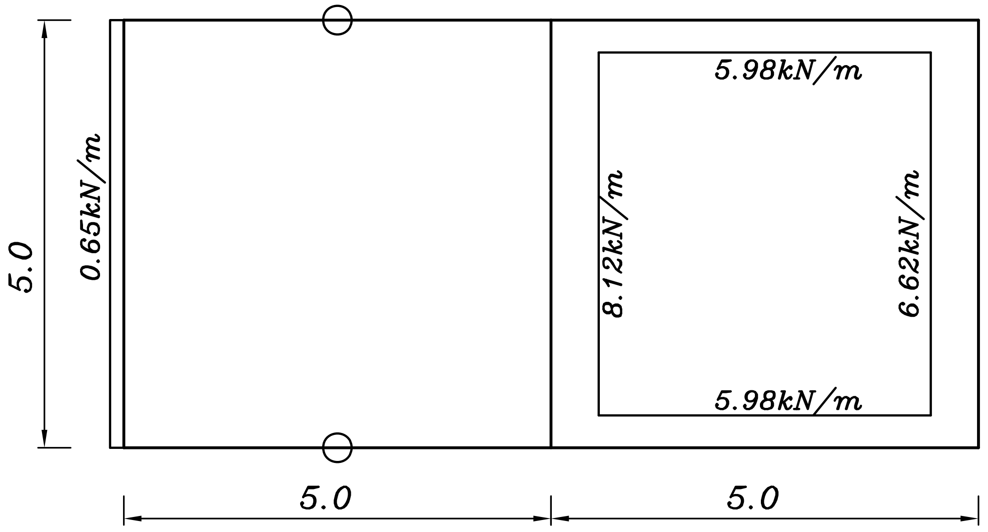
– HZ. strip (2) at h=1.0

sec (B–B)





– Loads on top hz. beam



5− Design of sections

Sec (1−1) water section

$M_{working}=49.11\ kN.m$, $T_{working}=48.78\ kN$, $b=1000mm$

Stage (I)

$$t_{(mm)}=\sqrt{\frac{M*10^{3}}{factor}}+40mm=\sqrt{\frac{49.11*10^{3}}{0.28}}+40mm=458.80mm$$

$\Longrightarrow$ Take $t\ =450mm$

Check stresses

$$f_t=+\frac{T}{A}+\frac{M}{Z}=+\frac{48.78*10^{3}}{1000*450}+\frac{49.11*10^{6}}{1000*(450)^2/6}$$

$$=0.11+1.46=1.57\ N/mm^2$$

$$\Longrightarrow f_{ct}=\frac{0.6\sqrt{25}}{1.7}=1.76N/mm^2 \quad \Longrightarrow f_t<f_{ct} \quad (safe)$$

Stage (II)

$M_{u.l.}=1.5*49.11=73.67\ kN.m$, $T_{u.l.}=1.5*48.78=73.17\ kN$

$$e=\frac{M_{u.l.}}{T_{u.l.}}=\frac{73.67}{73.17}=1.01m>\frac{t}{2}-cover$$

$$e_s=e-\frac{t}{2}+c=1.01-\frac{0.45}{2}+0.04=0.82m$$

$M_{us}=73.17*0.82=60.13kN.m$

$$410=C_1\sqrt{\frac{60.13*10^{6}}{1000*25}} \qquad C_1=8.36 \quad \& \quad J=0.826$$

$$A_s=\frac{1}{\beta_{cr}}*[\frac{M_{us}}{J*d*f_y}+\frac{T_{u.l.}}{f_y/\gamma_s}]$$

assume $\phi 16$ used $\Longrightarrow$ $\beta_{cr} = 0.75$

$$A_s = \frac{1}{0.75}\left[\frac{60.13*10^6}{0.826*410*360} + \frac{73.17*10^3}{360/1.15}\right]$$

$A_s = 969.25 mm^2/m' \Longrightarrow 5\phi 16/m'$

Sec (2−2) water section

$M_{working} = 33.17$ kN.m , $T_{working} = 73.41$ kN , b=1000mm

t=400mm , $A_s = 5\phi 16/m'$

Sec (3−3) water section

$M_{working} = 39.18$ kN.m , $T_{working} = 57.39$ kN , b=1000mm

t=400mm , $A_s = 5\phi 16/m'$

Sec (4−4) air section , t=300mm

$M_{working} = 30.07$ kN.m , $T_{working} = 48.78$ kN , b=1000mm

$A_s = 7\phi 12/m'$

Sec (5−5) water section

$M_{working} = 41.76$ kN.m , $T_{working} = 59.38$ kN , b=1000mm

t=400mm , $A_s = 8\phi 12/m'$

Sec (6−6) air section , t=300mm

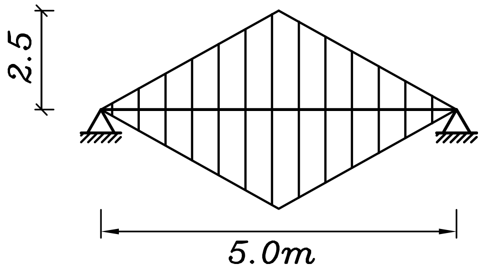
$M_{working} = 32.46$ kN.m , $T_{working} = 49.42$ kN , b=1000mm

$A_s = 7\phi 12/m'$

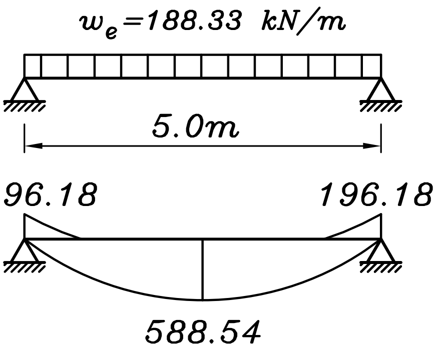
Sec (7−7) water section

t=350mm , $A_s = 6\phi 12/m'$

– Loads on wall (w) (wall acts as a beam)



$\Longrightarrow$



– Load for moment

$$w_e = o.w. + c_e \frac{L_s}{2} . w_f *2$$

$$w_e = 0.3*4.0*25+2/3*5/2*47.50*2$$

$$w_e = 188.33 \ \ kN/m$$

$$M_{u.l.} = 1.5*588.54 = 882.81 \ \ kN.m \ \ , \ \ L=5.0m$$

$$d = 4.0-0.10 = 3.90m \Longrightarrow \frac{d}{L} = \frac{3.9}{5.0} = 0.8 \Longrightarrow \text{deep beam}$$

$$y_{ct} = \left[\begin{array}{l} 0.86*5=4.3m \\ 0.87*3.9=3.39m \end{array}\right.$$

ايهما اقل $\Longrightarrow y_{ct}=3.39m$

$$T = \frac{M}{y_{ct}} = \frac{882.81}{3.39} = 260.42 \ \ kN$$

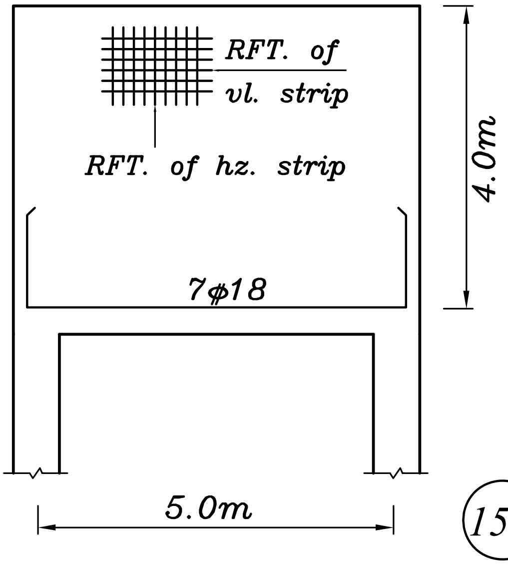
$$A_s = \frac{T_{u.l.}}{\beta_{cr}.(f_y/\gamma_s)} \qquad \text{assume } \phi 18 \text{ used} \Longrightarrow \beta_{cr}=0.75$$

$$A_s = \frac{260.42*10^3}{0.75*360/1.15} = 1109.20 \ \ mm^2$$

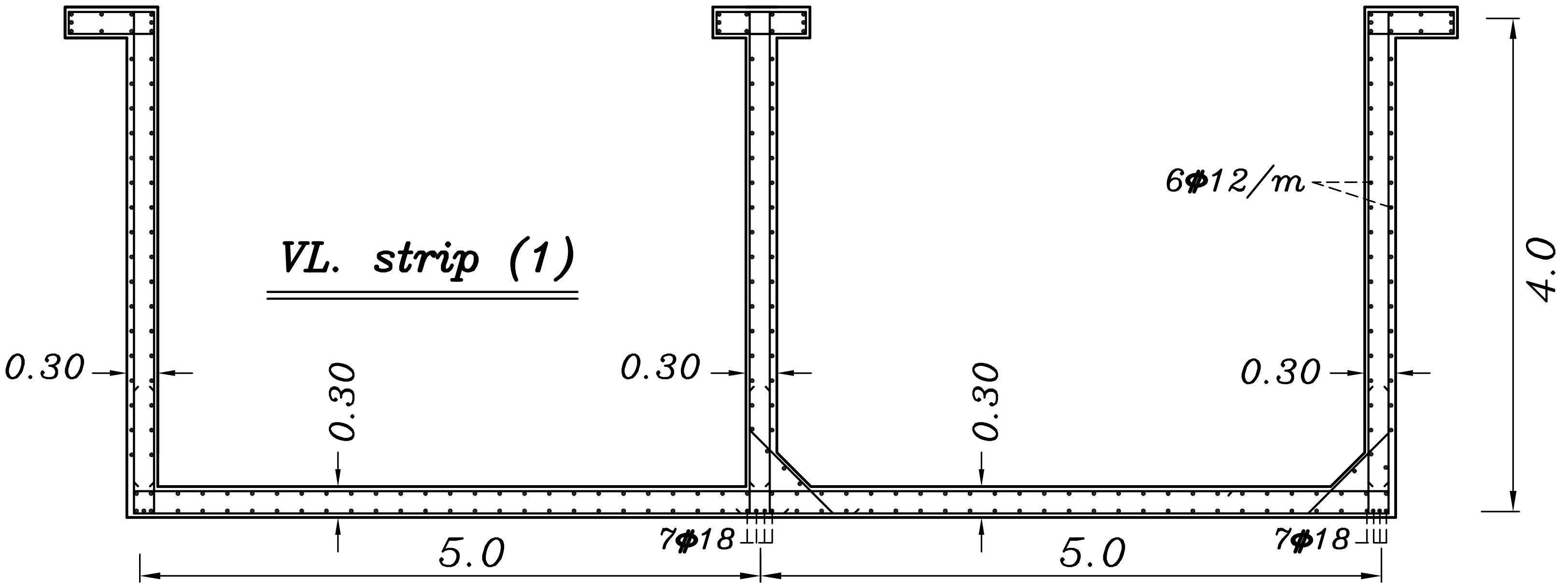
$$\frac{1.1}{f_y} bd = \frac{1.1}{360} 300*3900 = 3757mm^2 > A_s$$

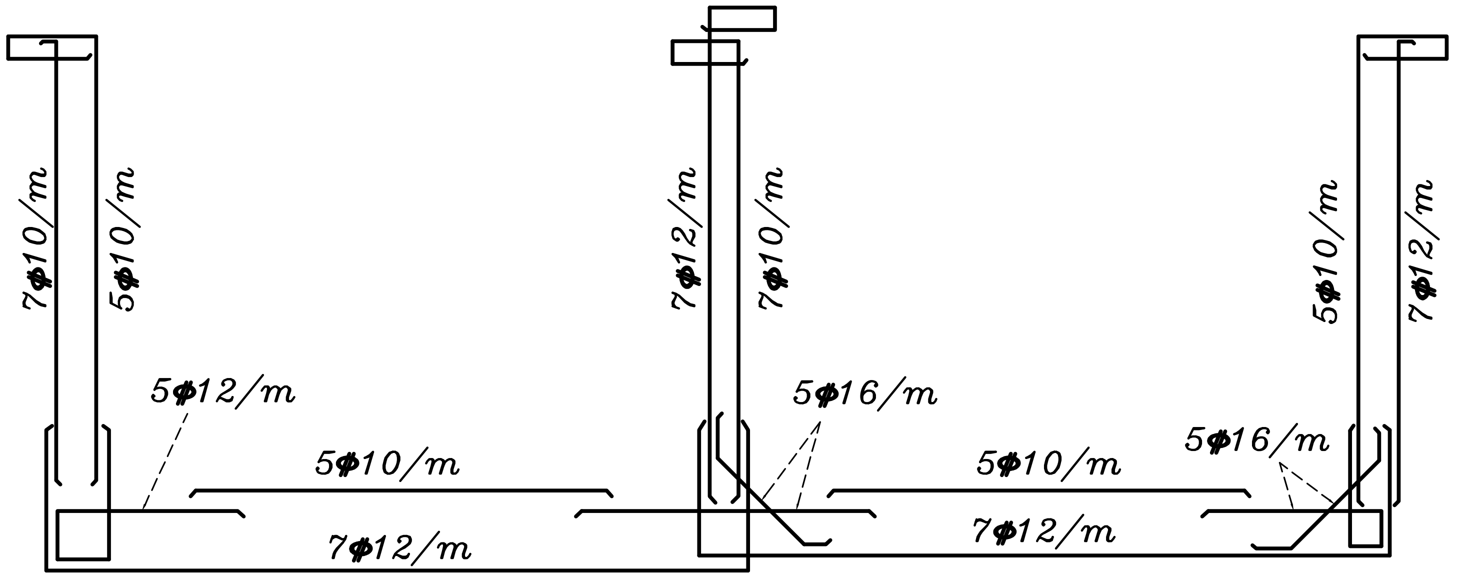
$$A_{s_{min}} = \left[\begin{array}{l} \frac{1.1}{f_y} bd = \frac{1.1}{360} 300*3900 = 3757mm^2 \\ 1.3A_{s_{req}} = 1.3*1109.2 = 1331mm^2 \\ \frac{0.15}{100} bd = \frac{0.15}{100} 300*3900 = 1755mm^2 \end{array}\right.$$

$$A_{s_{min}} = 1755 \ \ mm^2 = 7\phi 18$$

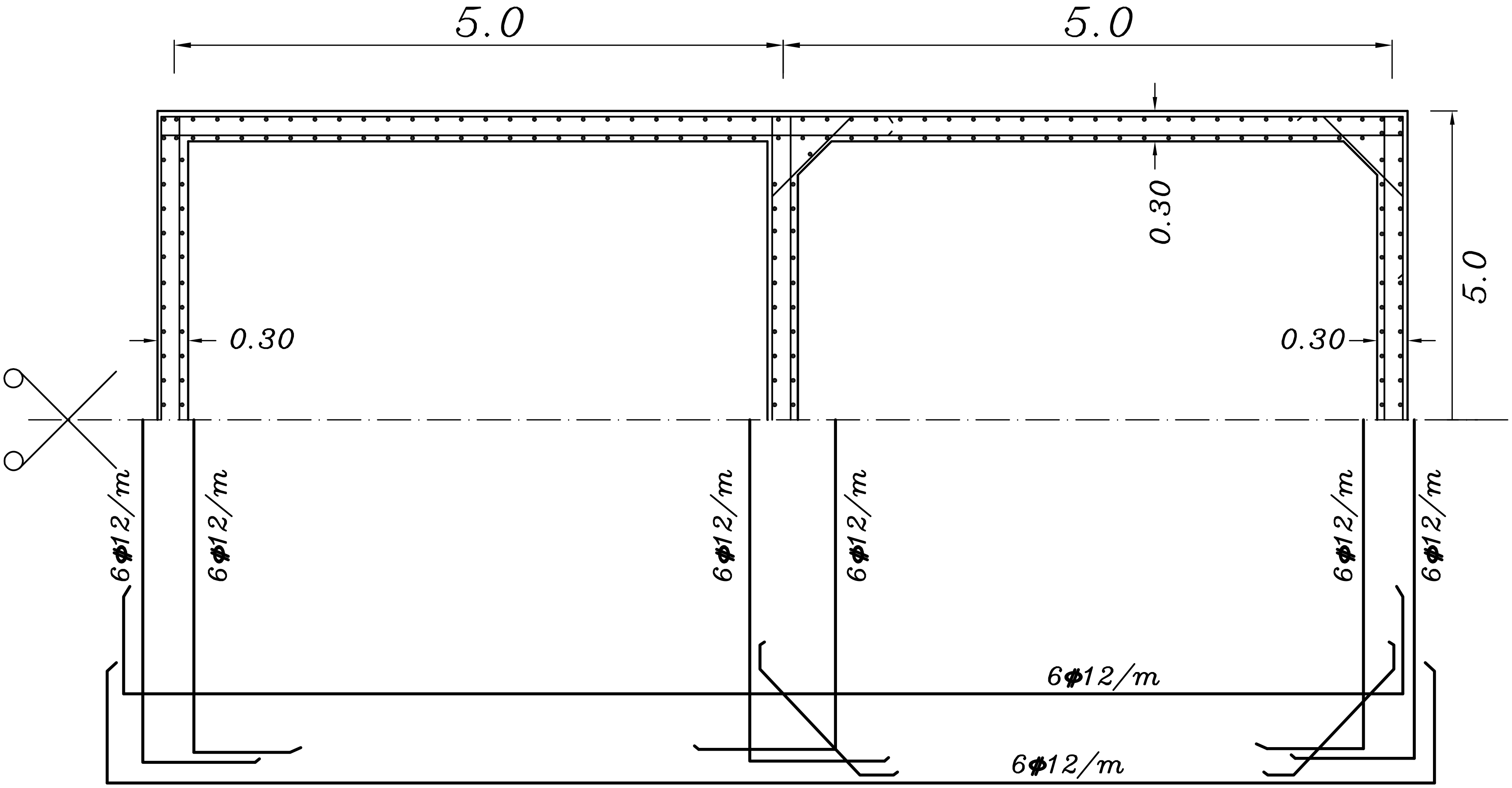


Details of RFT.





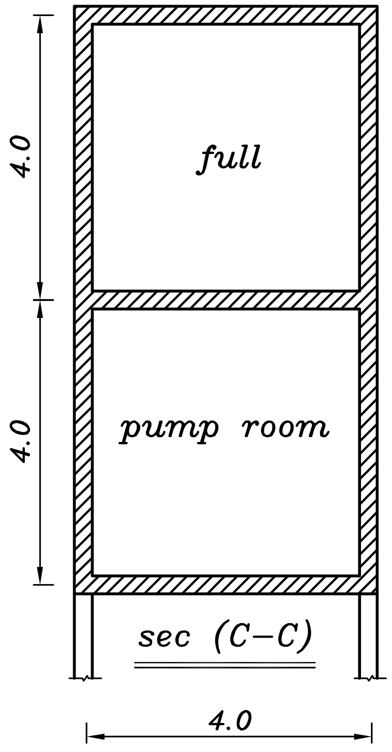
Hz. strip (2)

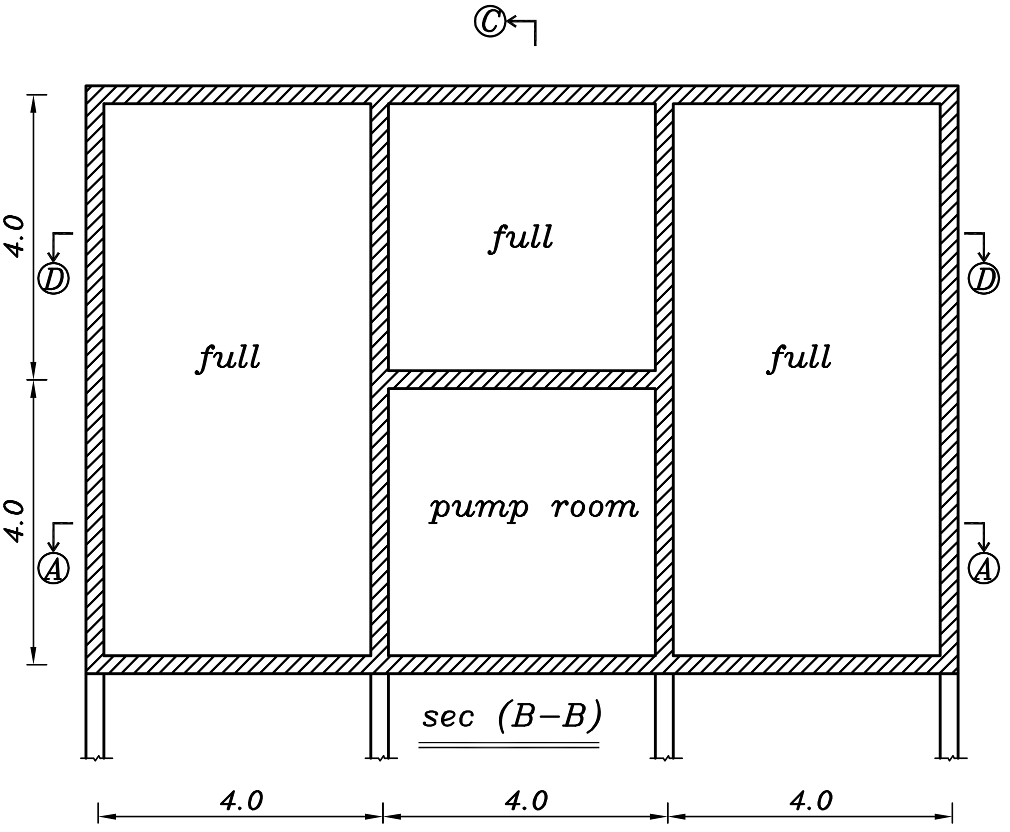

5.0
5.0
0.30
0.30
0.30
5.0
6ϕ12/m
6ϕ12/m
6ϕ12/m
6ϕ12/m
6ϕ12/m
6ϕ12/m
6ϕ12/m
6ϕ12/m

Example(12) *Term str. (2001)*

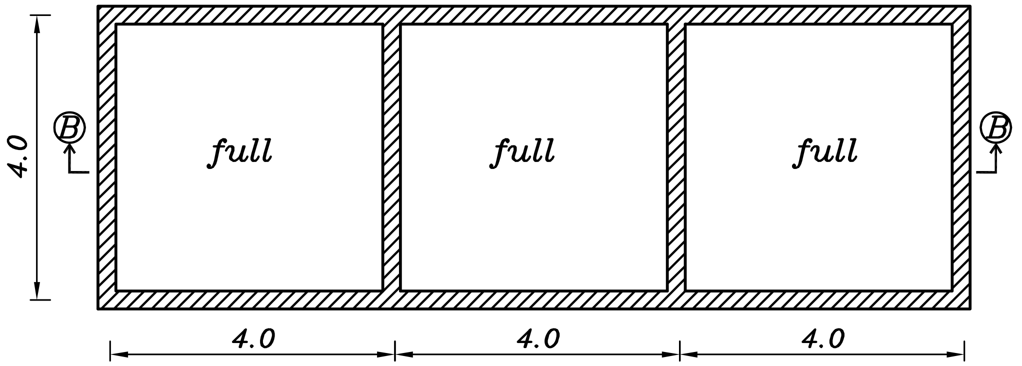
Required

Design the given tank.

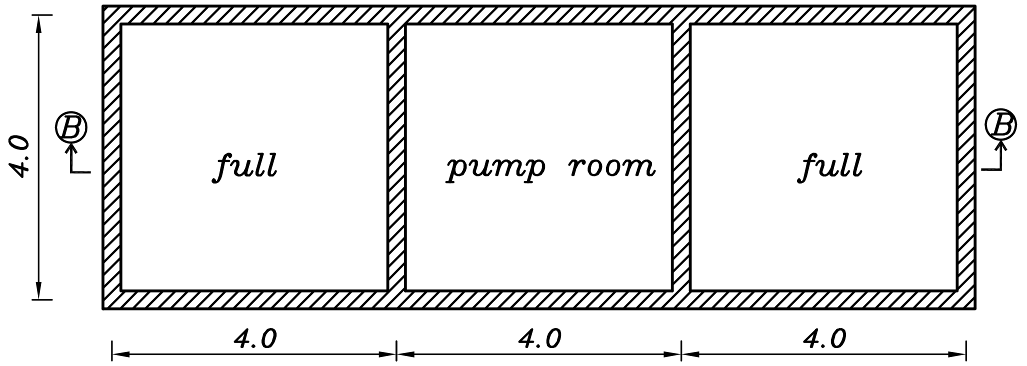

sec (C–C)


sec (B–B)

sec (D–D)



sec (A–A)

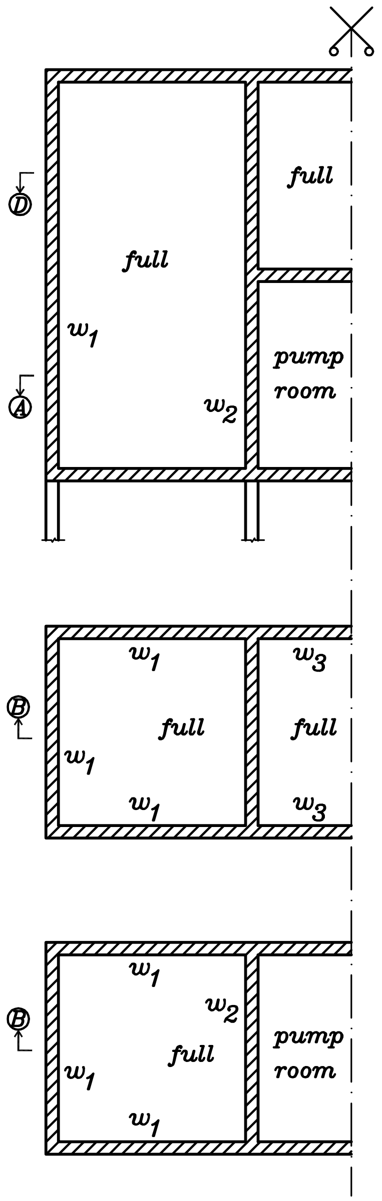


Solution

1− Concrete dimensions

$t_w = t_f = \frac{L}{16} = \frac{400}{16} = 25cm$

$\Longrightarrow$ Take $t_w = t_f = 25cm$, $t_{cover} = 15cm$



2− Loads on floor

$w_f = t_f \gamma_c + \gamma_w h$

for h=8m

$w_f = 0.25*25 + 10*8 = 86.25 \ kN/m^2$

for h=4m

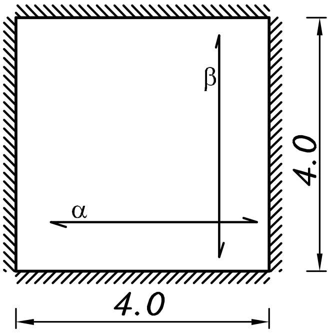
$w_f = 0.25*25 + 10*4 = 46.25 \ kN/m^2$

for empty floor

$w_f = 0.25*25 = 6.25 \ kN/m^2$

3− Load distribution

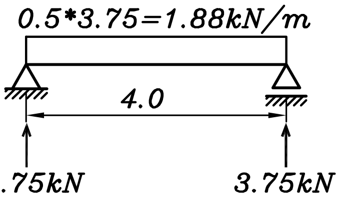
− Floor (4.0*4.0)

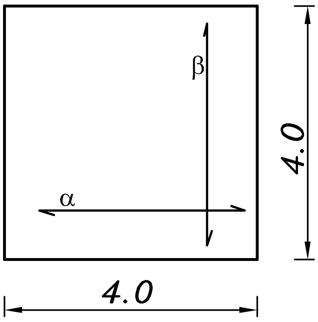


$r = \frac{0.76*4.0}{0.76*4.0} = 1.00$

$\alpha = \beta = 0.50$

− Cover (4.0*4.0)





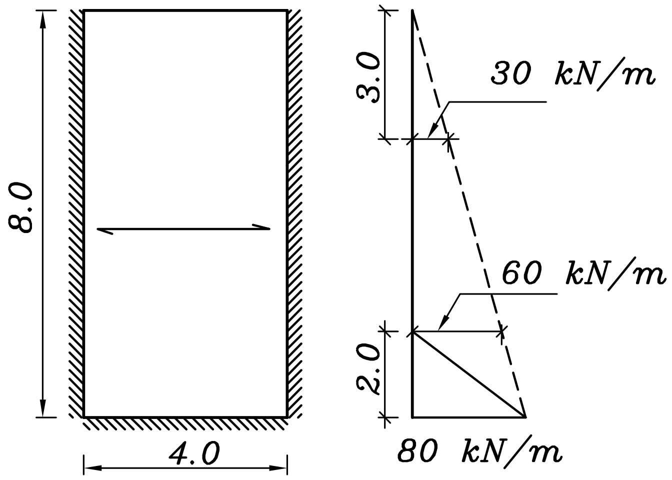
$r = \frac{1*4.0}{1*4.0} = 1.00$

$\alpha = \beta = 0.50$

$w_s = 0.15*25 = 3.75 \ kN/m^2$

– Wall (1) (4.0*8.0)

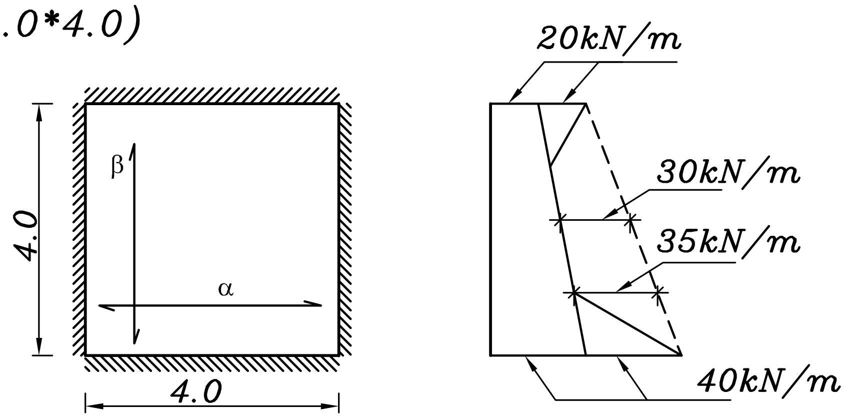
one way in hz. direction



– Wall (2) (4.0*4.0)

$r=\frac{0.76*4}{0.76*4}=1.0$

$\alpha=\beta=0.50$

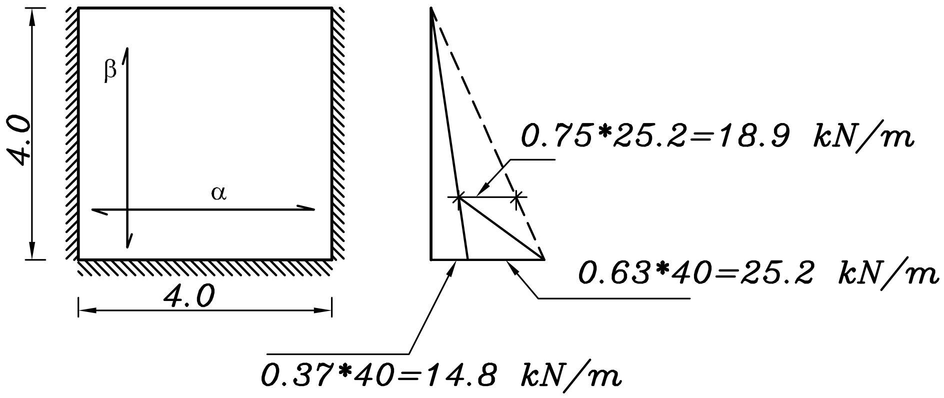


– Wall (3) (4.0*4.0)

$r=\frac{0.87*4}{0.76*4}=1.14$

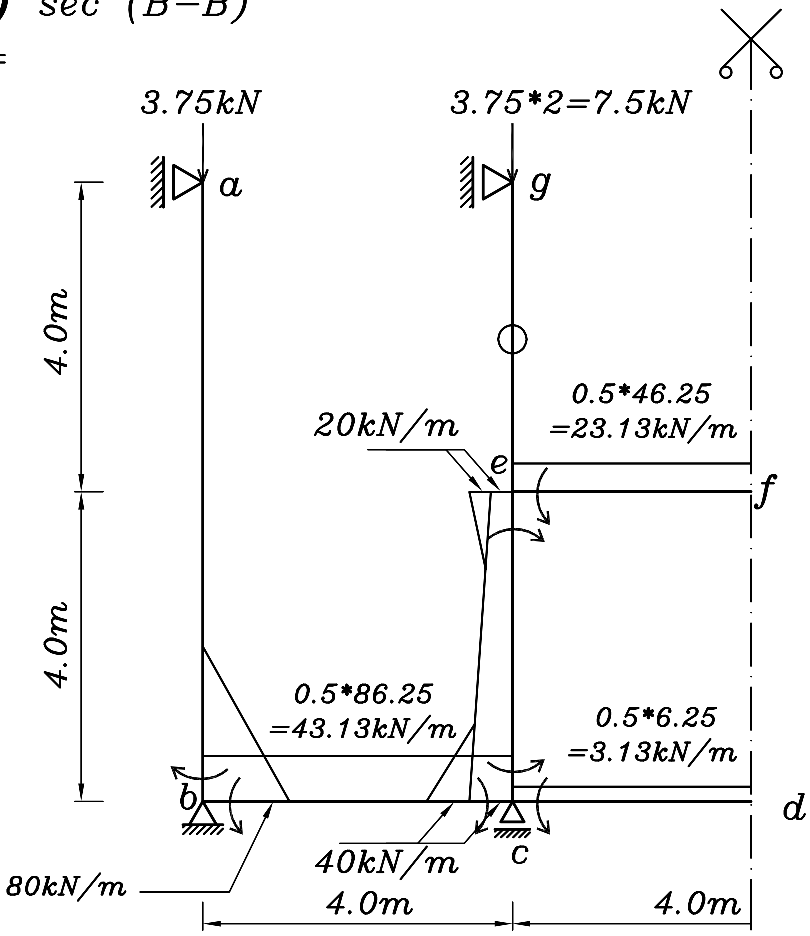
$\alpha=\frac{r^4}{1+r^4}=0.63$

$\beta=\frac{1}{1+r^4}=0.37$



4– Analysis of strips

– VL. strip (1) sec (B–B)



For Joint b

$$D.f_{ba} = \frac{0.75(I/8.0)}{0.75(I/8.0)+(I/4.0)} = 0.27$$

$$D.f_{bc} = \frac{(I/4.0)}{0.75(I/8.0)+(I/4.0)} = 0.73$$

For Joint c

$$D.f_{cb} = D.f_{ce} = \frac{(I/4.0)}{2(I/4.0)+0.5(I/4)} = 0.40$$

$$D.f_{cd} = \frac{0.5(I/4.0)}{2(I/4.0)+0.5(I/4)} = 0.20$$

For Joint e

$$D.f_{ec} = \frac{(I/4.0)}{(I/4.0)+0.5(I/4)+0.75(I/4.0)} = 0.44$$

$$D.f_{ef} = \frac{0.5(I/4.0)}{(I/4.0)+0.5(I/4)+0.75(I/4.0)} = 0.23$$

$$D.f_{eg}=\frac{0.75(I/4.0)}{(I/4.0)+0.5(I/4)+0.75(I/4.0)}=0.33$$

$$F.E.M._{ba}=\frac{80.0*(8)^2}{117}=43.76kN.m$$

$$F.E.M._{bc}=\frac{-43.13*(4)^2}{12}=-57.51kN.m \quad \& \quad F.E.M._{cb}=57.51kN.m$$

$$F.E.M._{cd}=\frac{-3.13*(4)^2}{12}=-4.17kN.m$$

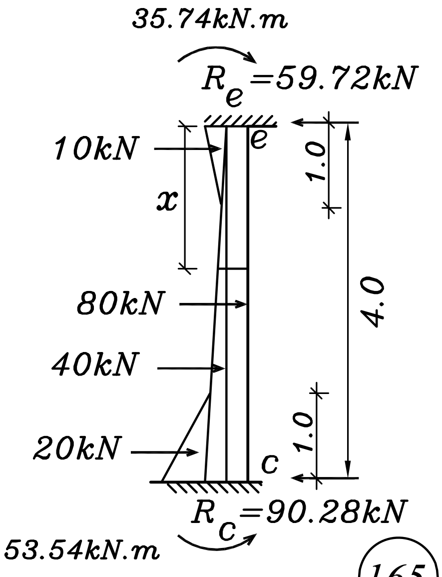
$$F.E.M._{ef}=\frac{-23.13*(4)^2}{12}=-30.84kN.m$$

$$F.E.M._{ce}=-\frac{20*(4)^2}{12}-\frac{20*(4)^2}{20}-\frac{40.0*(4)^2}{124}-\frac{20*(4)^2}{904}=-48.18kN.m$$

$$F.E.M._{ec}=\frac{20*(4)^2}{12}+\frac{20*(4)^2}{30}+\frac{40.0*(4)^2}{904}+\frac{20*(4)^2}{124}=40.62kN.m$$

Joint	b		c			e		
member	ba	bc	cb	cd	ce	ec	ef	eg
D.f.	0.27	0.73	0.40	0.20	0.40	0.44	0.23	0.33
F.E.M.	43.76	−57.51	57.51	−4.17	−48.18	40.62	−30.84	0
Bal.M.	3.71	10.04	−2.06	−1.03	−2.06	−4.30	−2.25	−3.23
C.O.M.	0	−1.03	5.02	0	−2.15	−1.03	0	0
Bal.M.	0.28	0.75	−1.15	−0.57	−1.15	0.45	0.24	0.34
M_f	47.75	−47.75	59.32	−5.77	−53.54	35.74	−32.85	−2.89

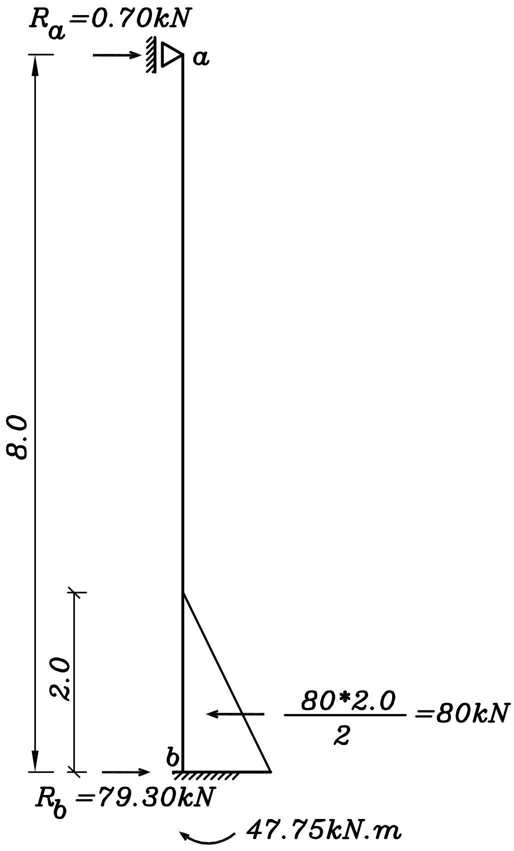
Point of zero shear

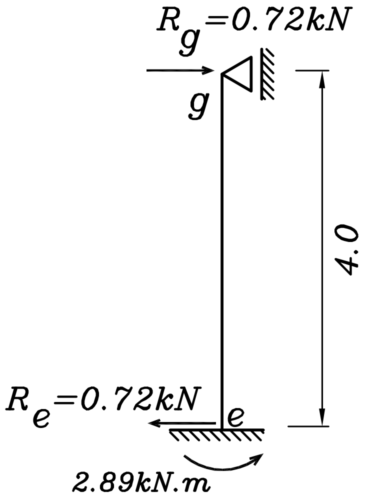


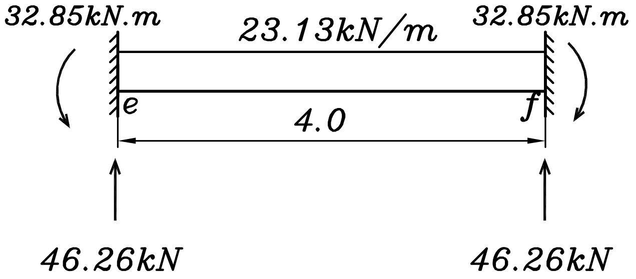
$$20x+[\frac{x}{4}*20]*\frac{x}{2}+10=59.72 \Longrightarrow x=1.99m$$

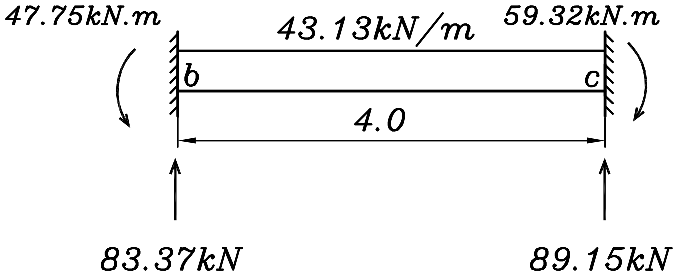
$$\Longrightarrow M_{+ve}=59.72x-20x\frac{x}{2}-(\frac{x}{4}*20)*(\frac{x^2}{6})$$

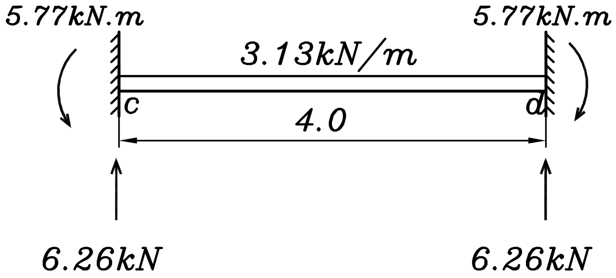
$$-10*(x-1/3)-35.74=20.37 \ kN.m$$

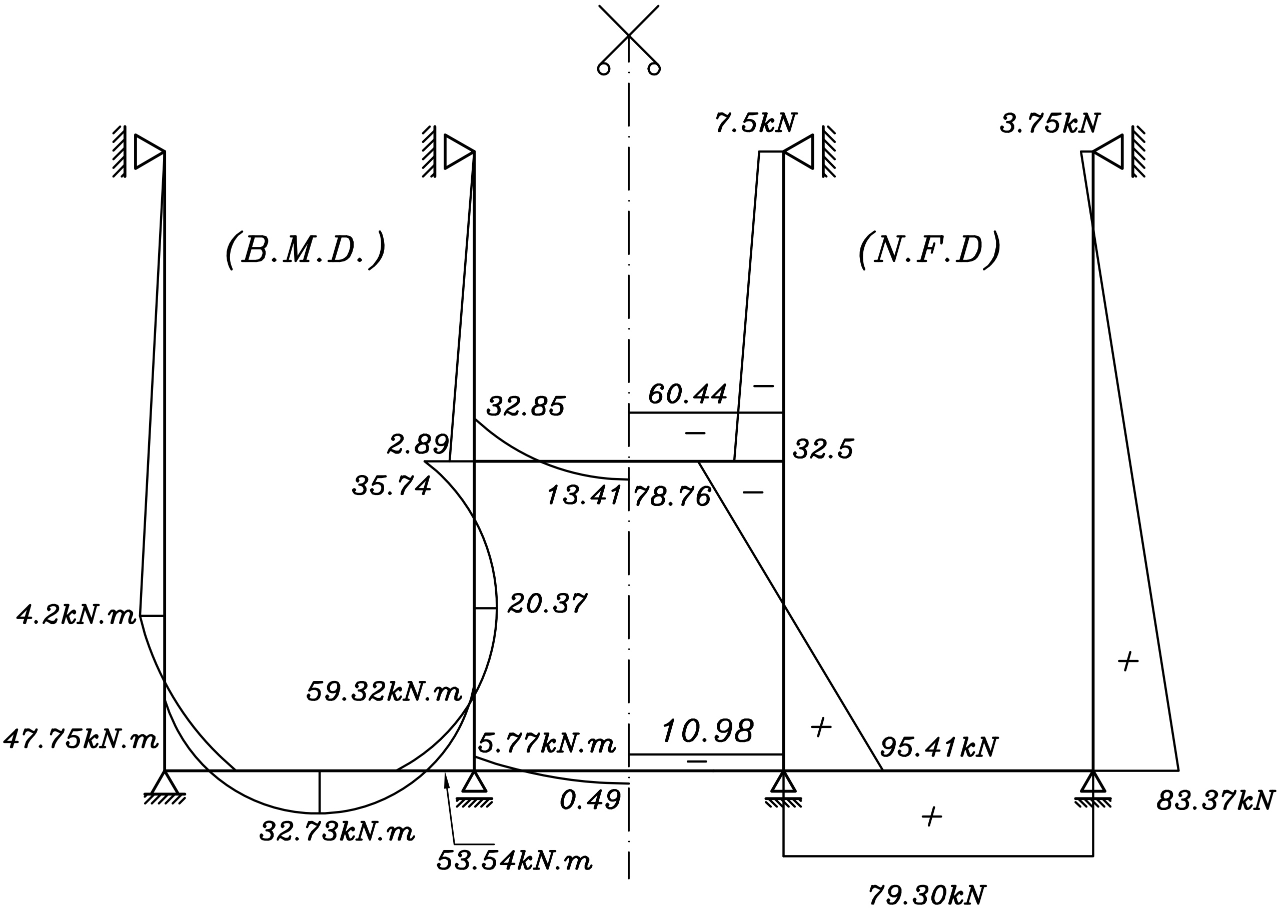

R_a=0.70kN
a
8.0
2.0
$\frac{80*2.0}{2}$ =80kN
b
R_b =79.30kN
47.75kN.m


R_g=0.72kN
g
4.0
R_e=0.72kN
e
2.89kN.m


32.85kN.m
23.13kN/m
32.85kN.m
e
f
4.0
46.26kN
46.26kN


47.75kN.m
43.13kN/m
59.32kN.m
b
c
4.0
83.37kN
89.15kN


5.77kN.m
3.13kN/m
5.77kN.m
c
d
4.0
6.26kN
6.26kN



– VL. strip (2) sec (C–C)

For Joint b

$$D.f_{ba} = \frac{0.75(I/4.0)}{0.75(I/4.0)+0.5(I/4)+(I/4.0)} = 0.33$$

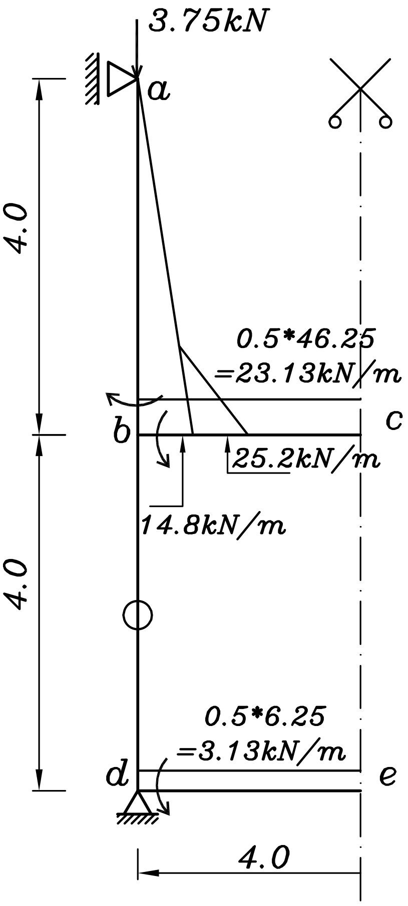
$$D.f_{bc} = \frac{0.5(I/4.0)}{0.75(I/4.0)+0.5(I/4)+(I/4.0)} = 0.23$$

$$D.f_{bd} = \frac{(I/4.0)}{0.75(I/4.0)+0.5(I/4)+(I/4.0)} = 0.44$$

For Joint d

$$D.f_{db} = \frac{(I/4.0)}{(I/4.0)+0.5(I/4.0)} = 0.67$$

$$D.f_{de} = \frac{0.5(I/4.0)}{(I/4.0)+0.5(I/4.0)} = 0.33$$

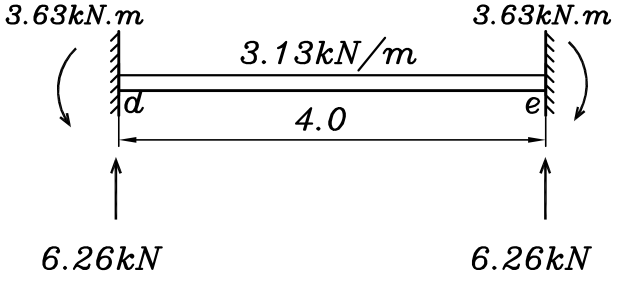


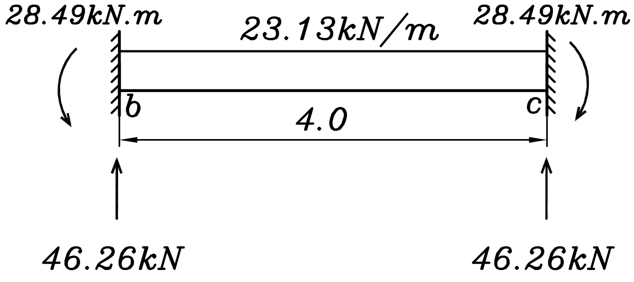
$$F.E.M._{bc}=\frac{-23.13*(4)^2}{12}=-30.84kN.m$$

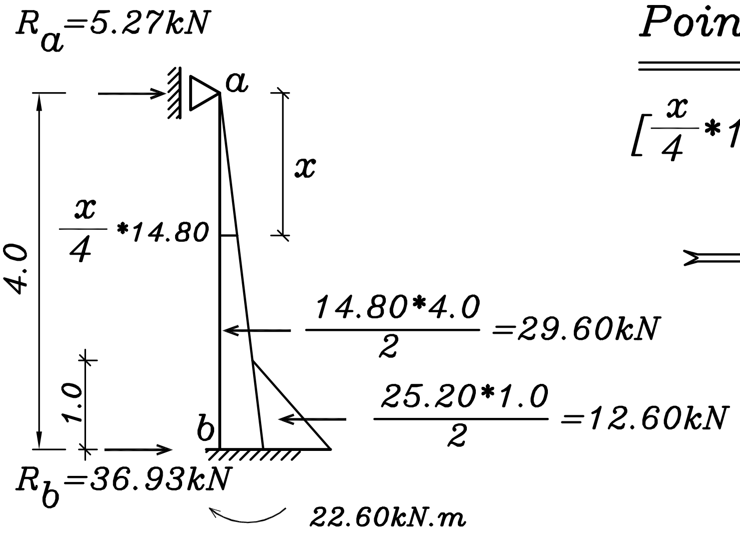
$$F.E.M._{de}=\frac{-3.13*(4)^2}{12}=-4.17kN.m$$

$$F.E.M._{ba}=\frac{14.80*(4)^2}{15}+\frac{25.20*(4)^2}{117}=19.23kN.m$$

Joint	b			d	
member	ba	bc	bd	db	de
D.f.	0.33	0.23	0.44	0.67	0.33
F.E.M.	19.23	−30.84	0	0	−4.17
Bal.M.	3.83	2.67	5.11	2.79	1.38
C.O.M.	0	0	1.40	2.56	0
Bal.M.	−0.46	−0.32	−0.62	−1.72	−0.84
M_f	22.60	−28.49	5.89	3.63	−3.63





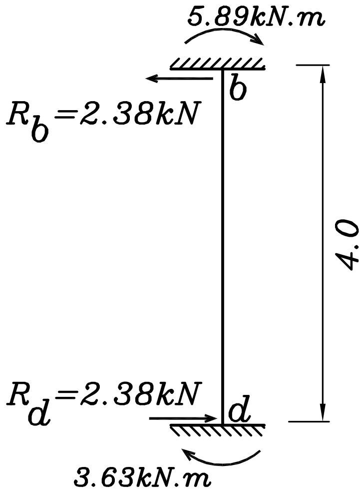


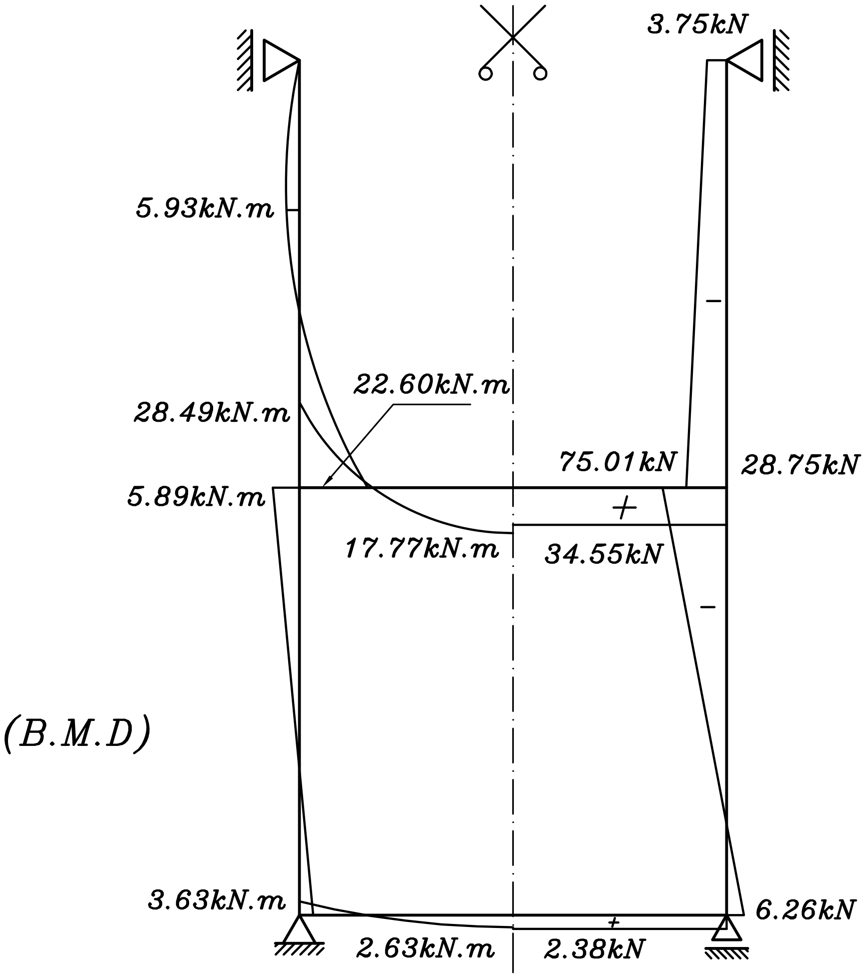
Point of zero shear

$$[\frac{x}{4}*14.80]*\frac{x}{2}=5.27 \Longrightarrow x=1.69m$$

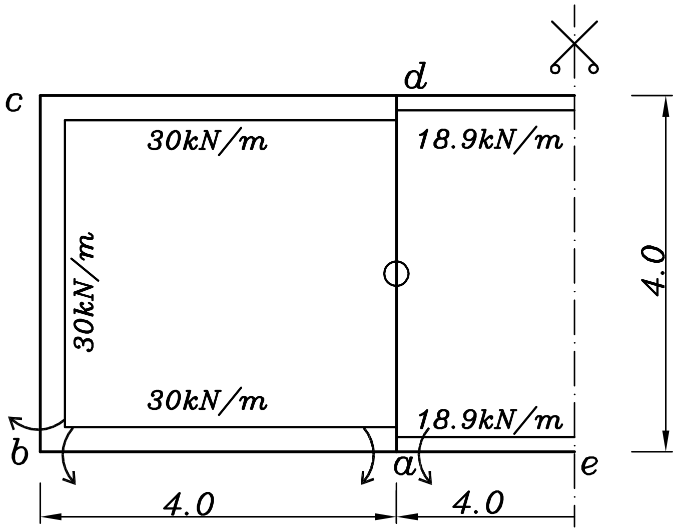
$$\Longrightarrow M_{+ve}=5.27x-(\frac{x}{4}*14.80)*(\frac{x^2}{6})$$

$$M_{+ve}=5.93\ kN.m$$





– HZ. strip (3) at h=5.0 sec (D–D)



For Joint b

$$D.f_{ba}=\frac{(I/4.0)}{(I/4.0)+0.5(I/4.0)}=0.67$$

$$D.f_{bc}=\frac{0.5(I/4.0)}{(I/4.0)+0.5(I/4.0)}=0.33$$

For Joint a

$$D.f_{ab}=\frac{(I/4.0)}{(I/4.0)+0.5(I/4)+0.5(I/4.0)}=0.50$$

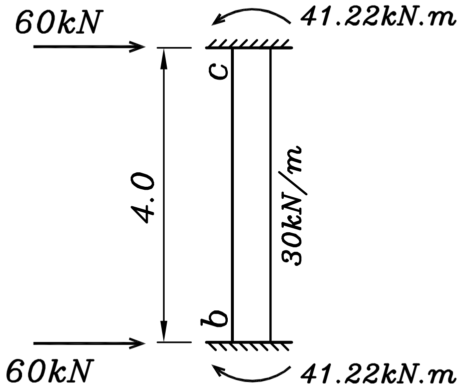
$$D.f_{ae}=D.f_{ad}=\frac{0.5(I/4.0)}{(I/4.0)+0.5(I/4)+0.5(I/4.0)}=0.25$$

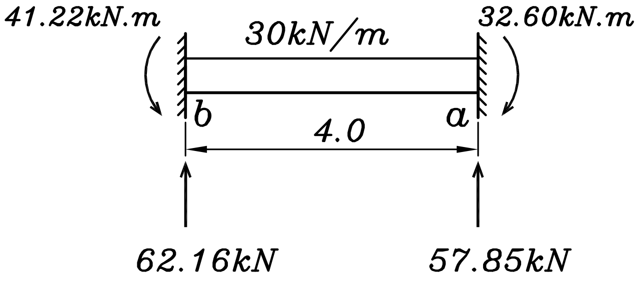
$$F.E.M._{ba}=\frac{-30.00*(4.0)^2}{12}=-40.00kN.m \qquad \& \qquad F.E.M._{ab}=40.00kN.m$$

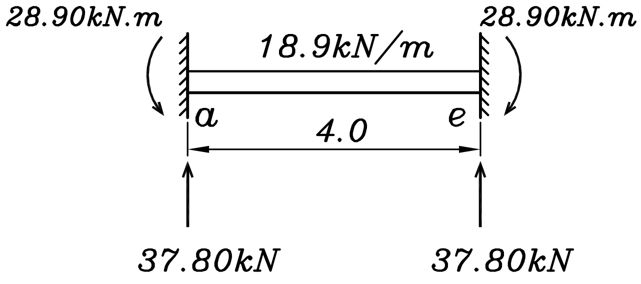
$$F.E.M._{bc}=40.00kN.m$$

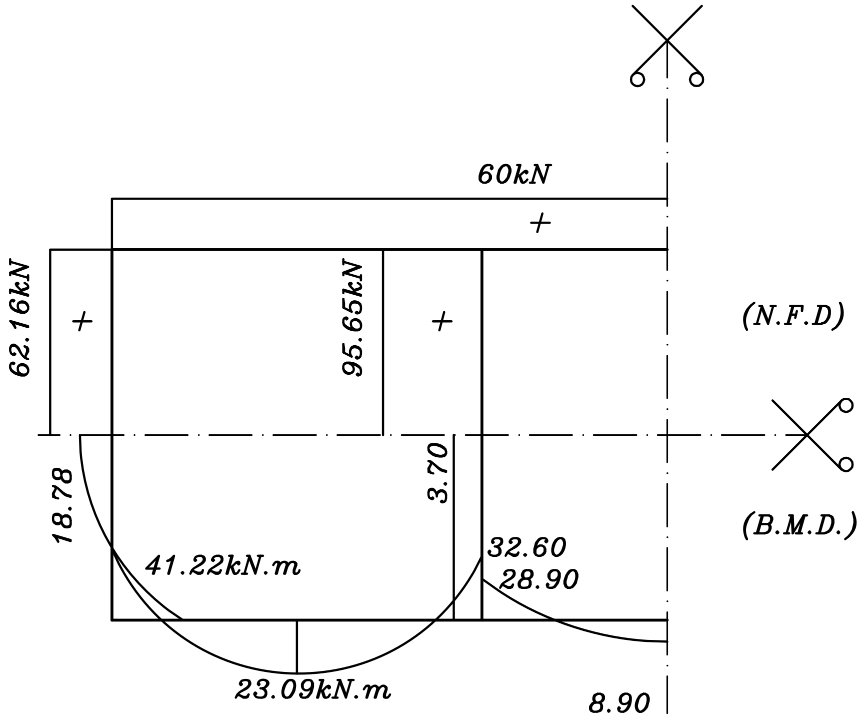
$$F.E.M._{ae}=\frac{-18.90*(4.0)^2}{12}=-25.20kN.m$$

Joint	b		a		
member	bc	ba	ab	ae	ad
D.f.	0.33	0.67	0.50	0.25	0.25
F.E.M.	40.00	−40.00	40.00	−25.20	0
Bal.M.	0	0	−7.40	−3.70	−3.70
C.O.M.	0	−3.70	0	0	0
Bal.M.	1.22	2.48	0	0	0
M_f	41.22	−41.22	32.60	−28.90	−3.70

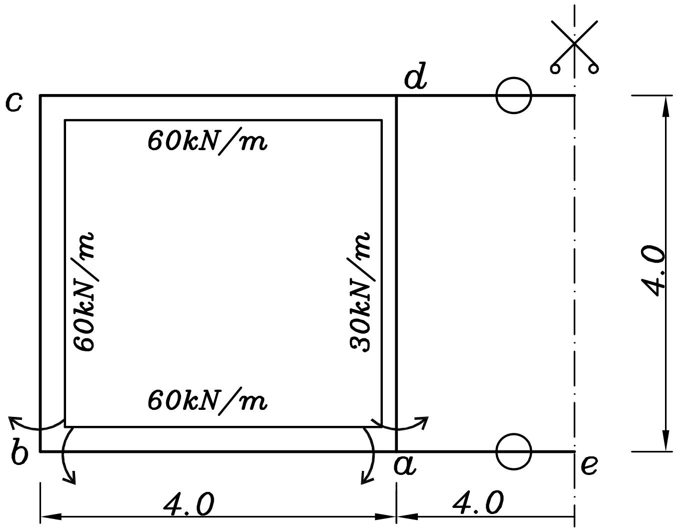

60kN
41.22kN.m
c
4.0
30kN/m
b
60kN
41.22kN.m


41.22kN.m
30kN/m
32.60kN.m
b
a
4.0
62.16kN
57.85kN


28.90kN.m
18.9kN/m
28.90kN.m
a
e
4.0
37.80kN
37.80kN


60kN
+
62.16kN
+
95.65kN
+
(N.F.D)
18.78
3.70
41.22kN.m
32.60
28.90
(B.M.D.)
23.09kN.m
8.90

– HZ. strip (4) at h=2.0 sec (A–A)

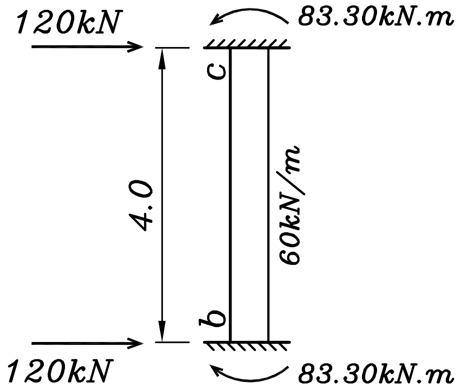


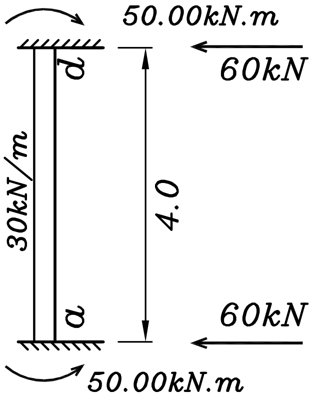
$$F.E.M._{ba}=\frac{-60.00*(4.0)^2}{12}=-80.00kN.m \quad \& \quad F.E.M._{ab}=80.00kN.m$$

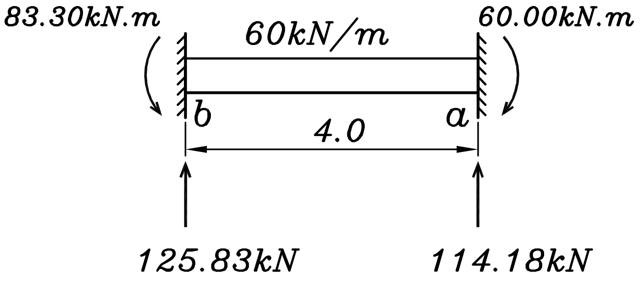
$$F.E.M._{bc}=80.00kN.m$$

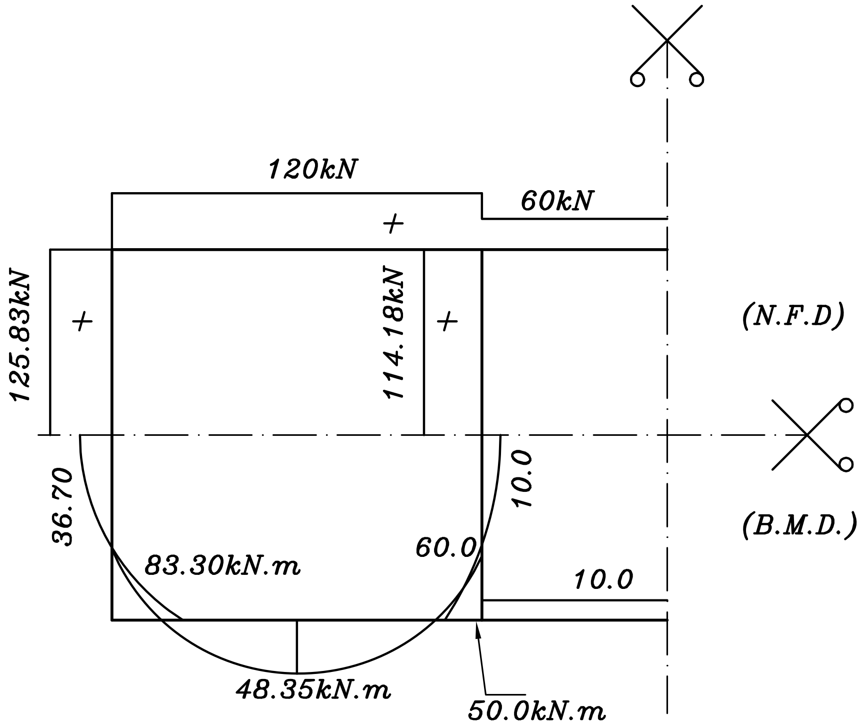
$$F.E.M._{ad}=\frac{-30.00*(4.0)^2}{12}=-40.00kN.m$$

Joint	b		a		
member	bc	ba	ab	ae	ad
D.f.	0.33	0.67	0.50	0.25	0.25
F.E.M.	80.00	–80.00	80.00	0	–40.00
Bal.M.	0	0	–20.00	–10.00	–10.00
C.O.M.	0	–10.00	0	0	0
Bal.M.	3.30	6.70	0	0	0
M_f	83.30	–83.30	60.00	–10.00	–50.00


120kN
83.30kN.m
c
4.0
60kN/m
b
120kN
83.30kN.m


50.00kN.m
60kN
d
30kN/m
4.0
a
60kN
50.00kN.m

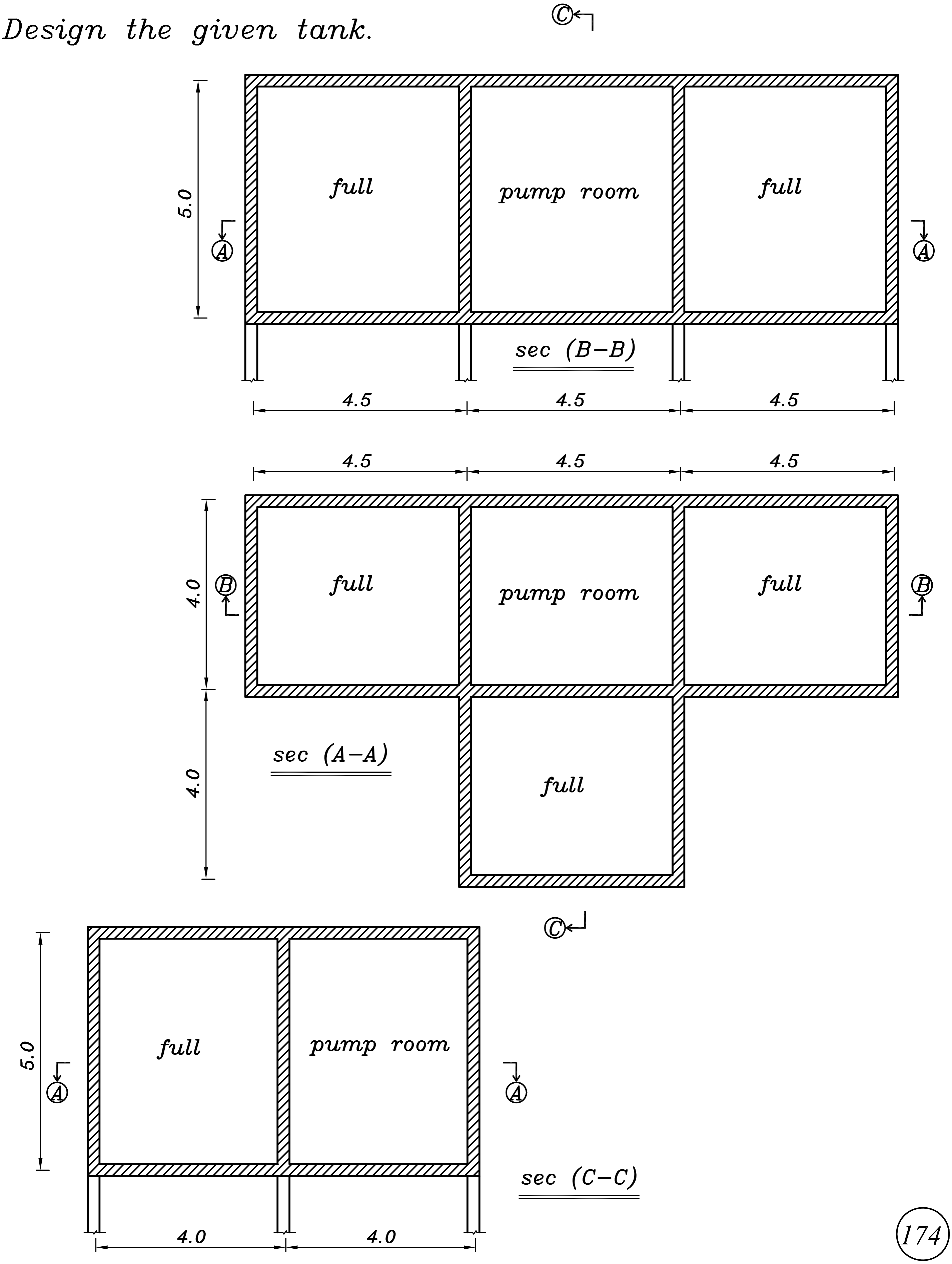

83.30kN.m
60kN/m
60.00kN.m
b
4.0
a
125.83kN
114.18kN


120kN
60kN
+
125.83kN
+
114.18kN
+
(N.F.D)
36.70
10.0
83.30kN.m
60.0
10.0
(B.M.D.)
48.35kN.m
50.0kN.m

Example(13)

Required

Design the given tank.



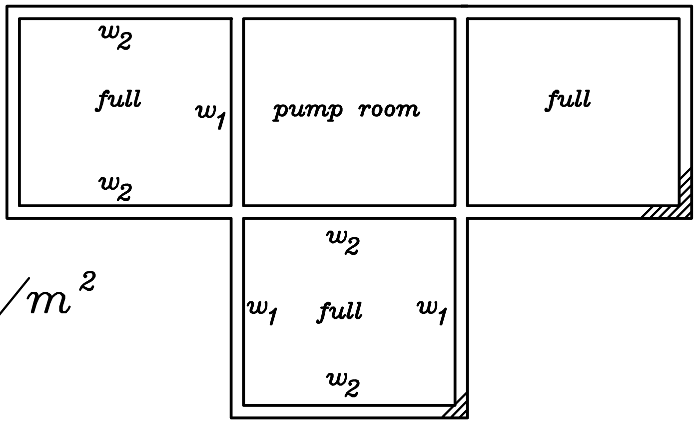
Solution

1- Concrete dimensions

$t_w = t = \quad = \quad = 28.13 cm$

$\Longrightarrow$ Take

2- Loads on floor



$w_f = t_f \gamma_c + \gamma_w h$

for floor (full of water)

$w_f = 0.25*25+10*5=56.25 \ kN/m^2$

for empty floor

$w_f = 0.25*25=6.25 \ kN/m^2$

3- Load distribution

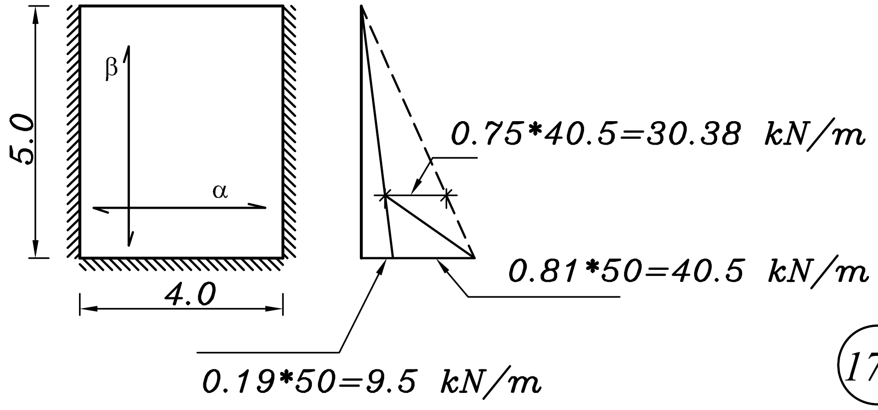
- Floor (4.5*4.0)

- Wall (1) (4.0*5.0)

$r = \frac{0.87*5}{0.76*4} = 1.43$

$\alpha = \frac{r^4}{1+r^4} = 0.81$

$\beta = \frac{1}{1+r^4} = 0.19$

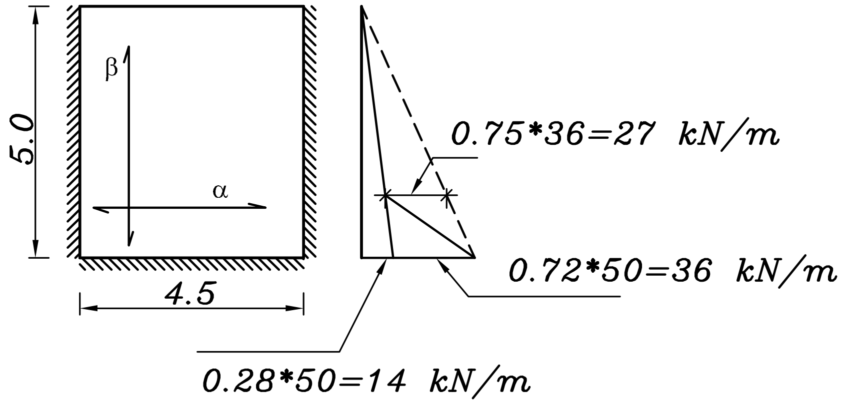


– Wall (2) (4.5*5.0)

$$r=\frac{0.87*5.0}{0.76*4.5}=1.27$$

$$\alpha=\frac{r4}{1+r^4}=0.72$$

$$\beta=\frac{1}{1+r^4}=0.28$$



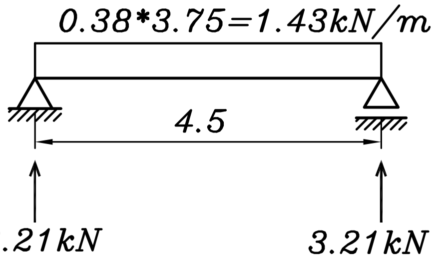
– Cover (4.5*4.0)

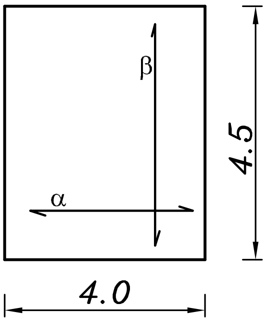
$$r=\frac{1.0*4.5}{1.0*4.0}=1.125$$

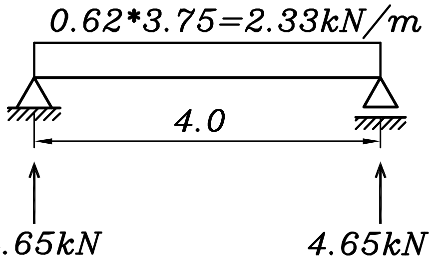
$$\alpha=\frac{r4}{1+r^4}=0.62$$

$$\beta=\frac{1}{1+r^4}=0.38$$

$$w_s=0.15*25=3.75 \ kN/m^2$$

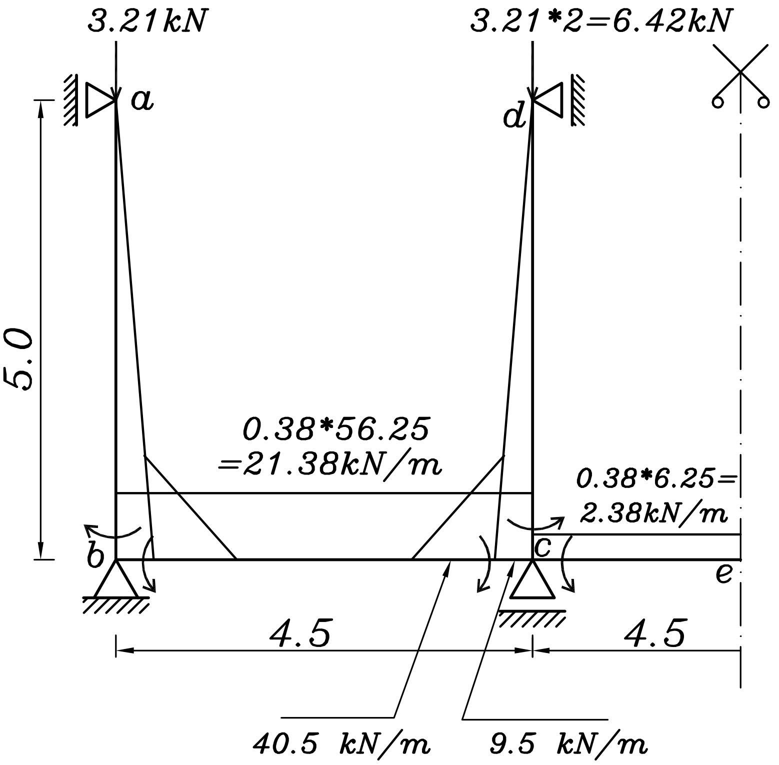






4– Analysis of strips

– VL. strip (1) sec (B–B)



$$F.E.M._{bc}=\frac{-21.38*(4.5)^2}{12}$$

$$F.E.M._{bc}=-36.08 \ kN.m$$

$$F.E.M._{cb}=36.08 \ kN.m$$

$$F.E.M._{ce}=\frac{-2.38*(4.5)^2}{12}$$

$$F.E.M._{ce}=-4.02 \ kN.m$$

$$F.E.M._{ba}=\frac{9.50*(5)^2}{15}+\frac{40.50*(5)^2}{117}=24.49kN.m$$

$$F.E.M._{cd}=-24.49kN.m$$

For Joint b

$$D.f_{ba}=\frac{0.75(I/5.0)}{0.75(I/5.0)+(I/4.5)}=0.40$$

$$D.f_{bc}=\frac{(I/4.5)}{0.75(I/5.0)+(I/4.5)}=0.60$$

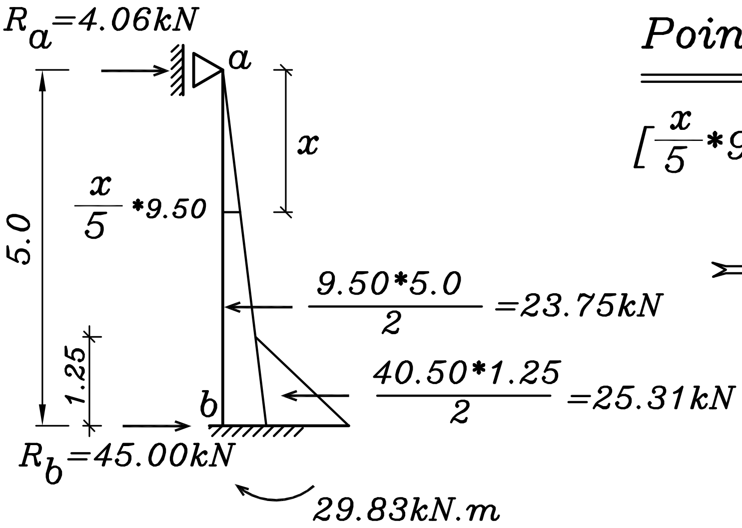
For Joint c

$$D.f_{cb}=\frac{(I/4.5)}{(I/4.5)+0.75(I/5.0)+0.5(I/4.5)}=0.46$$

$$D.f_{cd}=\frac{0.75(I/5.0)}{(I/4.5)+0.75(I/5.0)+0.5(I/4.5)}=0.31$$

$$D.f_{ce}=\frac{0.5(I/4.5)}{(I/4.5)+0.75(I/5.0)+0.5(I/4.5)}=0.23$$

Joint	b		c		
member	ba	bc	cb	ce	cd
D.f.	0.40	0.60	0.46	0.23	0.31
F.E.M.	24.49	−36.08	36.08	−4.02	−24.49
Bal.M.	4.64	6.95	−3.48	−1.74	−2.35
C.O.M.	0	−1.74	3.48	0	0
Bal.M.	0.70	1.04	−1.60	−0.80	−1.08
M_f	29.83	−29.83	34.48	−6.56	−27.92



Point of zero shear

$$[\frac{x}{5}*9.50]*\frac{x}{2}=4.06 \Longrightarrow x=2.07m$$

$$\Longrightarrow M_{+ve}=4.06x-(\frac{x}{5}*9.50)*(\frac{x^2}{6})$$

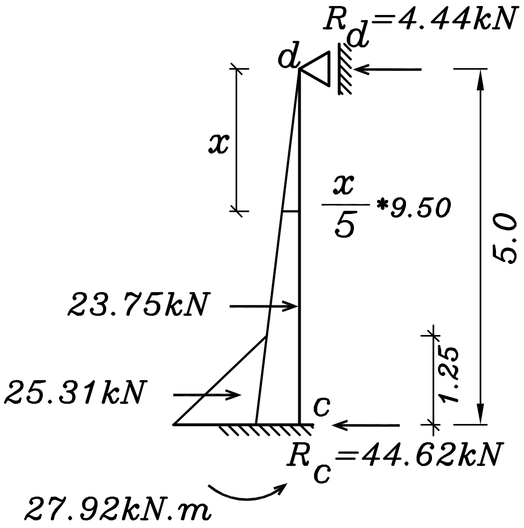
$$M_{+ve}=5.60\ kN.m$$

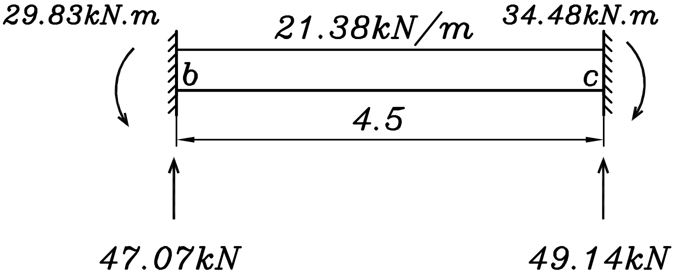
Point of zero shear

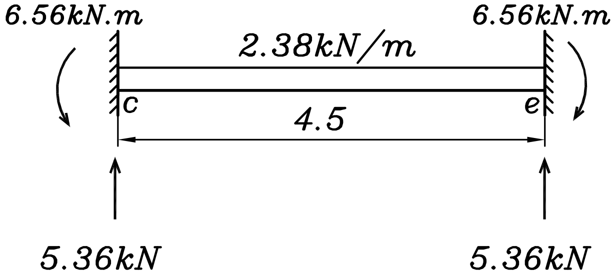
$$[\frac{x}{5}*9.50]*\frac{x}{2}=4.44 \Longrightarrow x=2.16m$$

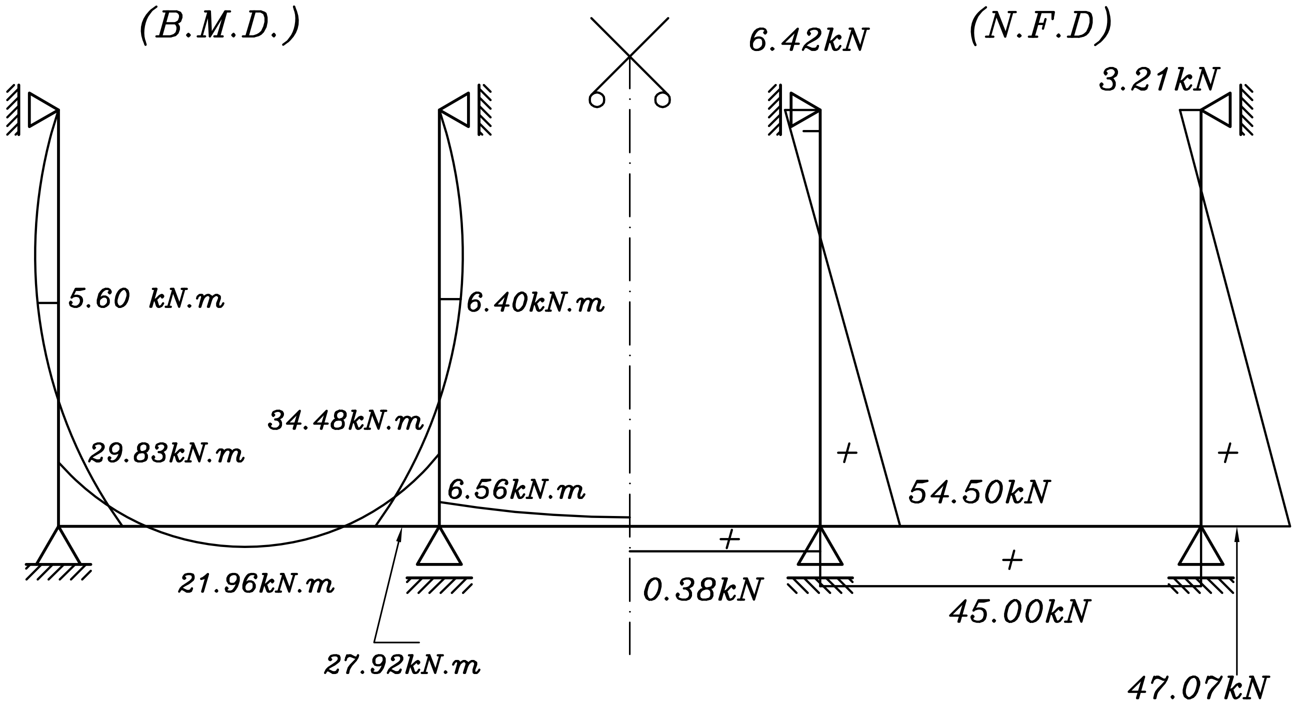
$$\Longrightarrow M_{+ve}=4.44x-(\frac{x}{5}*9.50)*(\frac{x^2}{6})$$

$$M_{+ve}=6.40\ \ kN.m$$

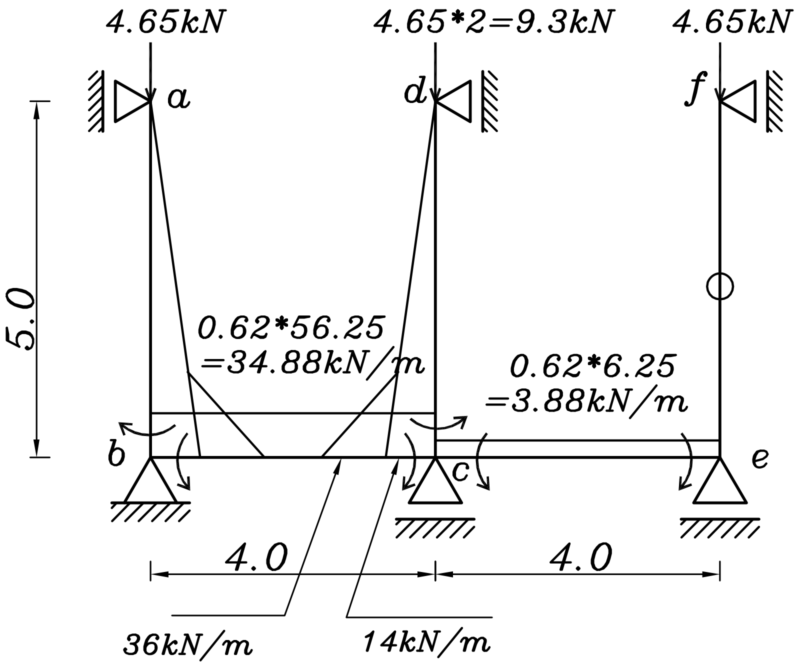








– VL. strip (2) sec (C–C)



For Joint b , e

$$D.f_{ba}=D.f_{ef}=\frac{0.75(I/5.0)}{0.75(I/5.0)+(I/4.0)}=0.38$$

$$D.f_{bc}=D.f_{ec}=\frac{(I/4.0)}{0.75(I/5.0)+(I/4.0)}=0.62$$

For Joint c

$$D.f_{\substack{cb\\ce}}=\frac{(I/4.0)}{(I/4.0)+0.75(I/5.0)+(I/4.0)}=0.38$$

$$D.f_{cd}=\frac{0.75(I/5.0)}{(I/4.0)+0.75(I/5.0)+(I/4.0)}=0.24$$

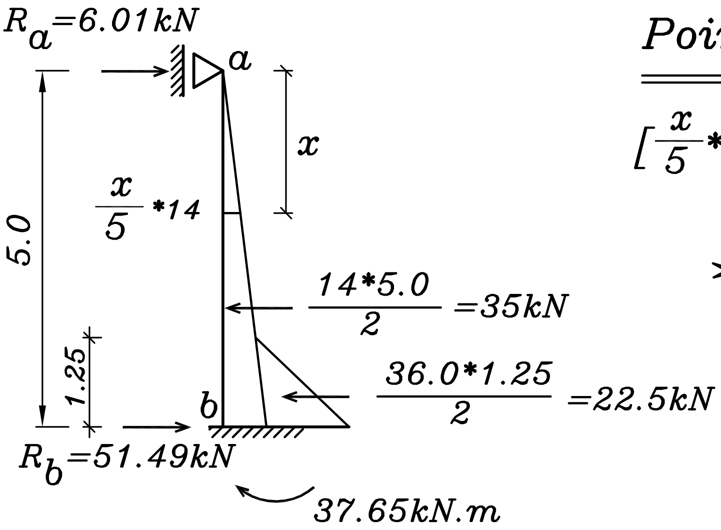
$$F.E.M._{ba}=\frac{14.00*(5)^2}{15}+\frac{36.00*(5)^2}{117}=31.03kN.m$$

$$F.E.M._{cd}=-31.03kN.m$$

$$F.E.M._{bc}=\frac{-34.88*(4)^2}{12}=-46.51kN.m \quad \& \quad F.E.M._{cb}=46.51kN.m$$

$$F.E.M._{ce}=\frac{-3.88*(4)^2}{12}=-5.17kN.m \quad \& \quad F.E.M._{ec}=5.17kN.m$$

Joint	b		c			e	
member	ba	bc	cb	cd	ce	ec	ef
D.f.	0.38	0.62	0.38	0.24	0.38	0.62	0.38
F.E.M.	31.03	−46.51	46.51	−31.03	−5.17	5.17	0
Bal.M.	5.88	9.60	−3.92	−2.47	−3.92	−3.21	−1.96
C.O.M.	0	−1.96	4.80	0	−1.61	−1.96	0
Bal.M.	0.74	1.22	−1.21	−0.77	−1.21	1.22	0.74
M_f	37.65	−37.65	46.18	−34.27	−11.91	1.22	−1.22



Point of zero shear

$$[\frac{x}{5}*14.0]*\frac{x}{2}=6.01 \Longrightarrow x=2.07m$$

$$\Longrightarrow M_{+ve}=6.01x-(\frac{x}{5}*14.0)*(\frac{x^2}{6})$$

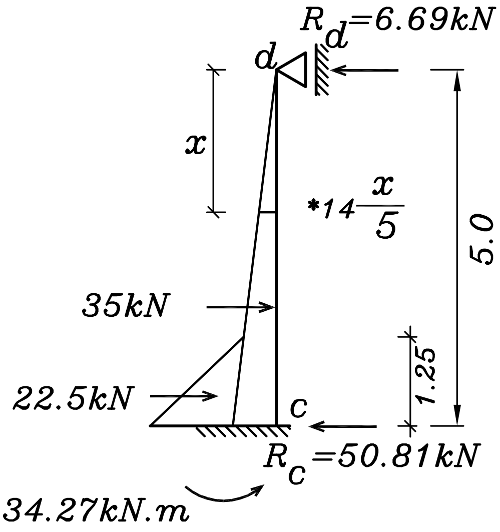
$$M_{+ve}=8.30\ kN.m$$

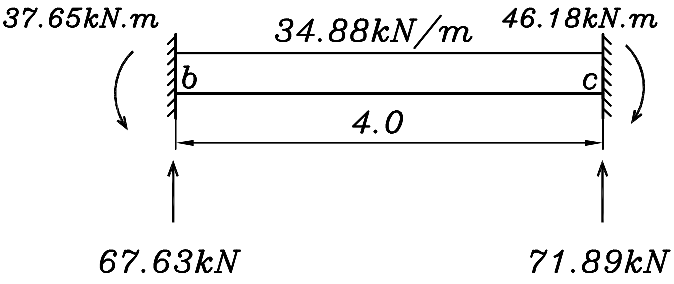
Point of zero shear

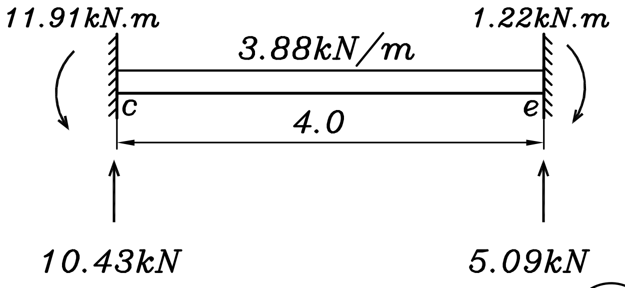
$$[\frac{x}{5}*14.0]*\frac{x}{2}=6.69 \Longrightarrow x=2.19m$$

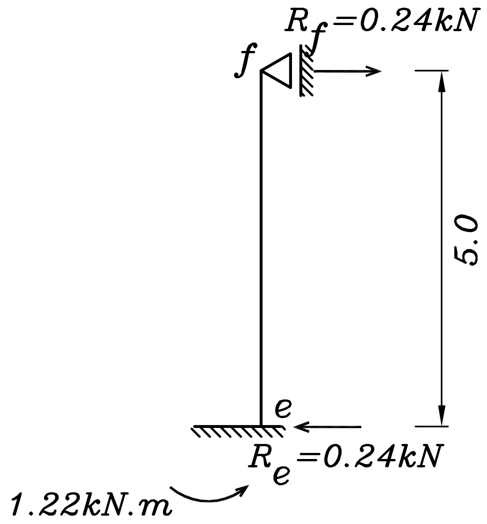
$$\Longrightarrow M_{+ve}=6.69x-(\frac{x}{5}*14.0)*(\frac{x^2}{6})$$

$$M_{+ve}=9.75\ kN.m$$

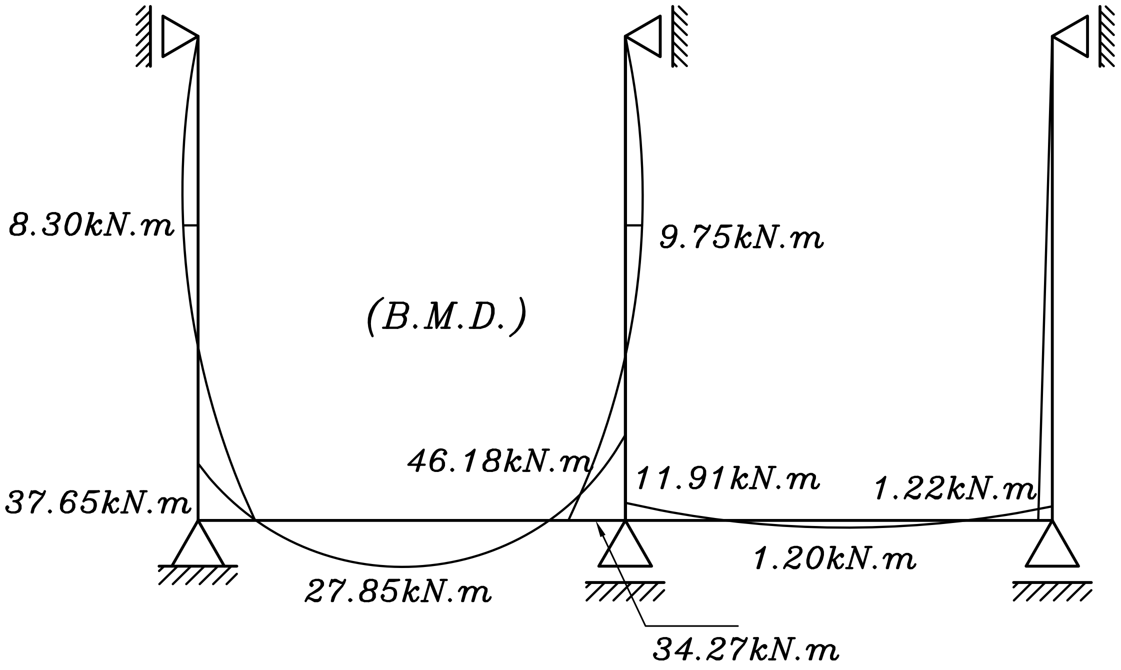




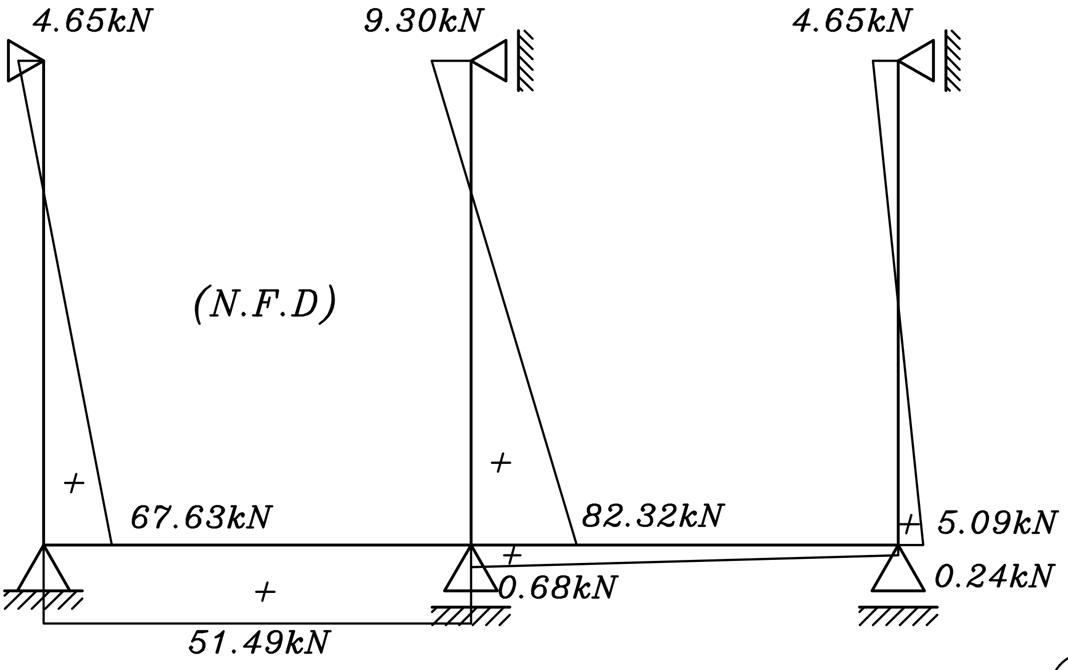




R_f=0.24kN
f
5.0
e
R_e=0.24kN
1.22kN.m

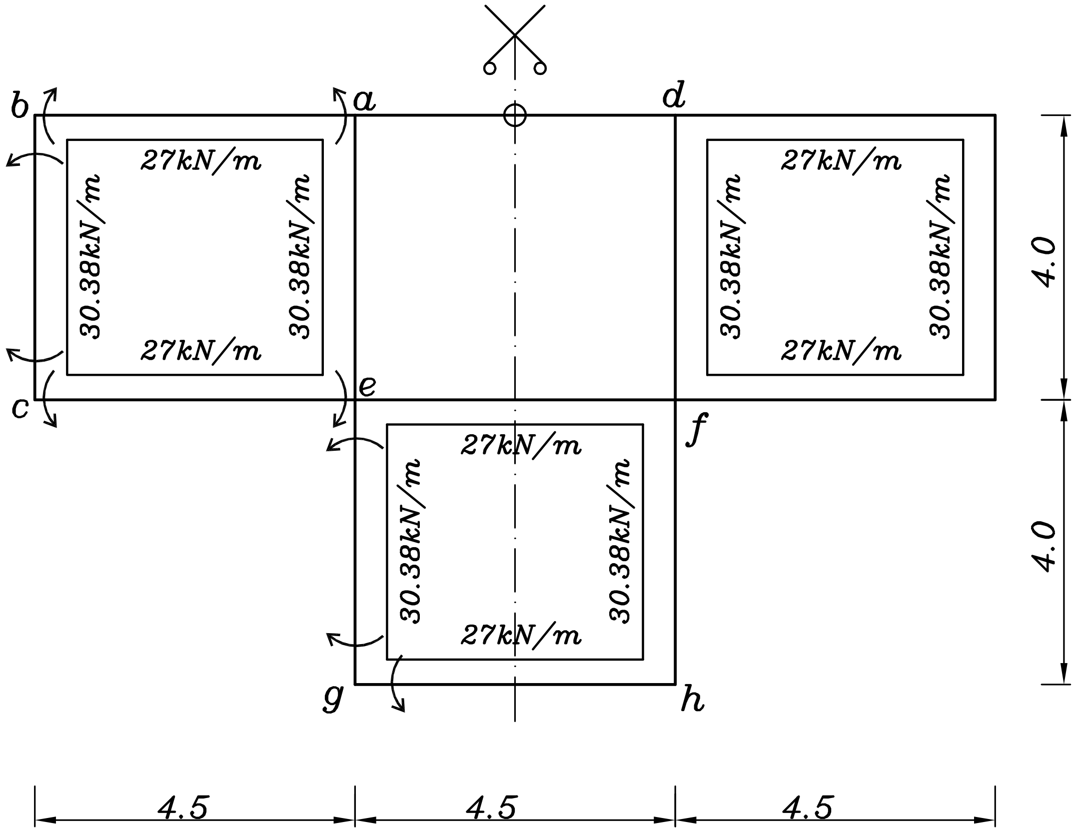


8.30kN.m
9.75kN.m
(B.M.D.)
46.18kN.m
11.91kN.m
1.22kN.m
37.65kN.m
1.20kN.m
27.85kN.m
34.27kN.m



4.65kN
9.30kN
4.65kN
(N.F.D)
+
+
67.63kN
82.32kN
+
5.09kN
+
0.68kN
0.24kN
+
51.49kN

– HZ. strip (5) at h=1.25 sec (A–A)



For Joint b , c

$$D.f_{ba} = D.f_{ce} = \frac{(I/4.5)}{(I/4.5)+(I/4.0)} = 0.47$$

$$D.f_{bc} = D.f_{cb} = 0.53$$

For Joint a

$$D.f_{ab} = \frac{(I/4.5)}{(I/4.5)+(I/4.0)+0.5(I/4.5)} = 0.38$$

$$D.f_{ad} = \frac{0.5(I/4.5)}{(I/4.5)+(I/4.0)+0.5(I/4.5)} = 0.19$$

$$D.f_{ae} = \frac{(I/4.0)}{(I/4.5)+(I/4.0)+0.5(I/4.5)} = 0.43$$

For Joint g

$$D.f_{ge} = \frac{(I/4.0)}{(I/4.0)+0.5(I/4.5)} = 0.69$$

$$D.f_{gh} = \frac{0.5(I/4.5)}{(I/4.0)+0.5(I/4.5)} = 0.31$$

For Joint e

$$D.f_{ec} = \frac{(I/4.5)}{(I/4.5)+2(I/4.0)+0.5(I/4.5)} = 0.27$$

$$D.f_{ef} = \frac{0.5(I/4.5)}{(I/4.5)+2(I/4.0)+0.5(I/4.5)} = 0.13$$

$$D.f_{\substack{eg\\ea}} = \frac{(I/4.0)}{(I/4.5)+2(I/4.0)+0.5(I/4.5)} = 0.30$$

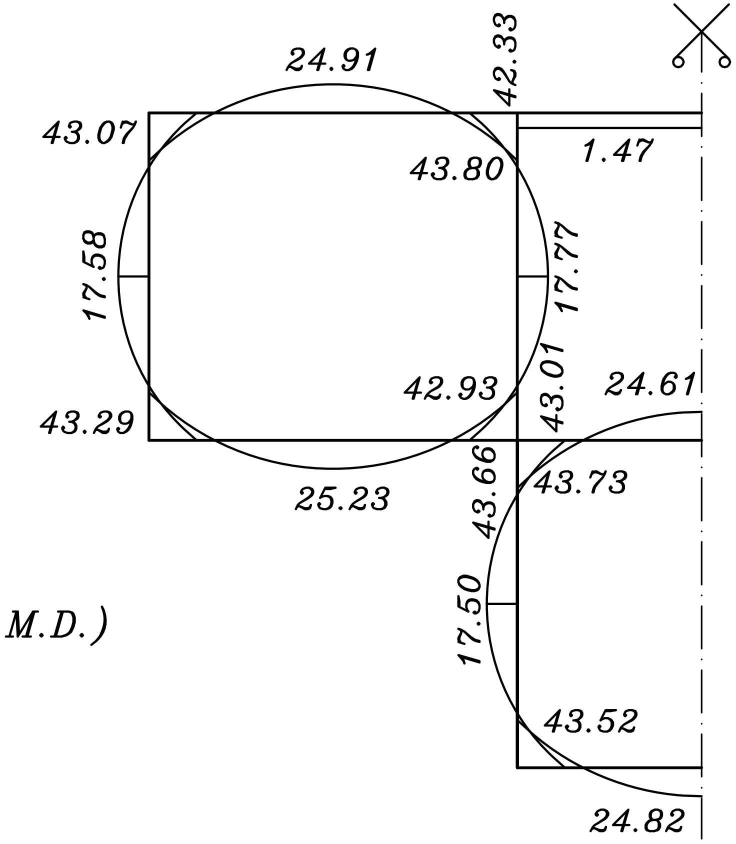
$$F.E.M._{\substack{ba\\ef\\ec}} = \frac{27.0*(4.5)^2}{12} = 45.56kN.m$$

$$F.E.M._{\substack{ab\\ce\\gh}} = -45.56kN.m$$

$$F.E.M._{\substack{cb\\ae\\ge}} = \frac{30.38*(4.0)^2}{12} = 40.51kN.m$$

$$F.E.M._{\substack{bc\\ea\\eg}} = -40.51kN.m$$

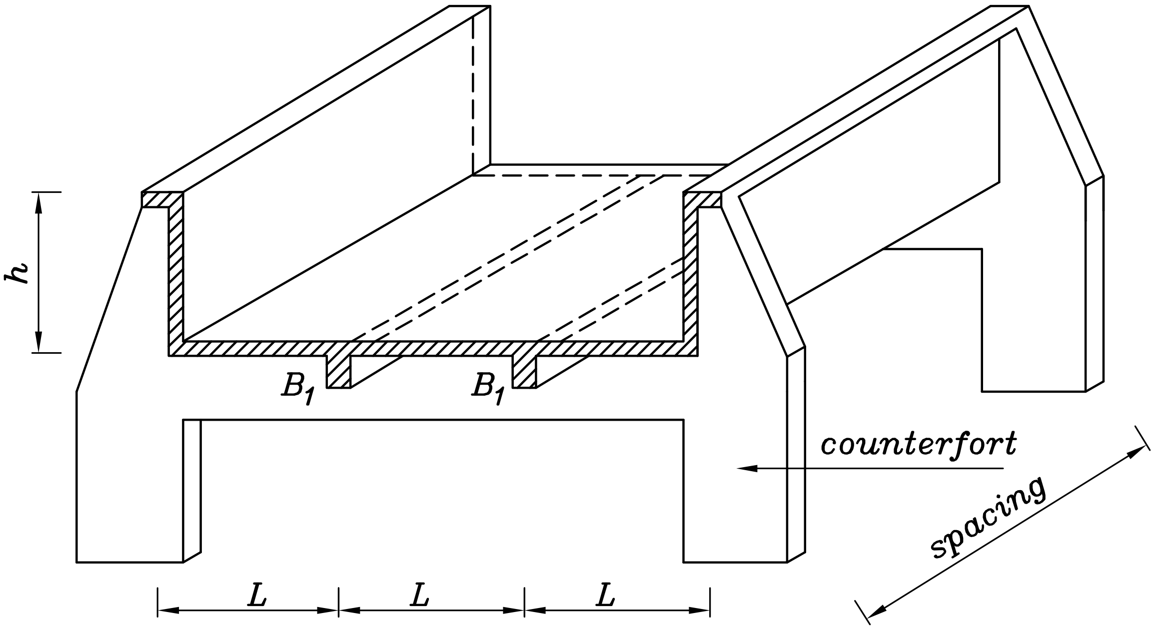
Joint	a			b		c		e				g	
member	ad	ae	ab	ba	bc	cb	ce	ec	ef	ea	eg	ge	gh
D.f.	0.19	0.43	0.38	0.47	0.53	0.53	0.47	0.27	0.13	0.30	0.30	0.69	0.31
F.E.M.	0	40.51	−45.56	45.56	−40.51	40.51	−45.56	45.56	45.56	−40.51	−40.51	40.51	−45.56
Bal.M.	0.96	2.17	1.92	−2.37	−2.68	2.68	2.37	−2.73	−1.31	−3.03	−3.03	3.48	1.57
C.O.M.	0	−1.52	−1.19	0.96	1.34	−1.34	−1.37	1.19	0	1.09	1.74	−1.52	0
Bal.M.	0.51	1.17	1.03	−1.08	−1.22	1.44	1.27	−1.09	−0.52	−1.21	−1.21	1.05	0.47
M_f	1.47	42.33	−43.80	43.07	−43.07	43.29	−43.29	42.93	43.73	−43.66	−43.01	43.52	−43.52



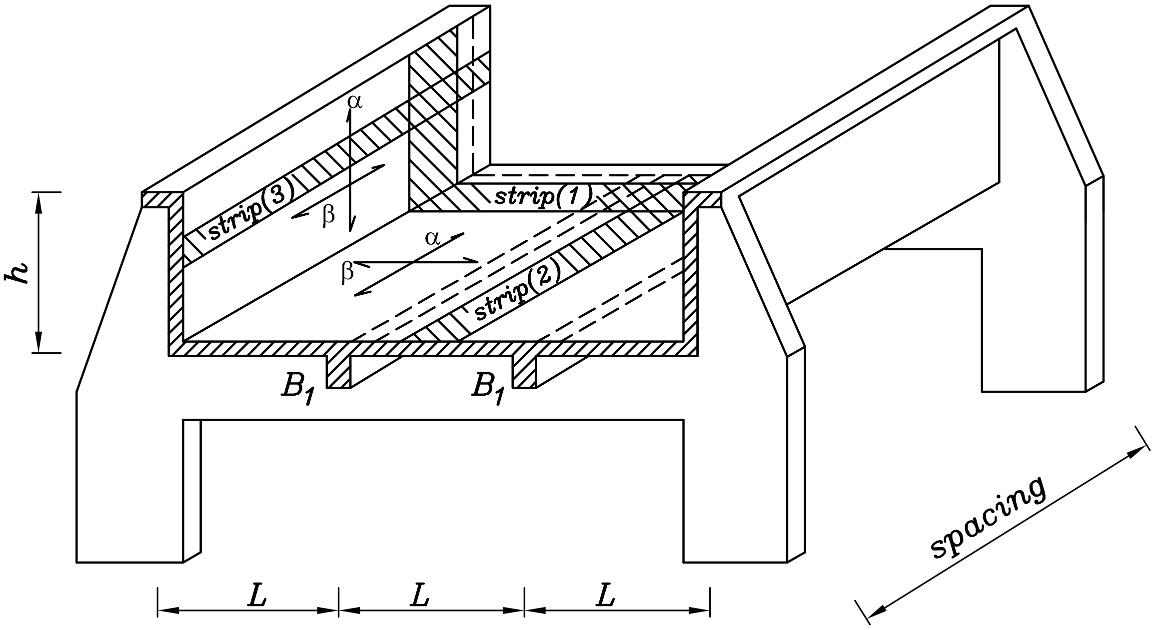
(B.M.D.)

– *Open channel with a counterfort*

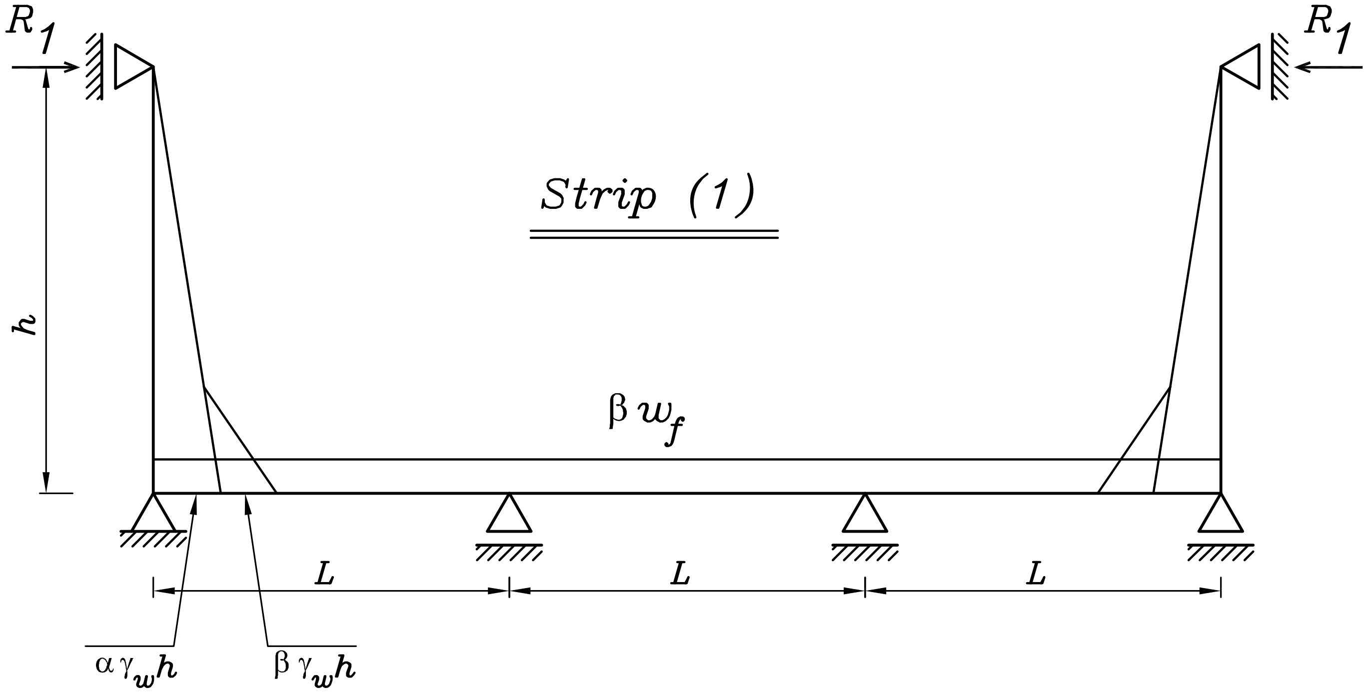
نلجأ الى عمل *(counterfort)* فى حالة *(deep tanks)* و ذلك لتقليل تخانة الحوائط او فى حالة حمامات السباحة *(swimming pools)* ذات الاعماق الكبيرة .



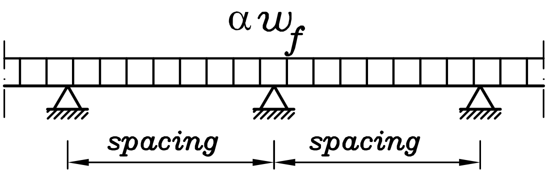
– *Analysis of strips*



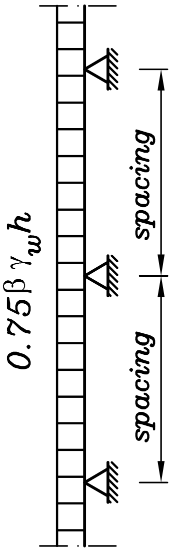
Strip (1)



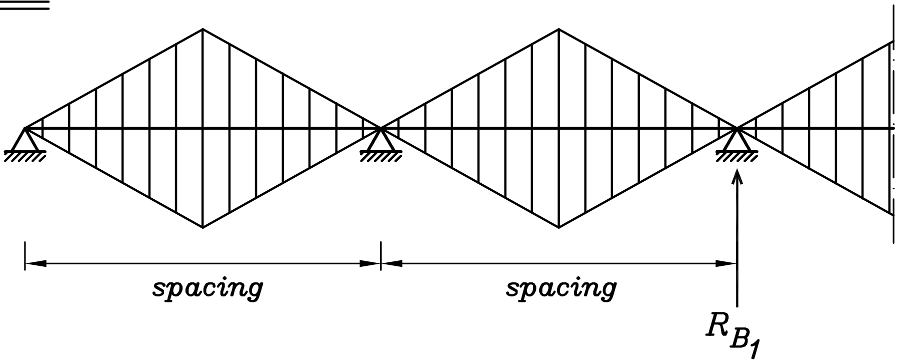
Strip (2)

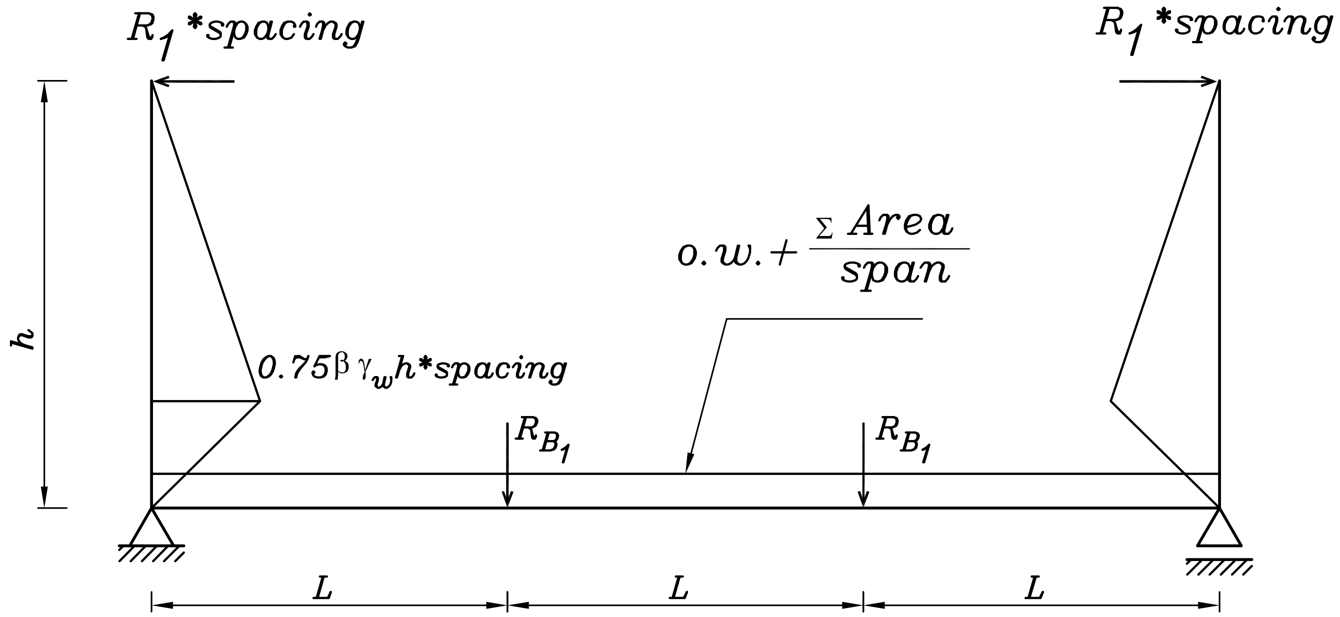


Strip (3)



For B_1





Statical system of counterfort

Example(14)

Given:

$f_{cu}=25\ N/mm^2$ &

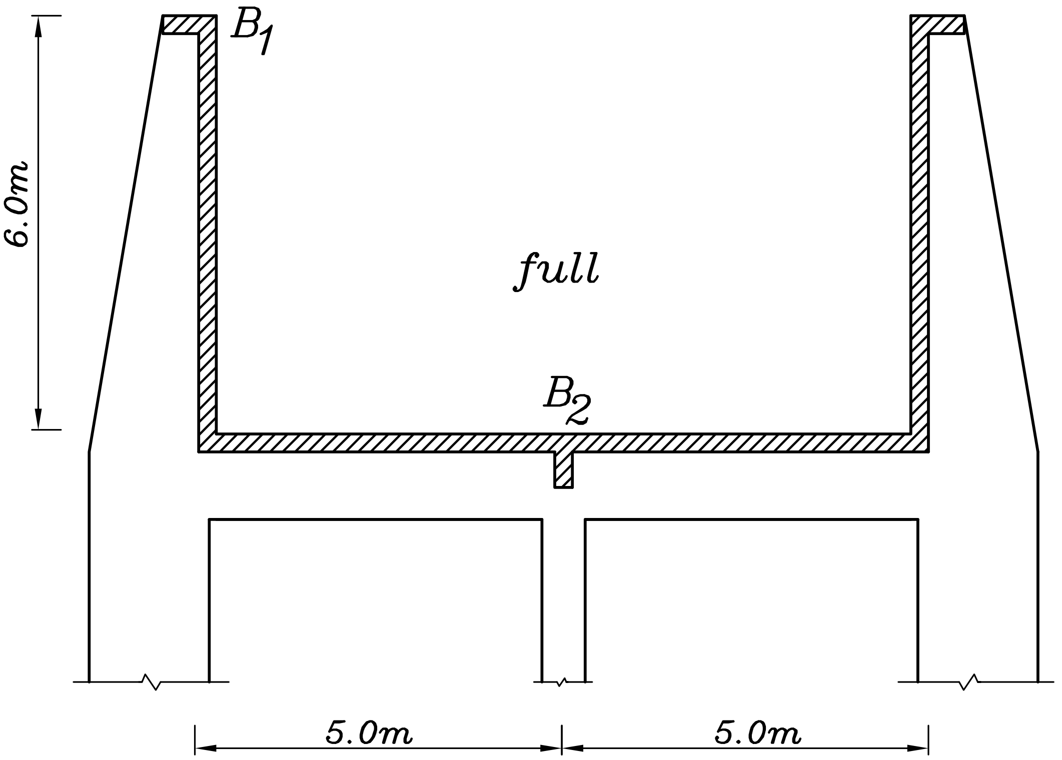
steel used is 360/520

Required

1−Calculate the loads acting on each element.

2−Calculate the straining actions acting on each element.

3−Sketch the shape of RFT. of the counterfort.



spacing=5.0m

Solution

1– Concrete dimensions

$$t_w = t_f = \frac{L}{16} = \frac{500}{16} = 31.25cm$$

$\Longrightarrow$ Take $t_w = t_f = 30cm$

2– Loads on floor

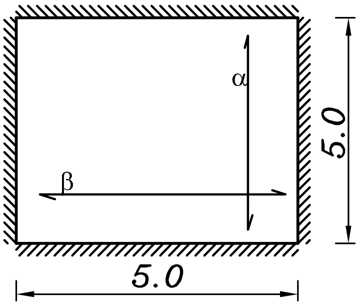
$$w_f = 0.30*25+10*6.0 = 67.50 \ \ kN/m^2$$

3– Load distribution

– for floor (5.0*5.0)

$$r = \frac{0.76*5.0}{0.76*5.0} = 1.00$$

$\alpha = \beta = 0.50$

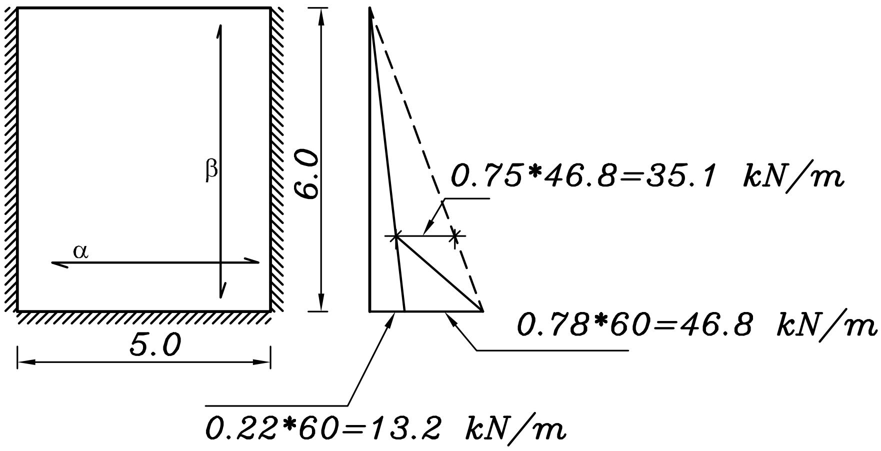


– Wall (1) (6.0*5.0)

$$r = \frac{0.87*6}{0.76*5} = 1.37$$

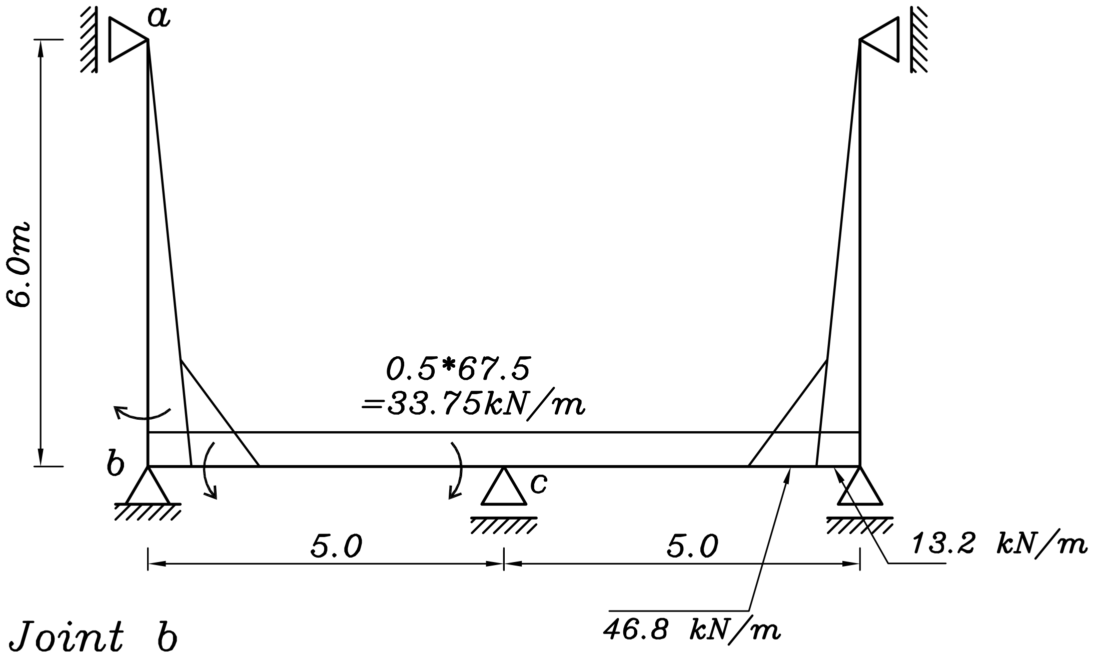
$$\alpha = \frac{r^4}{1+r^4} = 0.78$$

$$\beta = \frac{1}{1+r^4} = 0.22$$



4– Analysis of strips

– VL. strip (1)



For Joint b

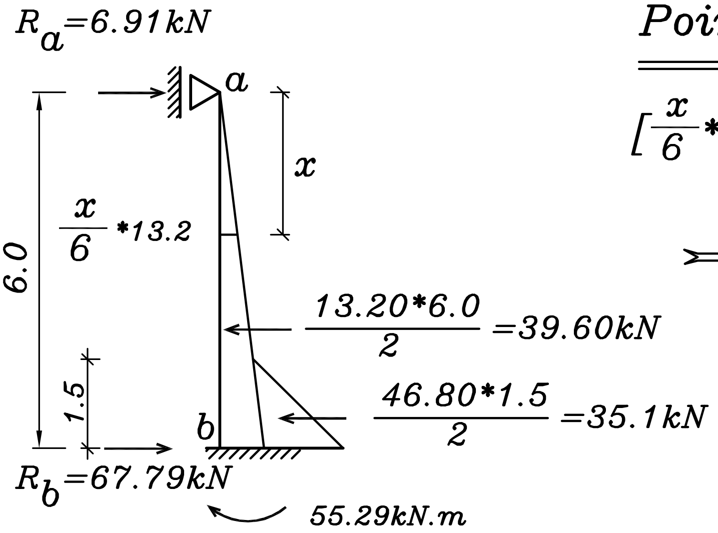
$$D.f_{ba}=\frac{0.75(I/6.0)}{0.75(I/6.0)+(I/5.0)}=0.38$$

$$D.f_{bc}=\frac{(I/5.0)}{0.75(I/6.0)+(I/5.0)}=0.62$$

$$F.E.M._{ba}=\frac{13.20*(6)^2}{15}+\frac{46.80*(6)^2}{117}=46.08kN.m$$

$$F.E.M._{bc}=\frac{-33.75*(5.0)^2}{12}=-70.31kN.m \quad \& \quad F.E.M._{cb}=70.31kN.m$$

Joint	b		c
member	ba	bc	cb
D.f.	0.38	0.62	0
F.E.M.	46.08	−70.31	70.31
Bal.M.	9.21	15.02	0
C.O.M.	0	0	7.51
M_f	55.29	−55.29	77.82

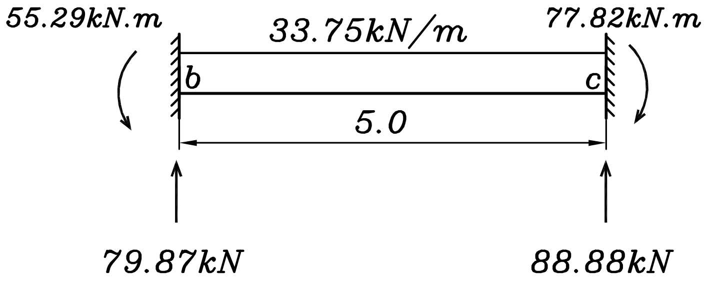


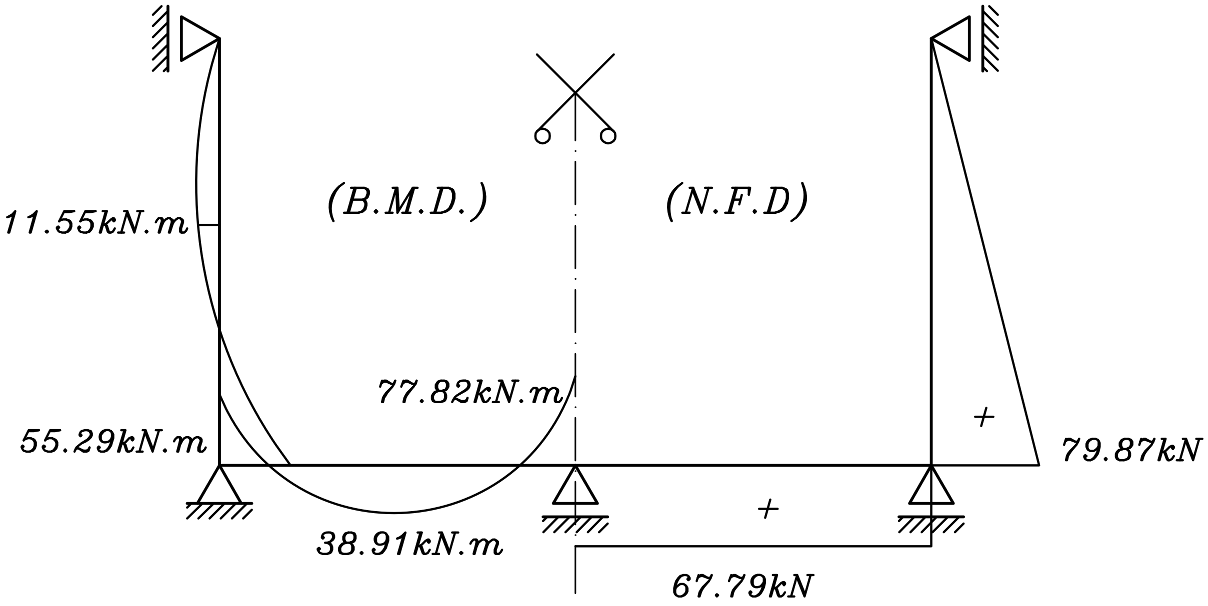
Point of zero shear

$$\left[\frac{x}{6}*13.20\right]*\frac{x}{2}=6.91 \Longrightarrow x=2.51m$$

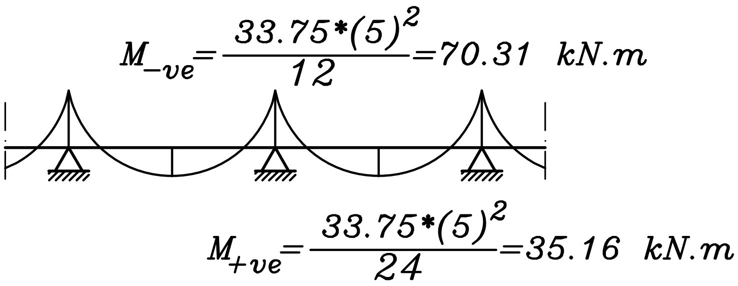
$$\Longrightarrow M_{+ve}=6.91x-\left(\frac{x}{6}*13.20\right)*\left(\frac{x^2}{6}\right)$$

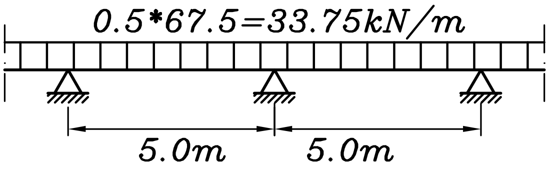
$$M_{+ve}=11.55\ \ kN.m$$



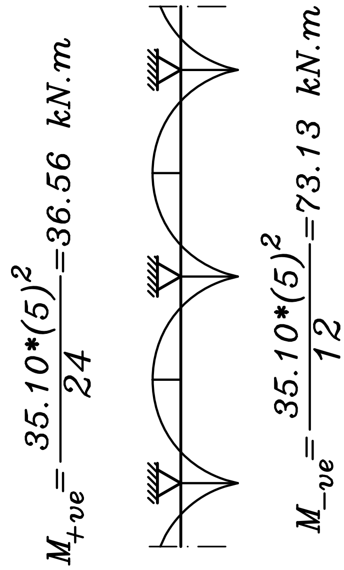


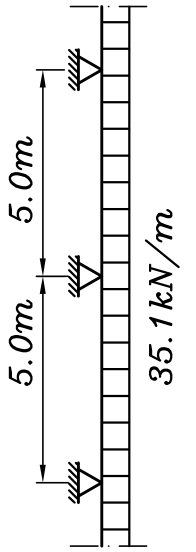
- Hz. strip at the floor (2)



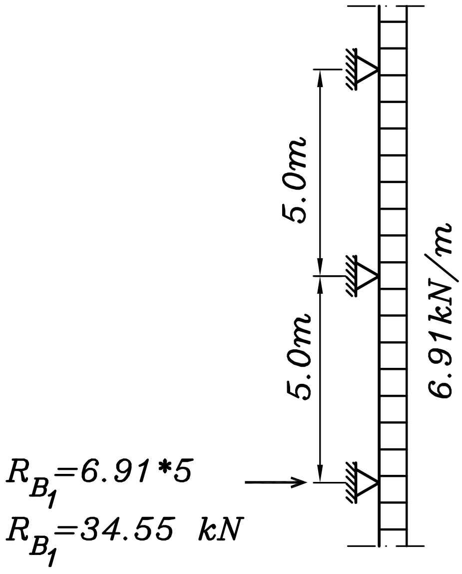


- Hz. strip at the wall (3)



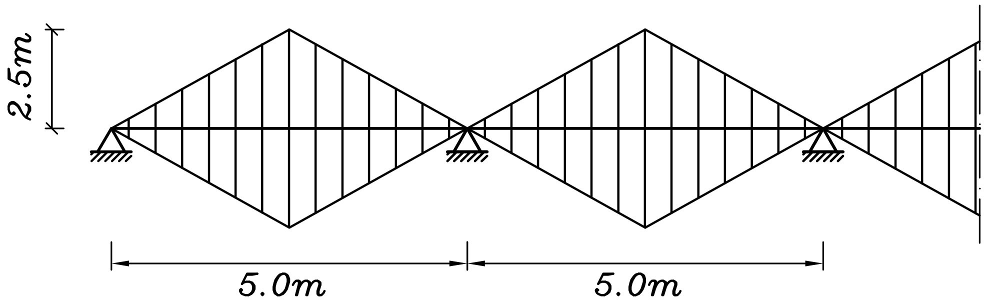


- Loads on top hz. beam (B_1)



– Loads on floor. beam (B_2)

Assume beam is (300*900)



– Load for shear

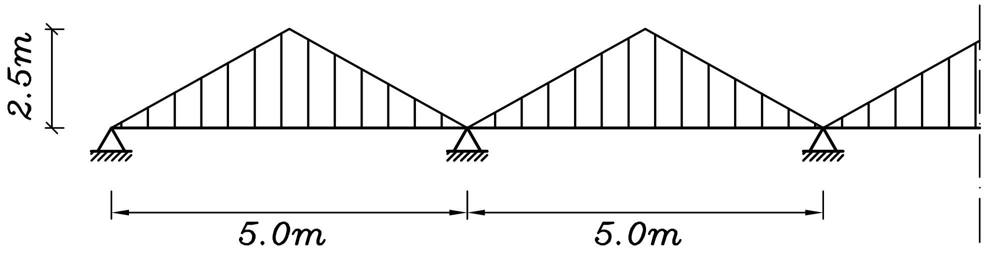
$$w_a = o.w. + c_a \frac{L_s}{2} . w_f *2$$

$$w_a = 0.3*(0.9-0.30)*25+1/2*5/2*67.50*2$$

$$w_a = 173.25 \ kN/m$$

$$R_{B_2} = 173.25*5 = 866.25 \ kN$$

– Loads on side wall (wall acts as a beam)



– Load for shear

$$w_a = o.w. + c_a \frac{L_s}{2} . w_f$$

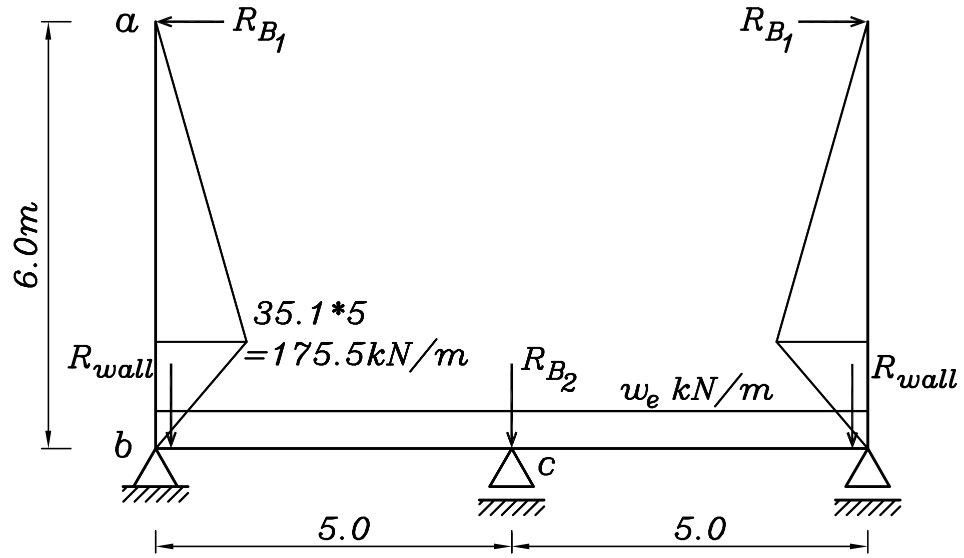
$$w_a = 0.3*6.0*25+1/2*5/2*67.50$$

$$w_a = 129.38 \ kN/m$$

$$R_{wall} = 129.38*5 = 646.88 \ kN$$

– Loads on counterfort

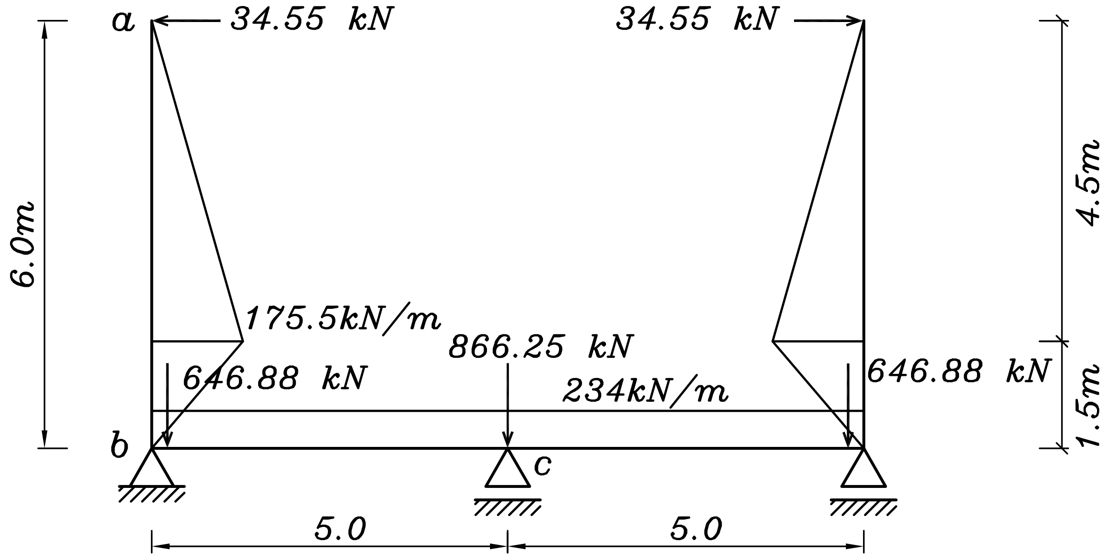
Assume counterfort is (300*1500)



$$w_e = o.w. + c_e \frac{L_s}{2} .w_f *2$$

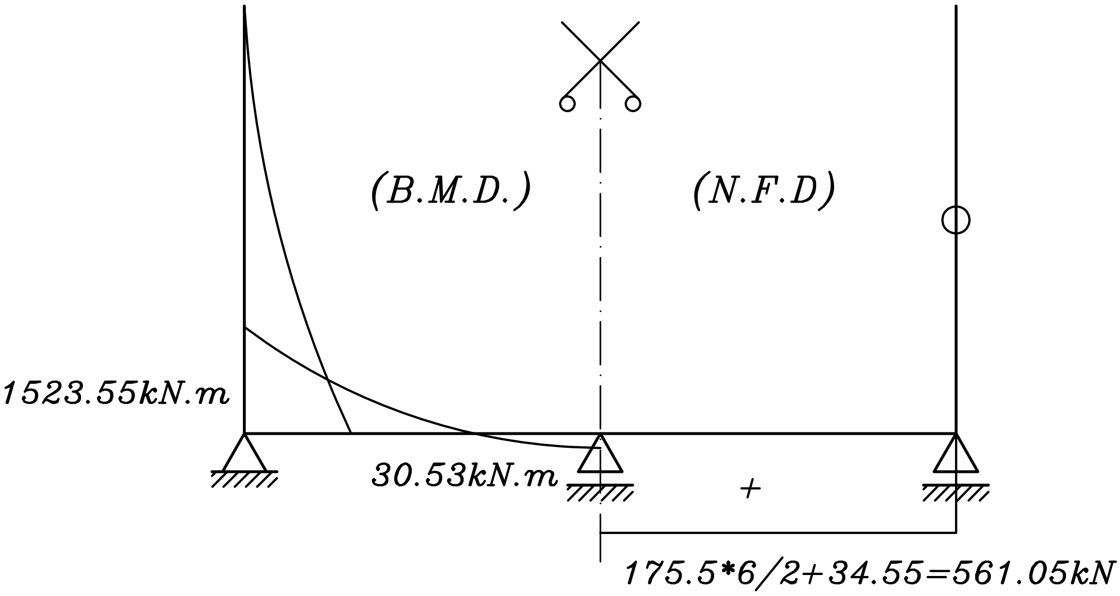
$$w_e = 0.3*(1.5-0.30)*25+2/3*5/2*67.50*2$$

$$w_e = 234 \ kN/m$$



$$M_{ba}=\frac{175.5*4.5}{2}*3.0+\frac{175.5*1.5}{2}*1.0+34.55*6=1523.55kN.m$$

$$F.E.M._{cb}=\frac{234.00*(5)^2}{8}-\frac{1523.55}{2}=-30.53kN.m$$



ـ ملحوظة هامة

لاحظ ان $(normal\ \ force)$ على (ab) تساوى صفر لانه فى حالة $(counterfort)$ ينتقل رد فعل (bc) الى العمود .

Details of RFT. of counterfort