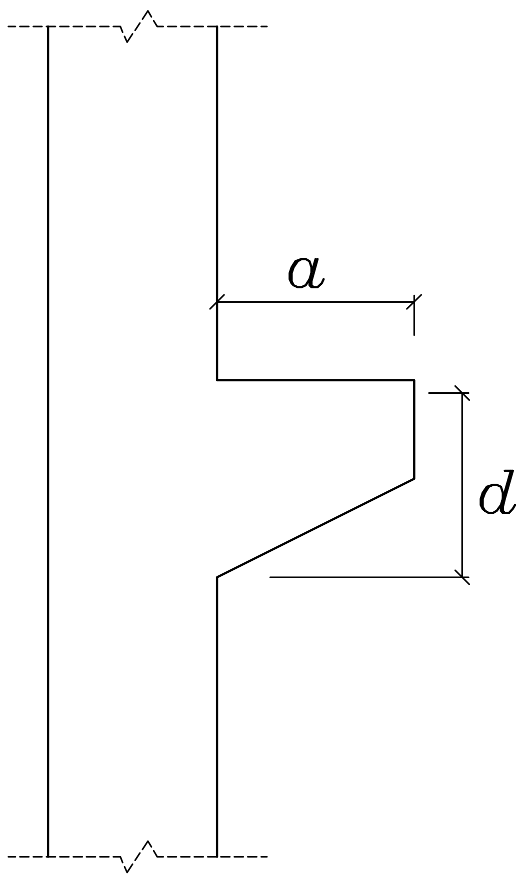
Design of short cantilevers

–Definition of short cantilevers or corbels or brackets

هى الكوابيل التى لا يزيد طول بروزها من وجه الركيزة (a) عن العمق الفعال عند وجه الركيزة (d)



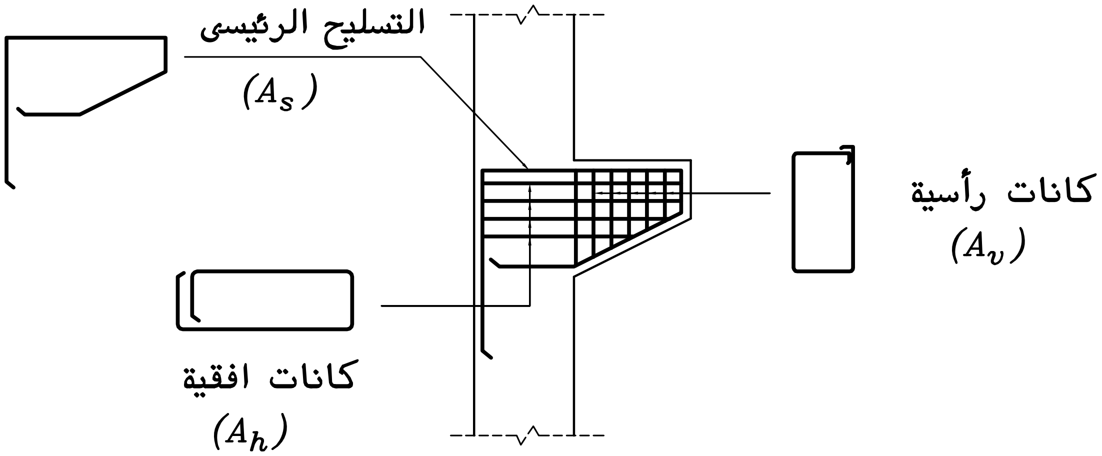
$$a \leq d$$

يتكون الحديد فى ال (short cantilevers) من الاتى

١ - التسليح الرئيسى (A_s)

٢ - التسليح الافقى (الكانات الافقية) (A_h)

٣ - التسليح الرأسى (الكانات الرأسية) (A_v)



١ - التسليح الرئيسى (A_s)

يؤخذ الحديد الرئيسى القيمة الاكبر من الاتى

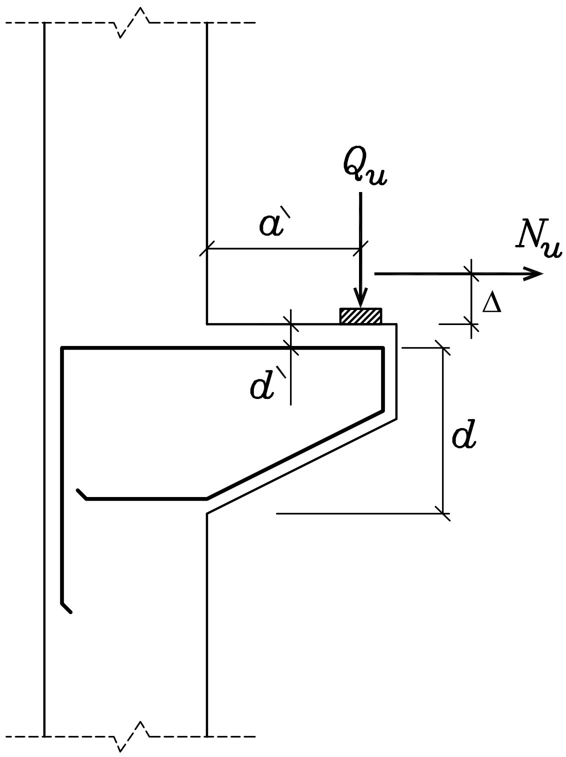
$$A_s = \begin{cases} A_n + A_f \\ A_n + \frac{2}{3} A_{sf} \\ 0.03 \frac{f_{cu}}{f_y} bd \end{cases}$$

نأخذ القيمة الاكبر

where

$A_n =$ مساحة الحديد اللازم لمقاومة قوة شد (N_u)

$$A_n = \frac{N_u}{f_y/\gamma_s}$$



ملحوظة -

قوة الشد (N_u) تمثل القوة الافقية التى يتعرض لها *(short cantilever)* مثل الصدمة الجانبية *(lateral shock)* الناتجة من حركة *(crane)* وتؤخذ

$$N_u = 0.2Q_u$$

$A_f =$ مساحة الحديد اللازم عند وجه الركيزة لمقاومة عزم مقداره (M_u) المحسوب عند وجه الركيزة

$$M_u = Q_u . a` + N_u(\Delta + d`)$$

$$d = C_1\sqrt{\frac{M_u}{b * f_{cu}}} \Longrightarrow get\ \ C_1 \ \&J \Longrightarrow A_f = \frac{M_u}{J * d * f_y}$$

حيث $(a`)$ هى المسافة المحصورة بين مكان تاثير (Q_u) ووجه الركيزة

(Δ) هى المسافة المحصورة بين مكان تاثير (N_u) والحافة العلوية لـ *(short cantilever)* و $(d`)$ تمثل *(concrete cover for top RFT.)*

$A_{sf} =$ مساحة الحديد اللازم لمقاومة قوة القص (Q_u) عن طريق الاحتكاك *(shear friction)*

$$A_{sf} = \frac{Q_u}{\mu(f_y/\gamma_s)} + \frac{N_u}{f_y/\gamma_s}$$

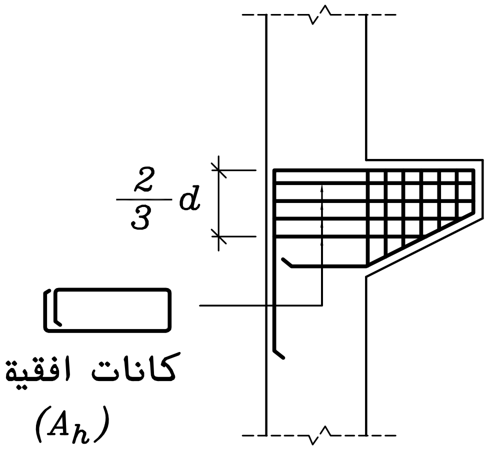
حيث (μ) هو معامل الاحتكاك و يؤخذ $(\mu = 1.2)$ للخرسانة المصبوبة *(monoliticaly)*

٢- التسليح الافقى (A_h)

(A_h) هو مساحة التسليح الافقى الموازى للتسليح الرئيسى و هو عبارة عن كانات افقية مغلقة موزعة بانتظام خلال ارتفاع $(\frac{2}{3}\ d)$ و يحسب كالتالى

$$A_h = 0.5(A_s - A_n)$$

حيث $(A_s \ \& \ A_n)$ هما المحسوبان سابقا



٣- التسليح الرأسى (A_v)

توضع الكانات الرأسية لمقاومة عزم لى (M_t) بحيث لا تقل عن

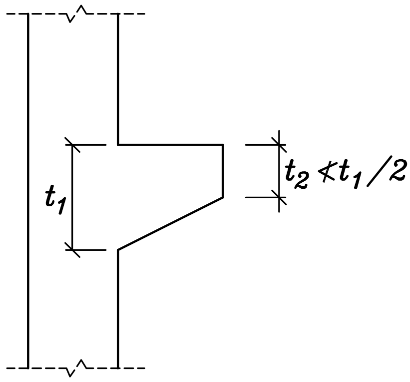
$$A_{v_{min}} = \frac{0.4}{f_y}\ b.S$$

حيث (S) هى $(spacing\ \ between\ \ stirrups)$ وتتراوح بين $(100-200mm)$

Check

$$\frac{Q_u}{bd} \not> 0.15\ f_{cu}$$

وبحد اقصى $(5.0\ \ N/mm^2)$



حيث (d) هو العمق $(depth)$ للقطاع (t_2)

$$d = t_2 - cover$$

Example(6)

The given figure shows a sectional elevation of two fixed frame covering an industrial area of (18*30 m). The duilding is provided with a crane which gives a maximum moving reaction of 100 kN. The spacing between frames is 6.0 m. It is required to:

1– Without any calculations but with reasonably concrete dimensions, draw sectional elevation & part paln to show the dimensions of all concrete elements to scale (1:50).

2– Design the short cantilever (corbel) carrying the crane load and draw its details of reinforcement in elevation to scale (1:10).

3– Design the main supporting element and draw its details of reinforcement in elevation and cross sections to scale (1:25).

4– Calculate the wind loads acting on the end gable columns. Design its section and draw details of reinforcement to scale (1:10).

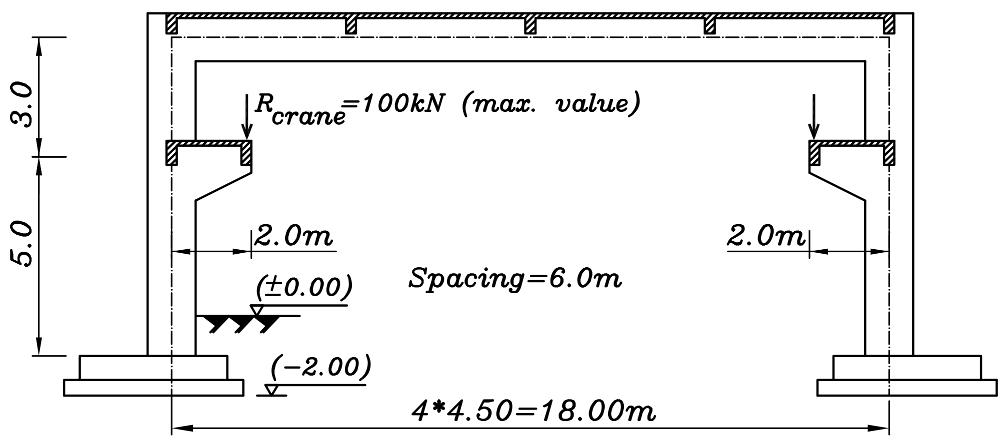
Given:

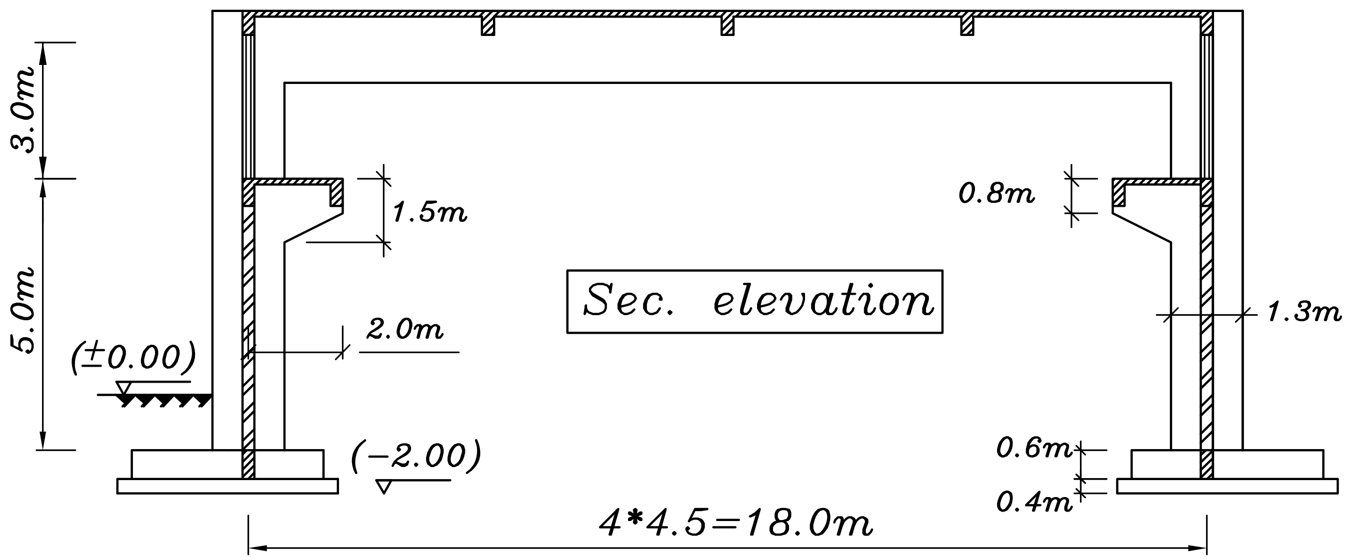
$f_{cu}=30\ N/mm^2$, $f_y=360\ N/mm^2$

F.C.+L.L.=2.0 kN/m^2 (on horizontal projection).

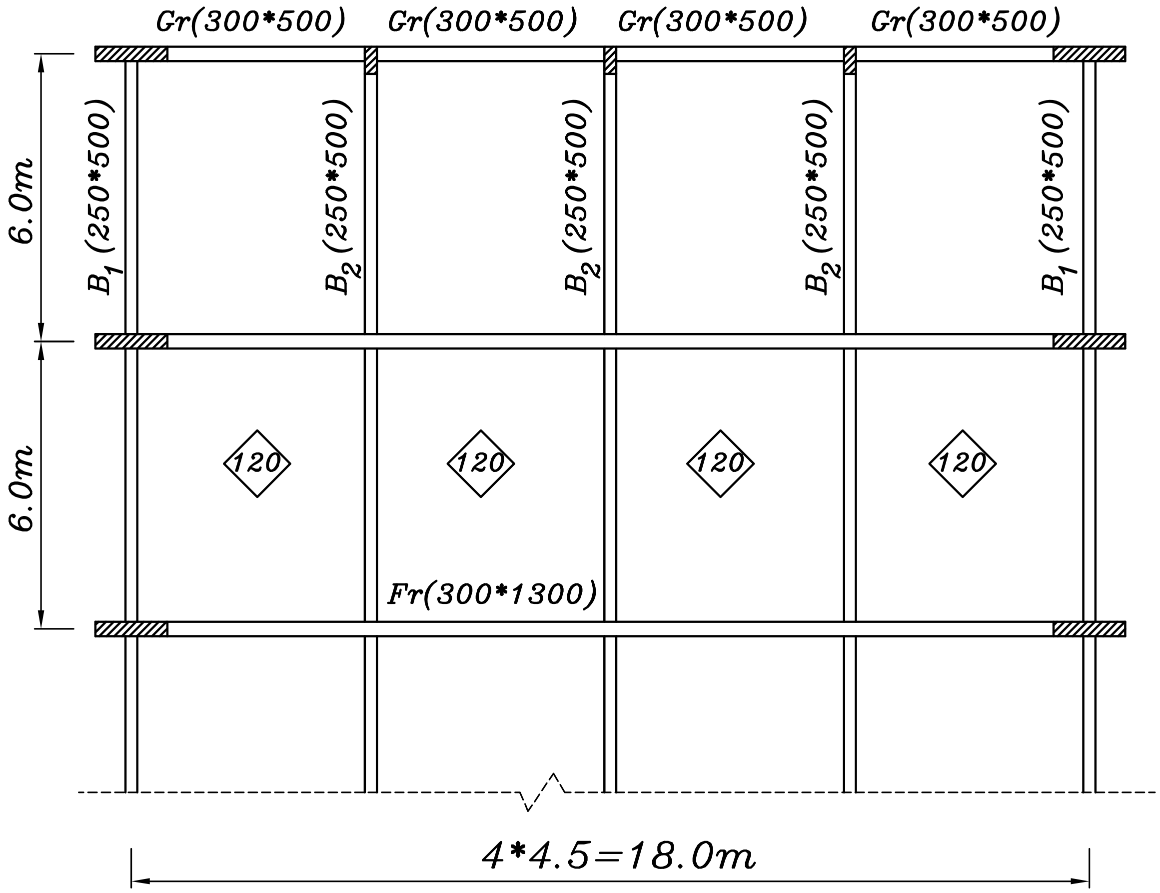
Wind intensity=0.10 kN/m^2

Foundation level=(−2.00m) , bearing capacity of soil=0.20 N/mm^2



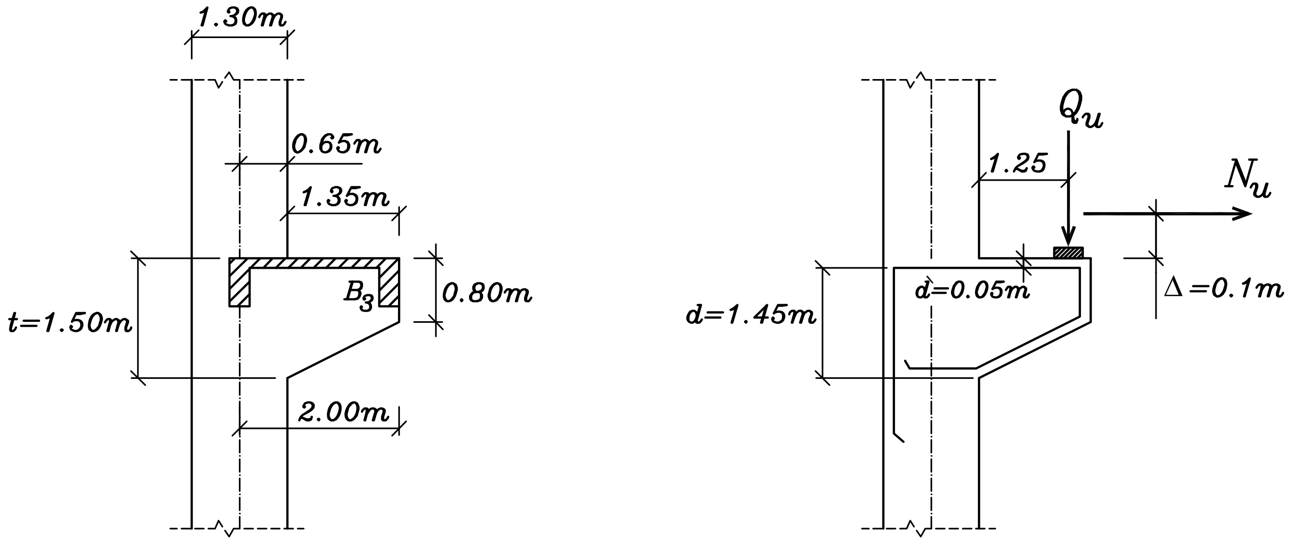


Sec. elevation



Structural plan

2–Design of short cantilever:



ـ ملحوظة

نأخذ المسافة $(\Delta=0.1m)$ ونفرض مكان تاثير (Q_u) على بعد $(0.10m)$ من طرف الكابولى .

To get (Q_u), we have to calculate reaction of (B_3)

a– Distributed load

$w_{su}=1.5[t_s\gamma_c+F.c.+L.L.]$

$w_{su}=1.5[0.12*25+2.0]=7.5\ \ kN/m^2$

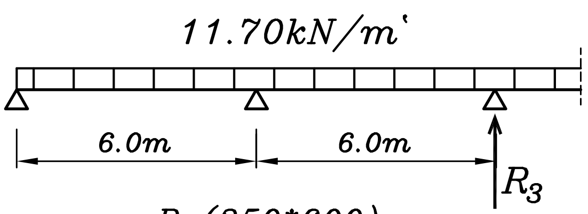
$w_3=\gamma_c b(t-t_s)*1.40+w_s\frac{a}{2}\ \ kN/m'$

$w_3 = \ 25*0.25*(0.60-0.12)*1.40+7.5*\frac{2.0}{2}$

$w_1=11.70kN/m'$

$R_3=w_3\ *\ Spacing$

$R_3=11.70*6=70.20kN$



$B_3\,(250*600)$

b−Concentrated moving load

max. reaction of crane load=100 kN

$R_{crane}=1.6*100=160kN$ (ultimate load)

$\Longrightarrow Q_u=R_3+R_{crane}=70.20+160=\underline{230.20kN}$

$\Longrightarrow N_u=0.2Q_u=0.2*230.20=\underline{46.04kN}$

١ - التسليح الرئيسى (A_s)

$$A_n=\frac{N_u}{f_y/\gamma_s}=\frac{46.04*10^3}{360/1.15}=\underline{147.07mm^2}$$

$M_u=Q_u\,.\,a` +N_u(\Delta+d`)$ المحسوب عند وجه الركيزة

$M_u=230.20*1.25+46.04*(0.10+0.05)$

$M_u=294.66$ kN.m

$$d=C_1\sqrt{\frac{M_u}{b*f_{cu}}} \Longrightarrow 1450=C_1\sqrt{\frac{294.66*10^6}{300*30}} \quad C_1=8.01 \;\; \& \;\; J=0.826$$

$$A_f=\frac{294.66*10^6}{0.826*1450*360}=\underline{683.39mm^2}$$

$$A_{sf}=\frac{Q_u}{\mu(f_y/\gamma_s)}+\frac{N_u}{f_y/\gamma_s}=\frac{230.20*10^3}{1.2*(360/1.15)}+\frac{46.04*10^3}{360/1.15}$$

$A_{sf}=\underline{759.87mm^2}$

$$A_s=\left[\begin{array}{l} A_n+A_f=147.07+683.39=830.46mm^2 \\ \\ A_n+\frac{2}{3}A_{sf}=147.07+(2/3)*759.87=653.65mm^2 \\ \\ 0.03\,\frac{f_{cu}}{f_y}\,bd = 0.03*\frac{30}{360}*300*1450=1087.5mm^2 \end{array}\right.$$

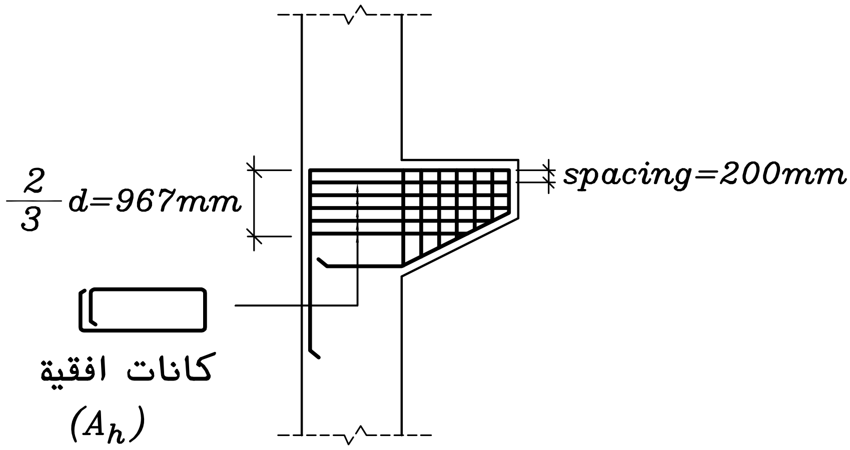
$A_s = 1087.5 mm^2$ (القيمة الاكبر)

$Take \ A_s = 6\phi 16$

٢ - التسليح الافقى (A_h)

$A_h = 0.5(A_s - A_n) = 0.5(1087.5 - 147.07) = 470.22 mm^2$

و يتم تركيزها خلال ارتفاع $(\frac{2}{3} d = 2/3 * 1450 = 967 mm)$



و بفرض ان $(spacing = 200mm)$ فان عدد الكانات الافقية يكون (٥كانات) كما بالرسم

$A_h = no. \ of \ stirrups * no. \ of \ branches \ * \ A_\phi$

عدد الكانات * عدد الفروع * مساحة مقطع الكانة

$470.22 = 5*2*A_\phi \implies A_\phi = 47.03 mm^2 \implies use \ \phi 8 = 50.3 mm^2$

$\implies Horizontal \ stirrups = \ 5\phi 8/m \ (2 \ branches)$

٣- التسليح الرأسى (A_v)

$Assume \ spacing \ between \ vl. \ stirrups = 200mm$

و بفرض ان عدد الفروع الراسية للكانة =٢

$$A_{v_{min}} = \frac{0.4}{f_y} b.S = \frac{0.4}{240} * 300 * 200 = 100 mm^2$$

$A_v = n \ * \ A_\phi$

عدد الفروع * مساحة مقطع الكانة

$100 = 2*A_\phi \implies A_\phi = 50.00 mm^2 \implies use \ \phi 8 = 50.3 mm^2$

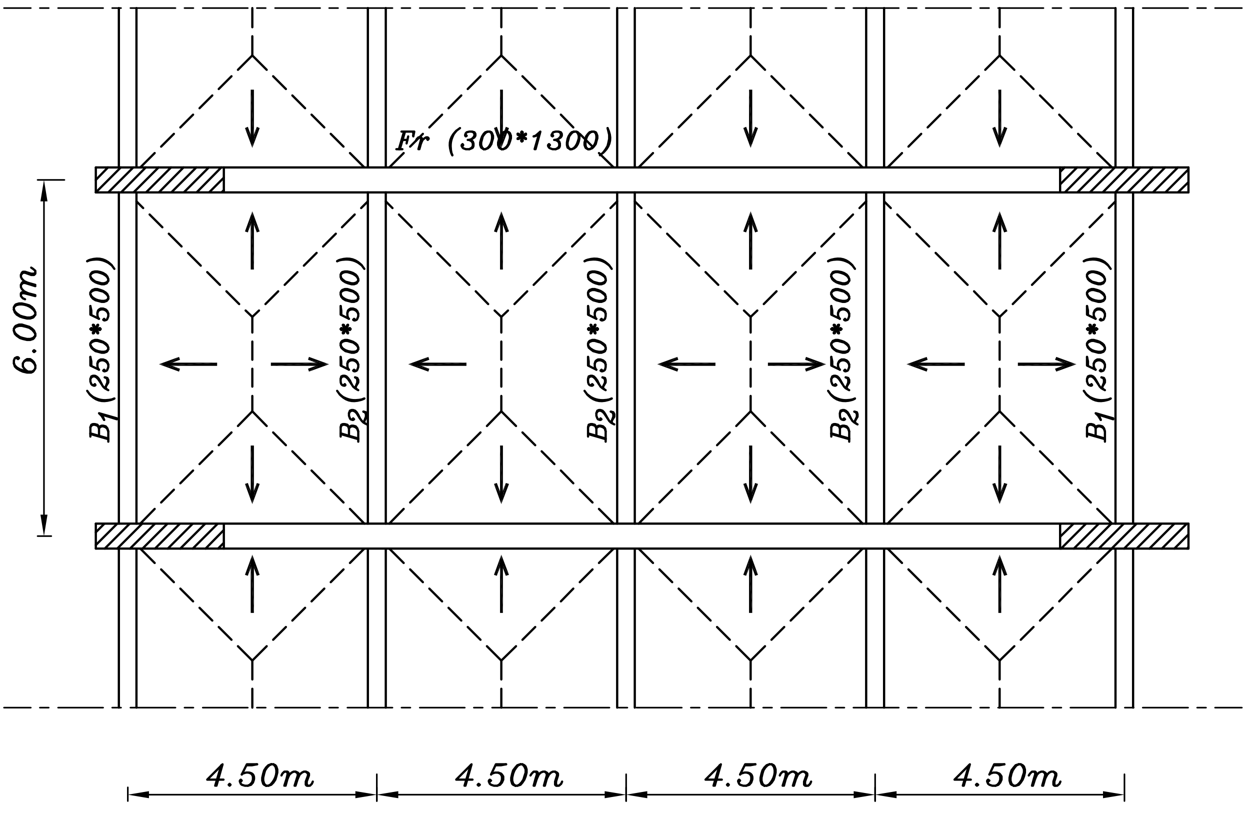
⟹ Vertical stirrups= 5ϕ8/m (2 branches)

Check

$0.15\ f_{cu}=0.15*30=4.50\ N/mm^2$

$$\frac{Q_u}{bd}=\frac{230.20*10^3}{300*750}=1.02\ N/mm^2<4.50\ N/mm^2\quad (safe)$$

3-Design of the frame



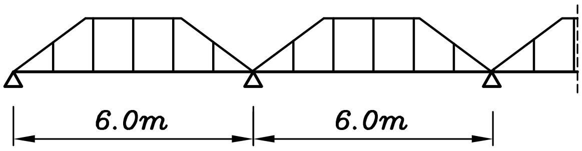
structural plan

$w_{su}=1.5[0.12*25+2.0]=7.5\ kN/m^2$

-Analysis of Beams

For B_1 (250*500)

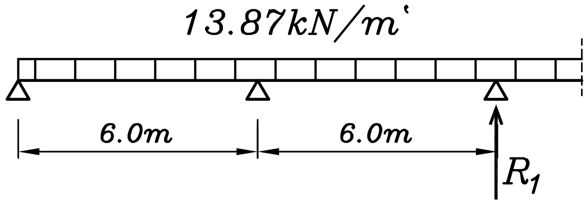
$$w_1=\gamma_c b(t-t_s)*1.4+c_a\frac{L_s}{2}w_s$$



$$c_a=1-\frac{1}{2}\left(\frac{4.5}{6.0}\right)=0.625$$

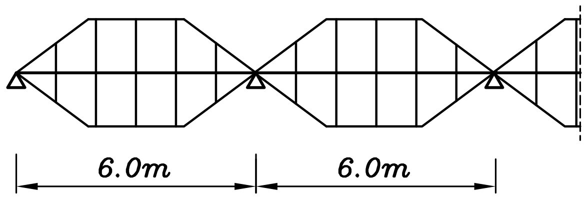
$$=25*0.25*(0.50-0.12)*1.4+0.625*4.5/2*7.5=13.87kN/m'$$

$$R_1=w_1*spacing=13.87*6.0=83.23kN$$



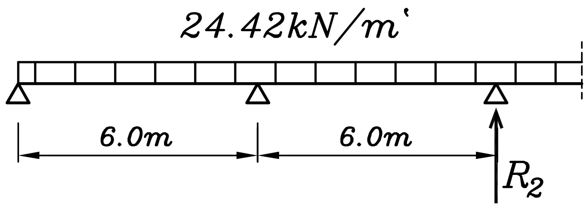
For B_2(250*500)

$$w_2=\gamma_c b(t-t_s)*1.4+c_a L_s w_s$$

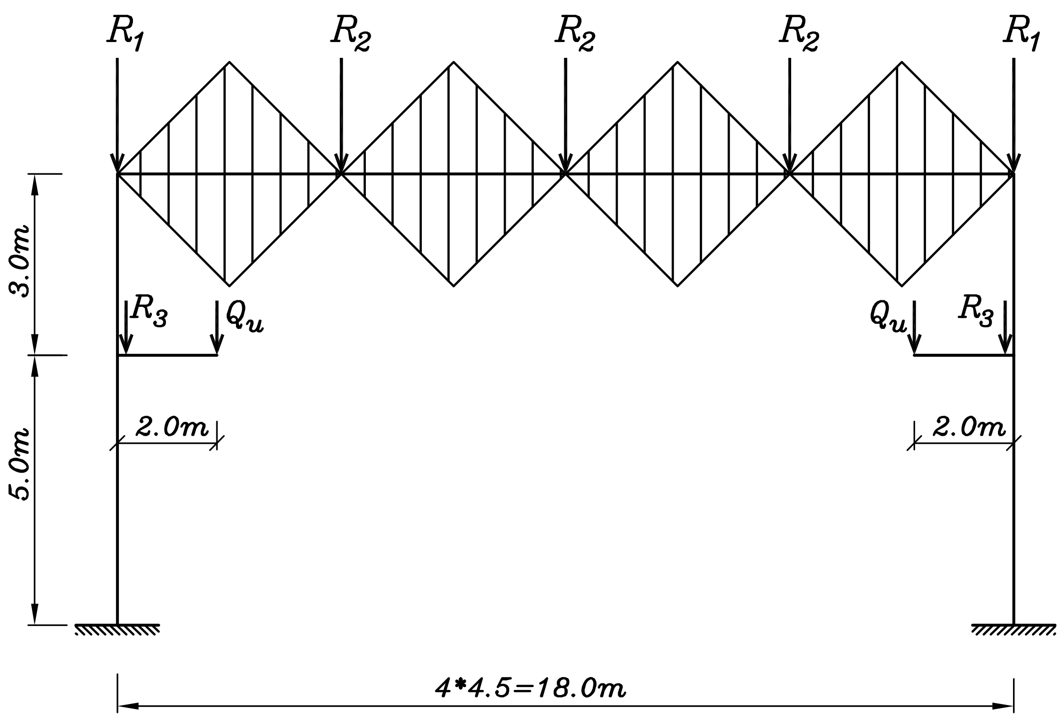


$$=25*0.25*(0.50-0.12)*1.4+0.625*4.5*7.5=24.42kN/m'$$

$$R_2=w_2*spacing=24.42*6.0=146.51kN$$



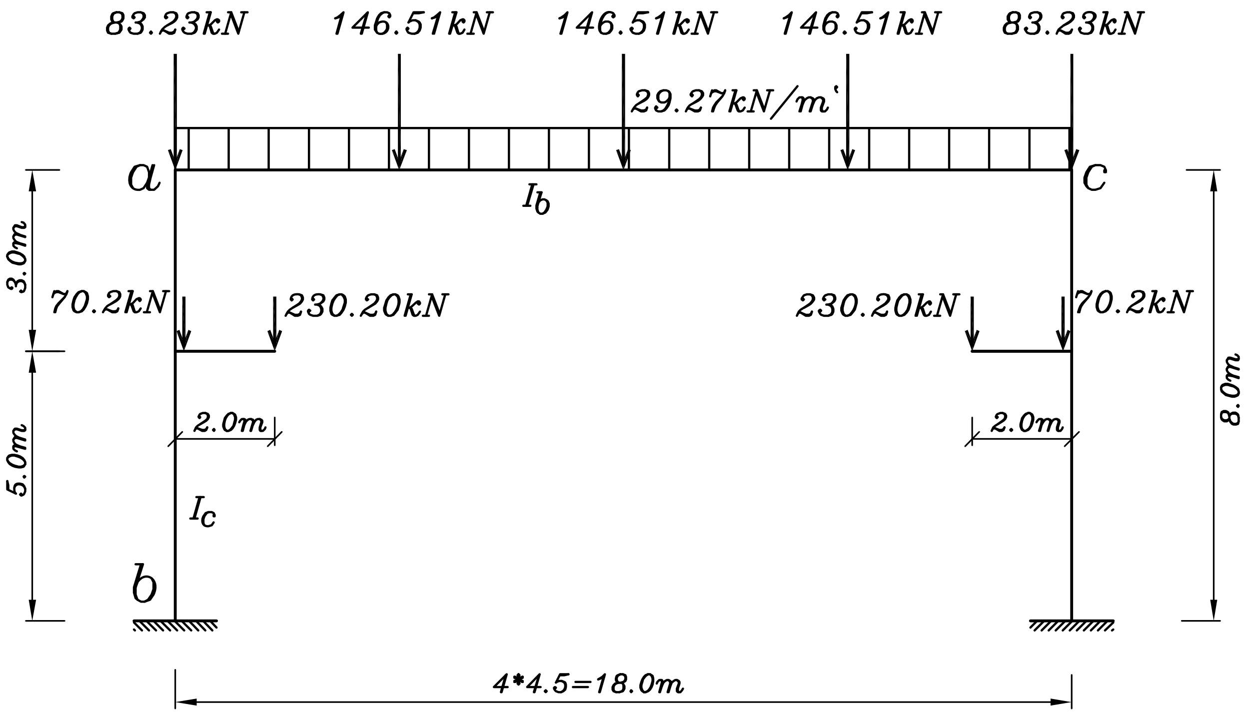
–Analysis of frame



$$w_f = \gamma_c b(t - t_s) * 1.4 + \frac{\Sigma A}{span} w_s$$

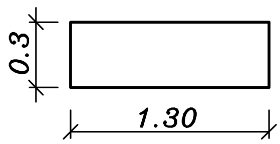
$$= 25*0.30*(1.30-0.12)*1.4 + \frac{8(0.5*4.5*2.25)}{18} *7.5$$

$$w_f = 29.27 kN/m$$



-Using moment distribution method to solve the frame

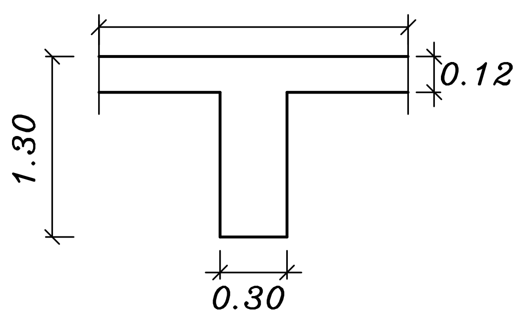
$$I_c = \frac{0.3*(1.3)^3}{12} = 0.0549 m^4$$



$$I_b = (\mu*10^{-4}) Bt^3$$

$$I_b = 355*(10)^{-4}*1.02*(1.3)^3$$

$$I_b = 0.0796 m^4$$



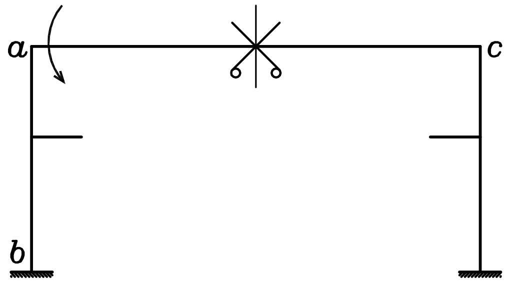
$$\frac{t_s}{t} = \frac{0.12}{1.30} = 0.092$$

$$\frac{b}{B} = \frac{0.3}{1.02} = 0.29$$

For Joint a

$$D.f_{ab} = \frac{(I_c/h)}{(\frac{I_c}{h})+(0.5\frac{I_b}{L})} = \frac{(0.0549/8.0)}{(0.0549/8.0)+0.50*(0.0796/18)}$$

$$D.f_{ab}=0.76 \quad \& \quad D.f_{ac}=1-0.76=0.24$$



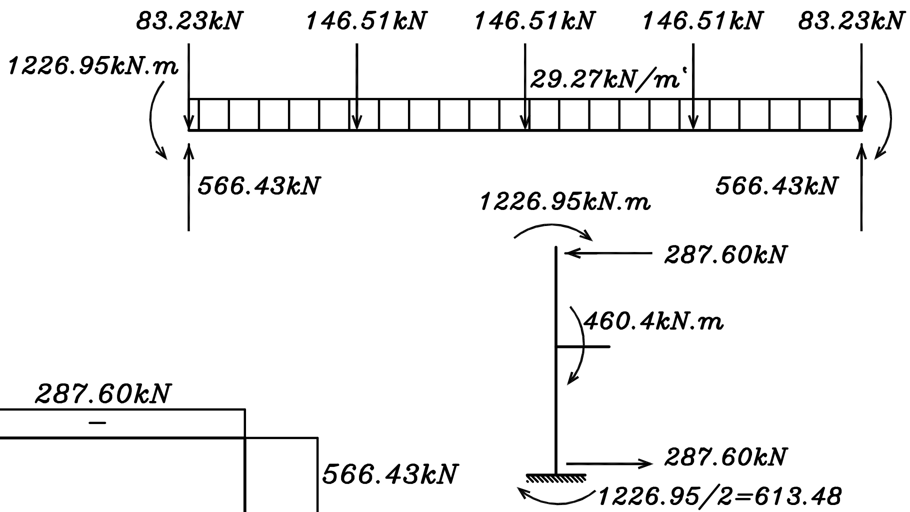
$$F.E.M._{ac}=-\frac{29.27*(18)^2}{12}$$

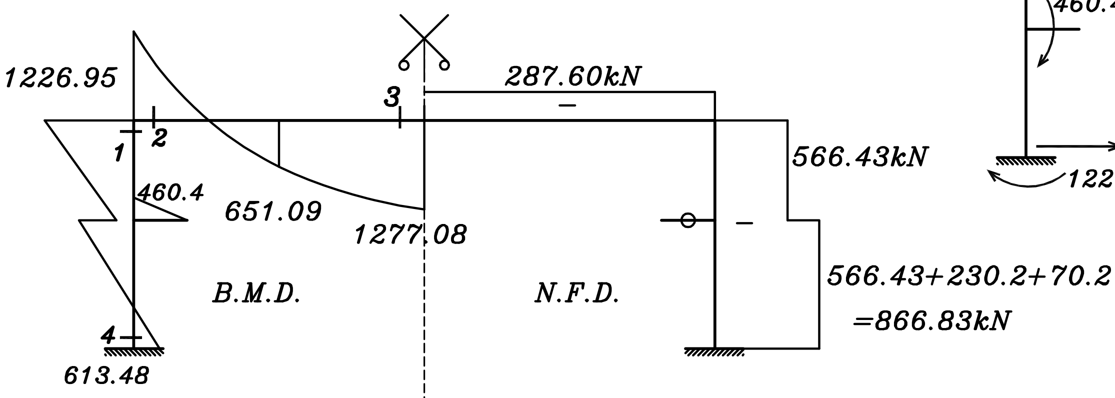
$$-\frac{146.51*4.5*(13.5)^2}{(18)^2}-\frac{146.51*18.0}{8}$$

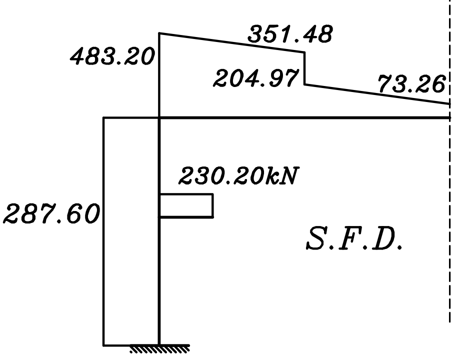
$$-\frac{146.51*13.5*(4.5)^2}{(18)^2}$$

$$F.E.M._{ac}=-1614.41 \ kN.m \quad \& \quad F.E.M._{ab}=0$$

Joint	a	
member	ab	ac
D.f.	0.76	0.24
F.E.M.	0	−1614.41
Bal.M.	1226.95	387.46
M_f	1226.95	−1226.95



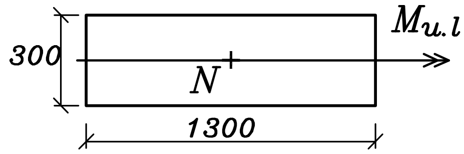




Design of Sections

Sec. (1−1) $M_{u.l.}=1226.95kN.m$ $N_{u.l.}=566.43kN$

$b=300mm$, $t=1300mm$



$$\frac{N_{u.l.}}{btf_{cu}}=\frac{566.43*10^3}{300*1300*30}=0.05>0.04 \text{ (Dont neglect } N_{u.l.})$$

$$e=\frac{M_{u.l.}}{N_{u.l.}}=\frac{1226.95}{566.43}=2.17m$$

$$\frac{e}{t}=\frac{2.17}{1.30}=1.67>0.5 \text{ (big eccentricity)}$$

$$e_s=e+\frac{t}{2}-c=2.17+\frac{1.30}{2}-0.1=2.72m$$

$$M_{us}=566.43*2.72=1538.49kN.m$$

$$d=C_1\sqrt{\frac{M_{us}}{b*f_{cu}}}$$

$$1200=C_1\sqrt{\frac{1538.49*10^6}{300*30}} \qquad C_1=2.90 \;\&\; J=0.73$$

$$A_s=\frac{M_{us}}{J.d.f_y}-\frac{N_{u.l.}}{f_y/\gamma_s}$$

$$A_s=\frac{1538.49*10^6}{0.73*1200*360}-\frac{566.43*10^3}{360/1.15}$$

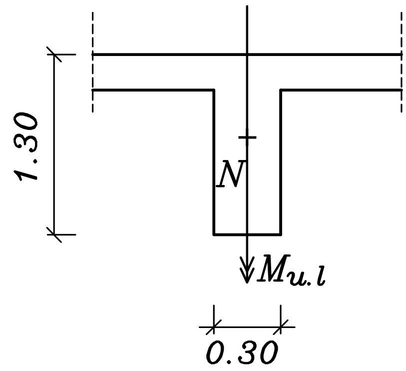
$$A_s=3055.20 \; mm^2=9\phi22$$

Sec. (2−2) $M_{u.l.}=1226.95kN.m$ $N_{u.l.}=287.60kN$

$b=300mm$, $t=1300mm$

$$\frac{N_{u.l.}}{btf_{cu}}=\frac{287.60*10^3}{300*1300*30}=0.02<0.04 \text{ (neglect } N_{u.l.})$$

$$d=C_1\sqrt{\frac{M_{u.l.}}{b*f_{cu}}}$$



$$1200=C_1\sqrt{\frac{1226.95*10^6}{300*30}}$$

$C_1=3.25$ & $J=0.76$

$$A_s=\frac{1226.95*10^6}{0.76*1200*360}$$

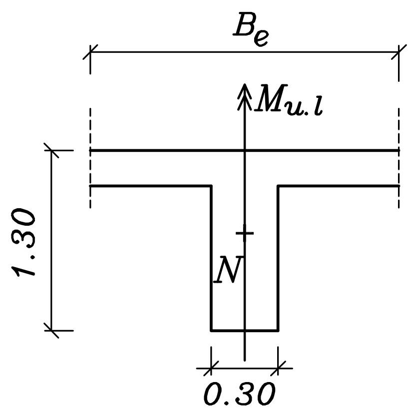
$A_s=3715.01\ mm^2=10\phi22$

Sec. (3-3) $M_{u.l.}=1277.08kN.m$ $N_{u.l.}=287.60kN$

$b=300mm$, $t=1300mm$

$$\frac{N_{u.l.}}{btf_{cu}}=\frac{287.60*10^3}{300*1300*30}=0.02<0.04\ (\text{neglect } N_{u.l.})$$

$$B=\begin{cases}16t_s+b=16*120+300=2220mm\\ ℄\longrightarrow ℄=6000mm\\ \frac{KL}{5}+b=\frac{0.76*18000}{5}+300=3036mm\end{cases}$$



$B=2220mm$ $d=C_1\sqrt{\frac{M_{u.l.}}{B*f_{cu}}}$

$$1200=C_1\sqrt{\frac{1227.08*10^6}{2220*30}}$$

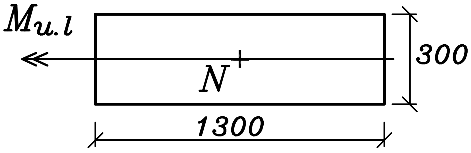
$C_1=8.84$ & $J=0.826$

$$A_s=\frac{1227.08*10^6}{0.826*1200*360}$$

$A_s=3438.82\ mm^2=10\phi22$

Sec. (4-4) $M_{u.l.}=613.48kN.m$ $N_{u.l.}=866.83kN$

$b=300mm$, $t=1300mm$



$$\frac{N_{u.l.}}{btf_{cu}}=\frac{866.83*10^{3}}{300*1300*30}=0.07>0.04 \text{ (Dont neglect } N_{u.l.})$$

$$e=\frac{M_{u.l.}}{N_{u.l.}}=\frac{613.48}{866.83}=0.71m$$

$$\frac{e}{t}=\frac{0.71}{1.30}=0.54 > 0.5 \text{ (big eccentricity)}$$

$$e_s=e+\frac{t}{2}-c=0.71+\frac{1.30}{2}-0.1=1.26m$$

$$M_{us}=866.83*1.26=1090.24kN.m$$

$$1200=C_1\sqrt{\frac{1090.24*10^6}{300*30}} \qquad C_1=3.45 \ \& \ J=0.78$$

$$A_s=\frac{1090.24*10^6}{0.783*1200*360}-\frac{866.83*10^3}{360/1.15}$$

$$A_s=475.75 \ mm^2=3\phi16$$

Check Shear

$$Q_{cr}=Q_{max}-w\left(\frac{c}{2}+\frac{d}{2}\right)$$

$$Q_{cr}=483.20-29.27\left(\frac{1.30}{2}+\frac{1.20}{2}\right)$$

$$Q_{cr}=446.62kN$$

$$q_{su}=\frac{Q_{cr}}{bd}=\frac{446.62*10^3}{300*1200}=1.24 \ N/mm^2$$

$$q_{cu}=0.24\sqrt{\frac{30}{1.5}}=1.07 \ N/mm^2$$

$$q_{max}=0.7\sqrt{\frac{30}{1.5}}=3.13 \ N/mm^2$$

$$q_{cu}<q_u<q_{umax}$$

$$q_u - \frac{q_{cu}}{2} = \frac{nA_s f_y / \gamma_s}{bS}$$

assume $n=2$ $A_s = 78.5mm^2 = \phi 10$

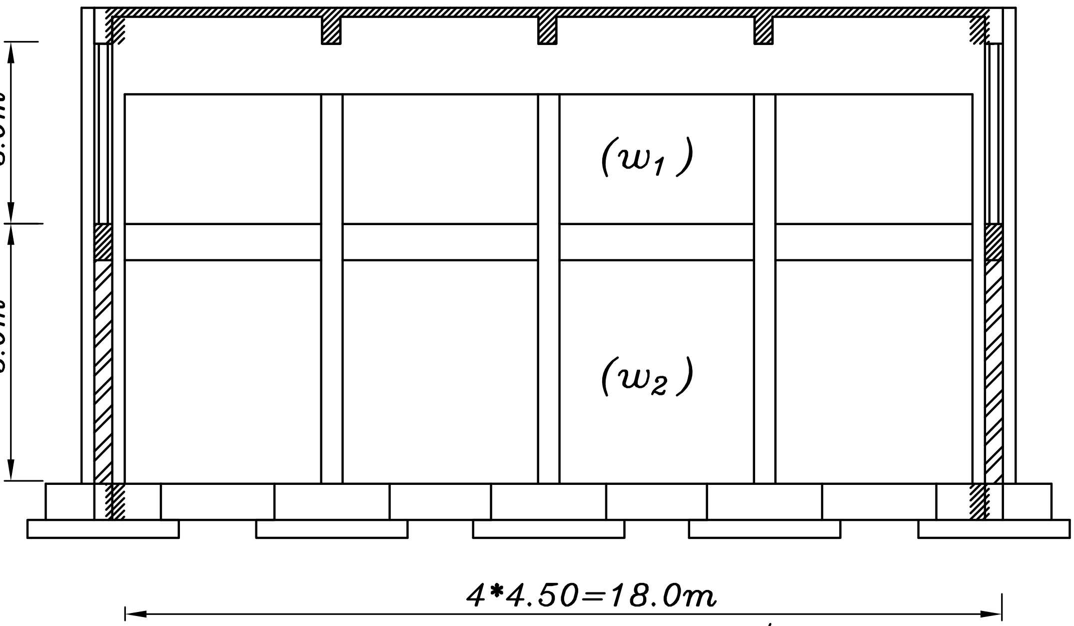
$$1.24 - \frac{1.07}{2} = \frac{2*78.5*240/1.15}{300*S} \Longrightarrow S = 154.92mm$$

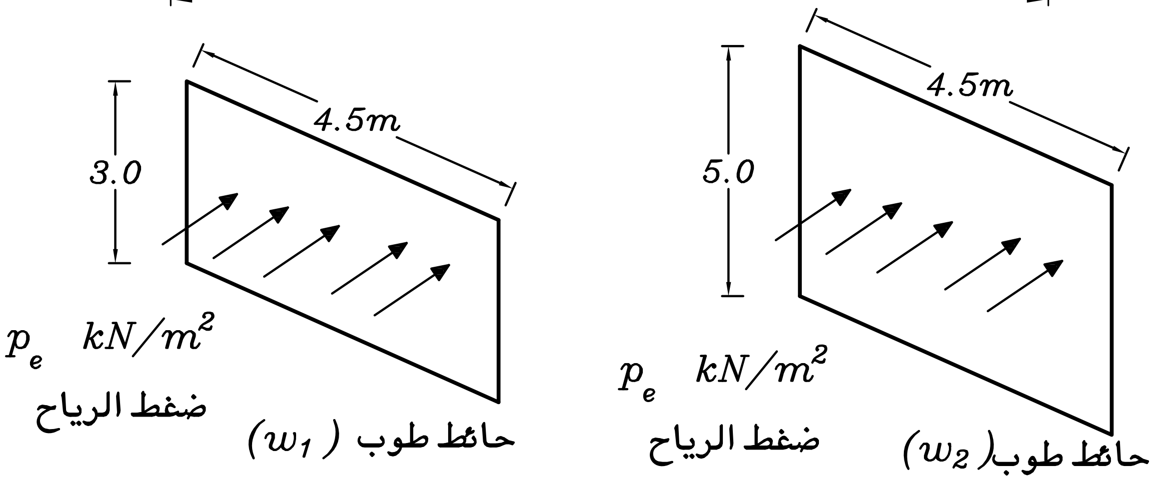
$$No.of\ stirrups/m' = \frac{1000}{S} = 6.5$$

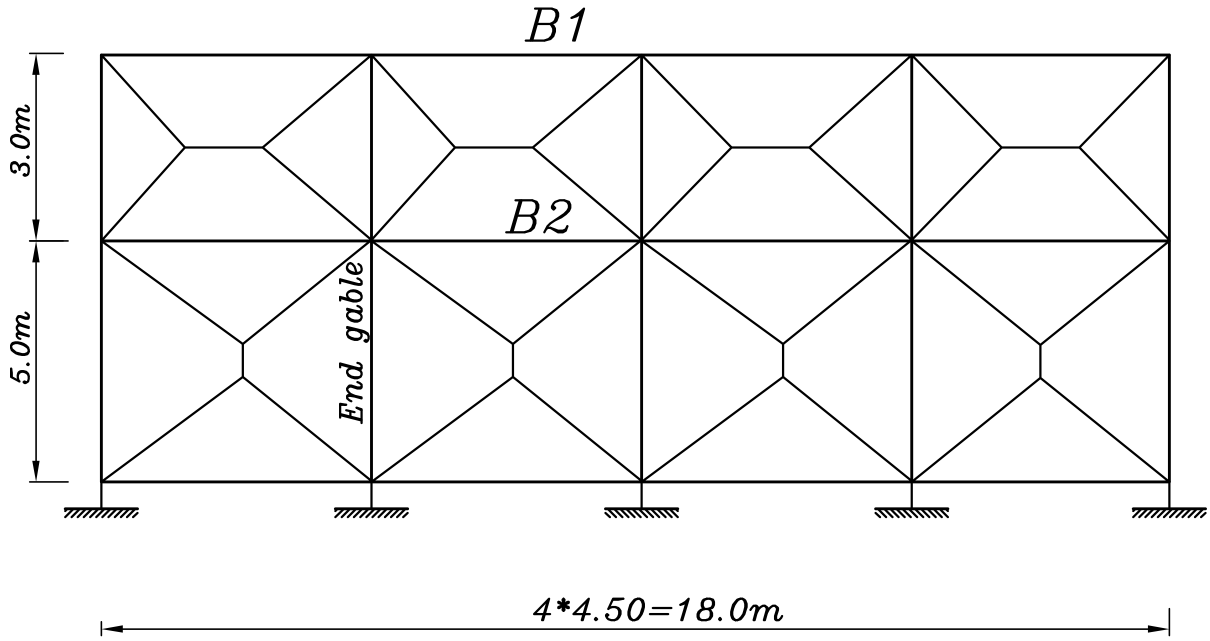
Take Stirrups $7\phi 10/m'$ (2 branches)

– Analysis of end gable:

–Assume case of no future extension



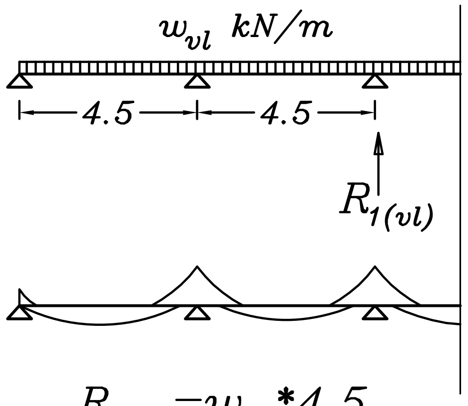




For B1

VL. Load

$w_{vl} = o.w. + \text{Load from slab}$

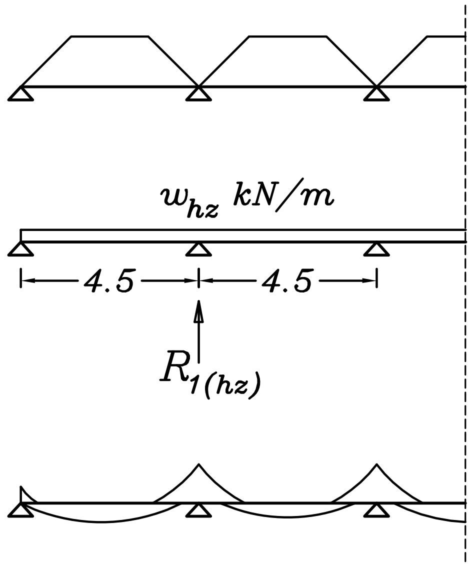


$R_{1(vl)} = w_{vl} * 4.5$

HZ. Load

$w_{hz} = C_a \, p_e \, (\frac{3}{2})$ Load for Shear

$w_{hz} = C_e \, p_e \, (\frac{3}{2})$ Load for Moment

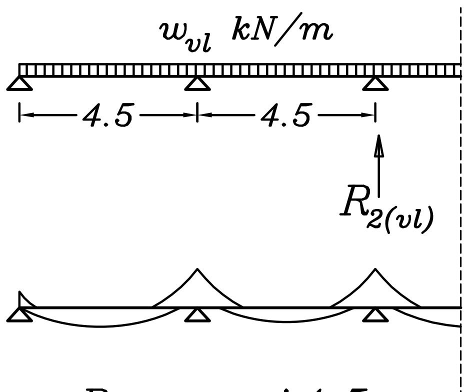


$R_{1(hz)} = w_{hz} * 4.5$

For B2

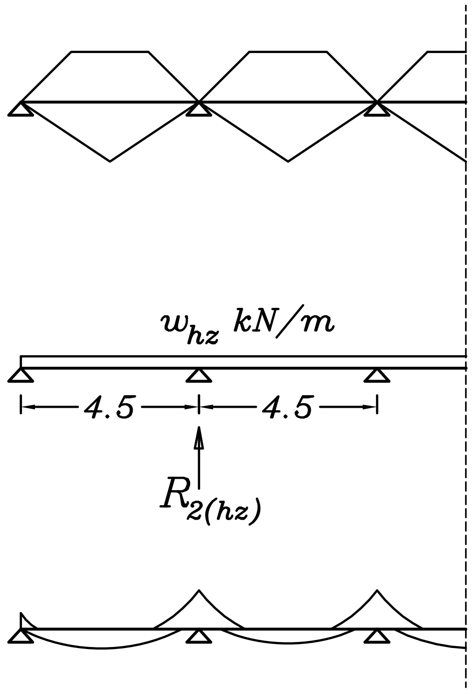
VL. Load

$w_{vl} = o.w. + b_w h_w \gamma_w$



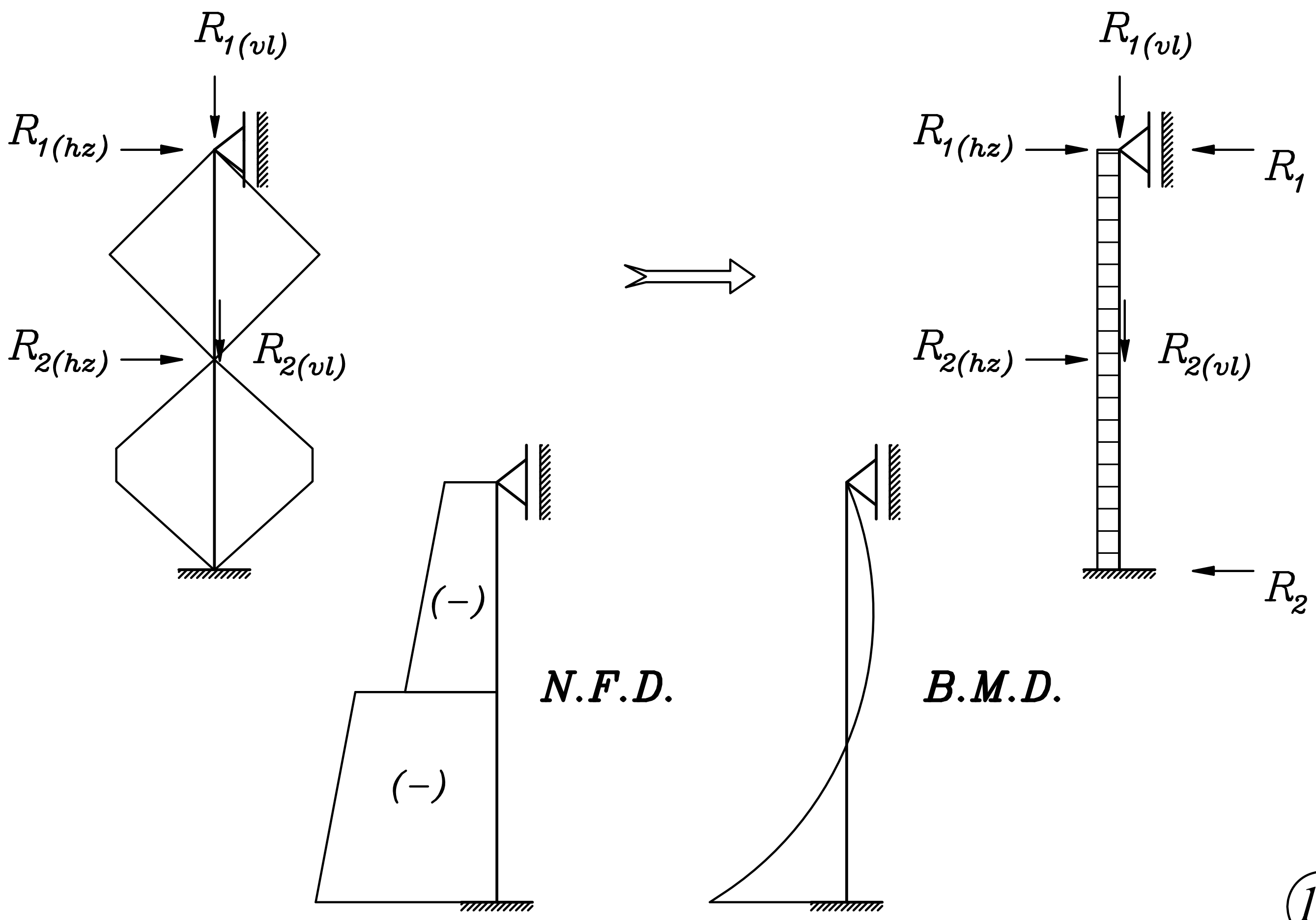
$R_{2(vl)} = w_{vl} * 4.5$

HZ. Load



$R_{2(hz)} = w_{hz} * 4.5$

For End Gable



R.F.T. of the Frame