٦,٥٠

4th Year Civil
Public Works Department
Foundation Engineering
2012 - 2013

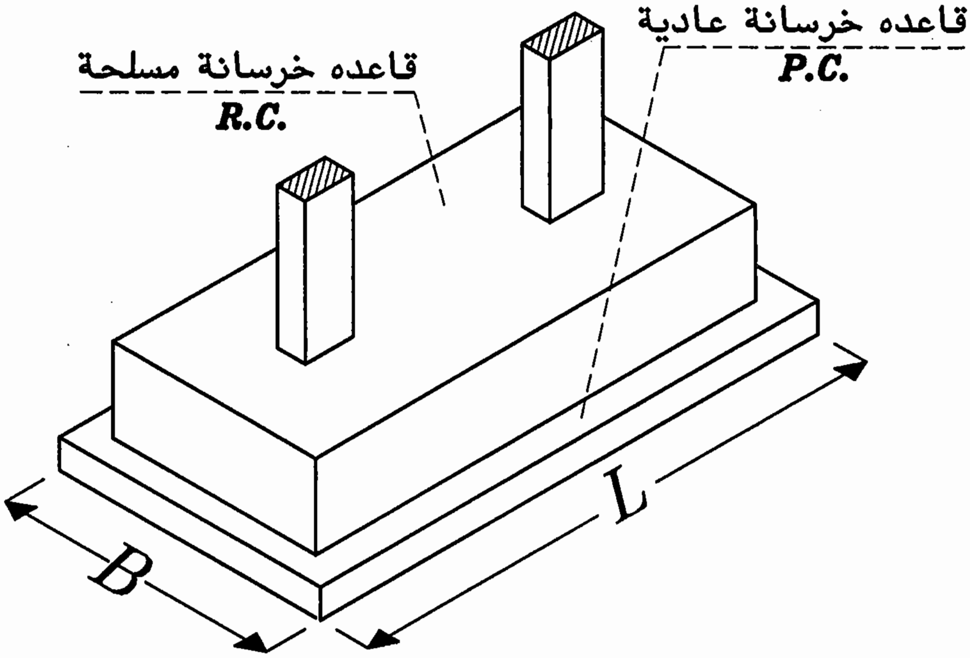
فونديشن رابعه
أشغال (٣)
م/محمود فوزي

3

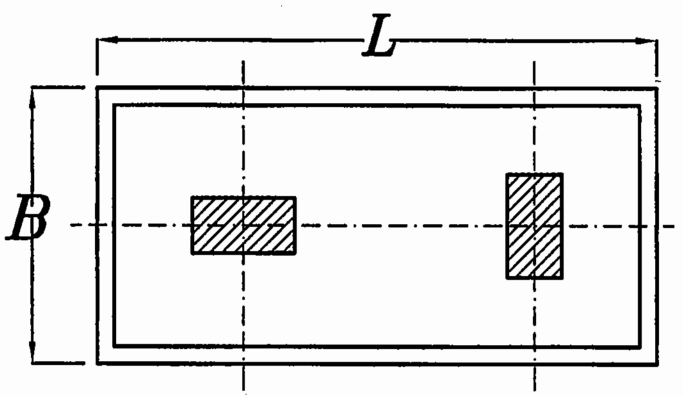
Shallow Foundations
Combined Footing

Design of combined Footing

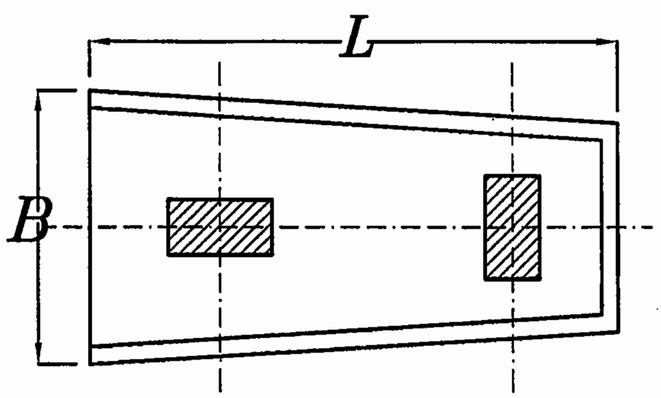
القاعدة المشتركة ***Combined Footing*** هى قاعدة تصمم لتحمل عمودين فقط.



للقواعد المشتركة ***Combined Footings*** نوعان وهم :-



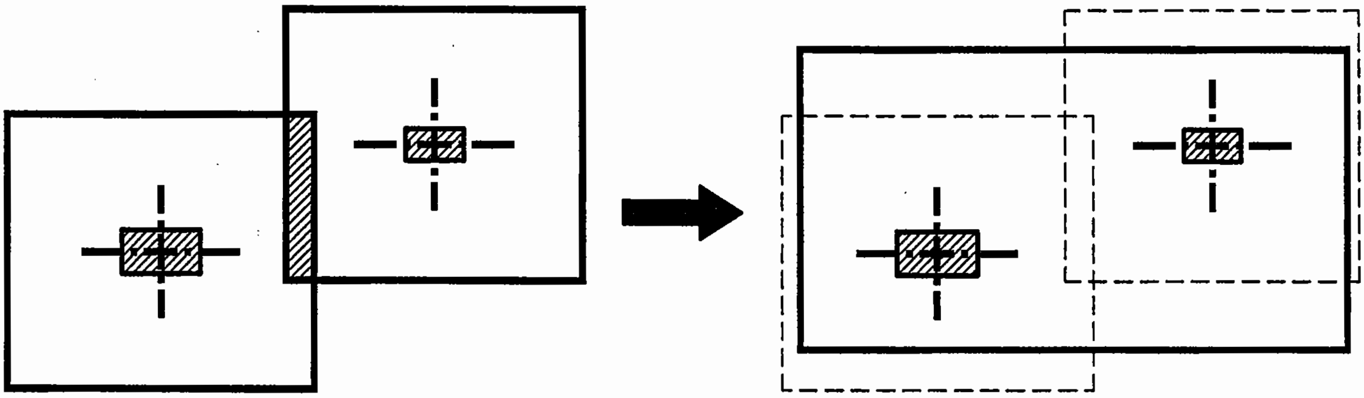
Rectangular



Trapezoidal

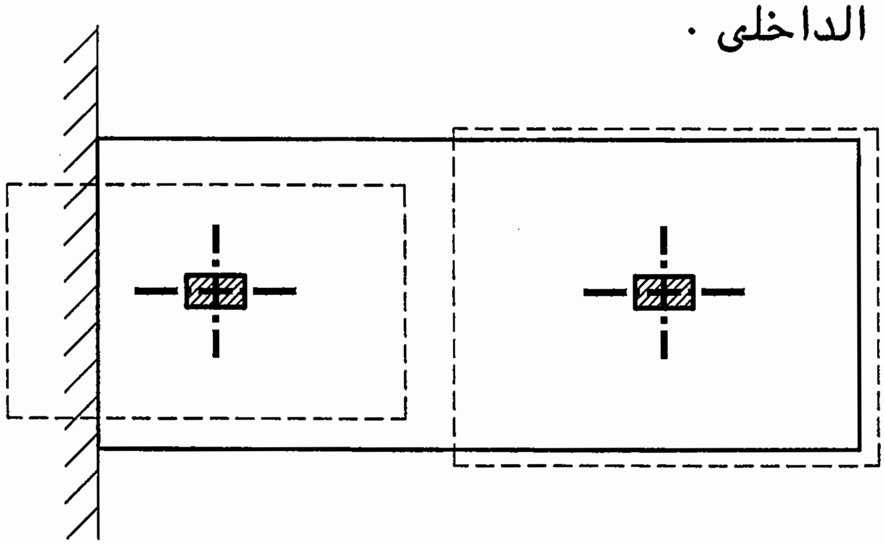
مقدمة تصميم القواعد المشتركة

- عاده نحتاج لعمل قواعد مشتركه عند تداخل أكثر من قاعده منفصله أى عند تحديد أبعاد الـ ***R.C.*** لقاعدتين منفصلتين لعمودين متجاورين و وجد أن القاعدتين سوف يتداخلان معا وهذا يعنى زيادة كبيرة فى الاجهادات فى المنطقة المشتركة بين القاعدتين المنفصلتين لذلك نلجأ لعمل قاعدة مشتركة بين العمودين ٠

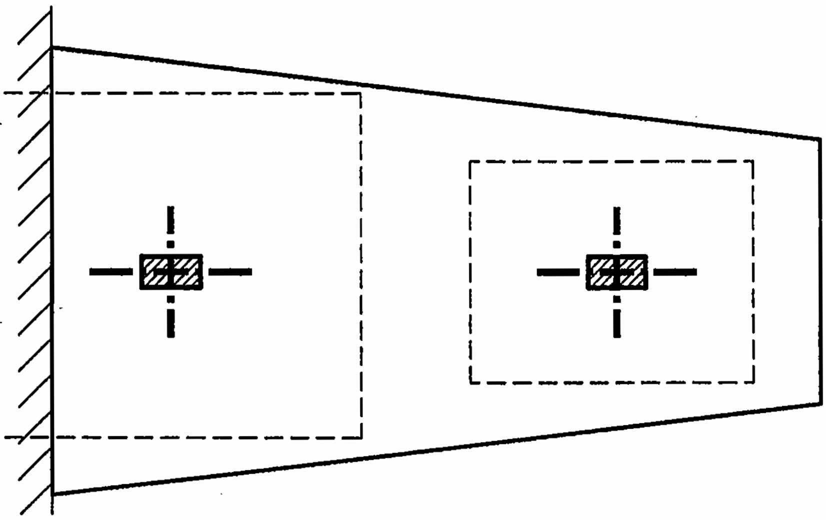


R.C. Isolated Footings ***R.C. Combined Footing***

- فى حالة وقوع جزء من القاعدة المسلحة لعمود داخل حدود الجار نلجأ لعمل قاعدة مشتركة مع أقرب عمود داخلى بجوارة ٠
وتكون القاعدة ***Rectangular*** فى حالة حمل عمود الجار أقل من حمل العمود الداخلى ٠

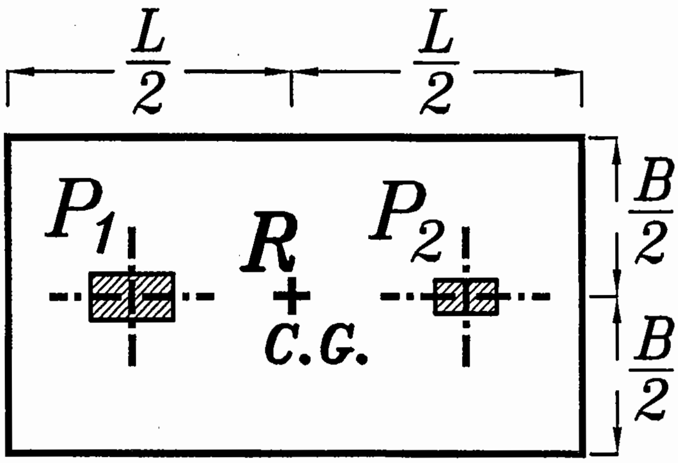


- اذا كان حمل عمود الجار اكبر من حمل العمود الداخلى نكون القاعدة ***Trapezoidal***

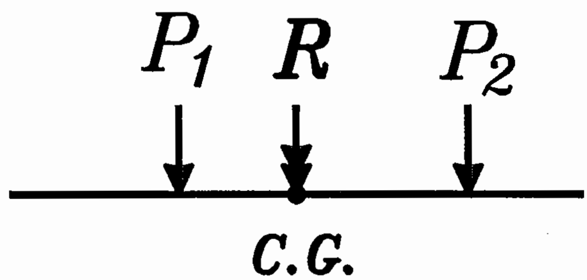


المبدأ الرئيسى لتصميم القواعد المشتركه :-

نحاول قدر المستطاع أن يكون مركز محصلة الاحمال ينطبق على ***C.G.*** القاعده المسلحه حتى يكون على التربه اجهادات منتظمه ***Uniform stresses***



Plan



Steps of design of rectangular combined Footing.

Givens :

P_1 , P_2 = Columns Load

q_{all} = Allowable bearing capacity

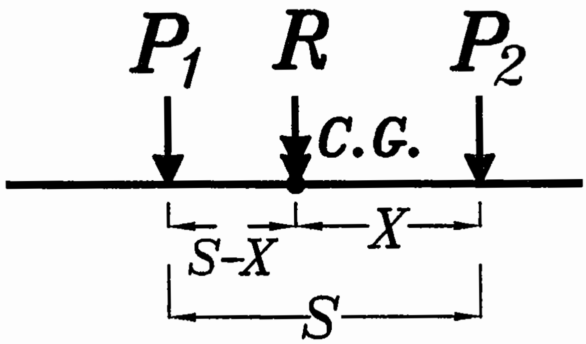
a_1, a_2, b_1, b_2 = Columns Dimensions

$t_{P.C.}$ = Plain concrete thickness

S = Spacing between columns

F_{cu} , F_y

1- Calculate the Footing Dimensions :



R يتم حساب قيمه محصله الاحمال

$$R = P_1 + P_2$$

X يتم تحديد مكان محصله الاحمال
عن طريق اخذ العزوم عند العمود ذو
الحمل الاقل P_2.

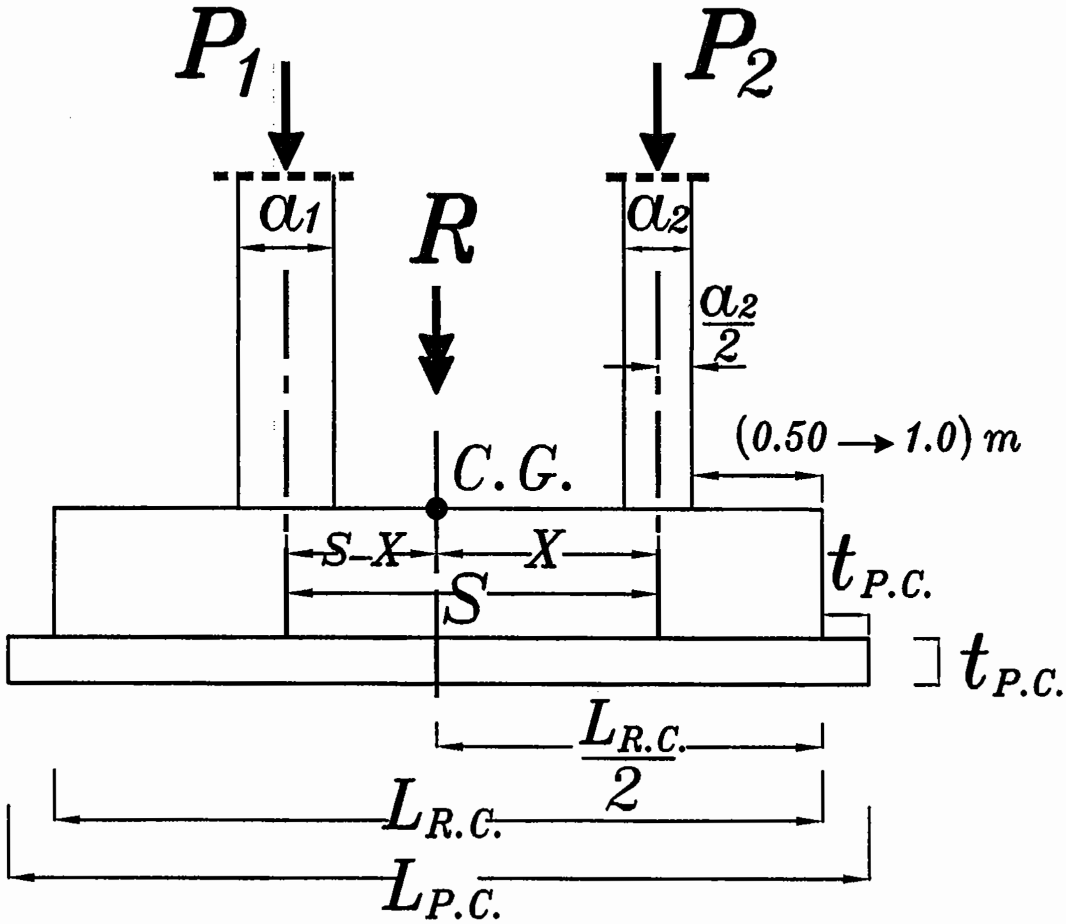
$$P_1 > P_2$$

$$R * X = P_1 * S \longrightarrow X = \frac{P_1}{R} * S$$

ملحوظه مهمة جدا

المسافة X هى المسافة بين المحصلة R وأقل حمل عمود .

المحصلة R تكون اقرب للعمود ذات الحمل الاكبر .



نأخذ طول القاعده المسلحه بحيث تكون نهايتها بعد وش العمود الخارجى بمسافه $(0.50\, m \rightarrow 1.0\, m)$ من جهه الحمل الاصغر .

مثلا فى هذا المثال P_2 هو الاصغر .

$$\frac{L_{R.C.}}{2} = (X) + \frac{a_2}{2} + (0.50 \rightarrow 1.0)\, m \longrightarrow \boxed{L_{R.C.} = \checkmark}$$

$$\boxed{L_{P.C.} = L_{R.C.} + 2\, t_{P.C.}}$$

IF $t_{P.C.} \geq 20\ cm$

$$A_{P.C.} = \frac{R_w}{q_{all}} = B_{P.C.} * L_{P.C.} \longrightarrow \boxed{B_{P.C.} = \checkmark}$$

$$\boxed{B_{R.C.} = B_{P.C.} - 2\, t_{P.C.}}$$

IF $t_{P.C.} < 20$ cm

$$A_{R.C.} = \frac{R_w}{q_{all}} = B_{R.C.} * L_{R.C.} \longrightarrow \boxed{B_{R.C.} = \checkmark}$$

$$\boxed{B_{P.C.} = B_{R.C.} + 2\ t_{P.C.}}$$

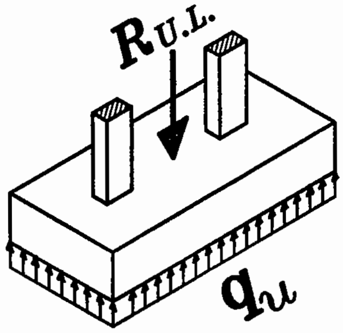
2- Design of Footing in longitudinal direction :

يجب تحويل جميع الاحمال الى **ultimate loads** قبل البدء فى حساب العزوم .

$$P_{1\,U.L.} = 1.5 * P_{1w} \quad , \quad P_{2\,U.L.} = 1.5 * P_{2w} \quad , \quad R_{U.L.} = 1.5 * R_w$$

Ultimate uniform stress on R.C. Footing

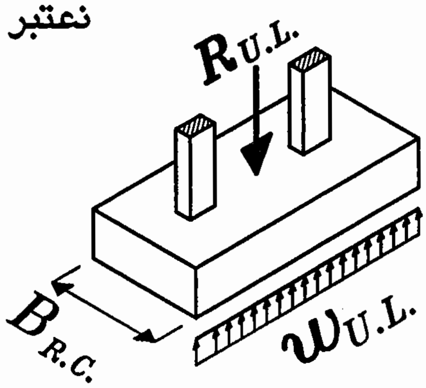
$$q_u = \frac{R_{U.L.}}{B_{R.C.} * L_{R.C.}} \quad (kN/m^2)$$



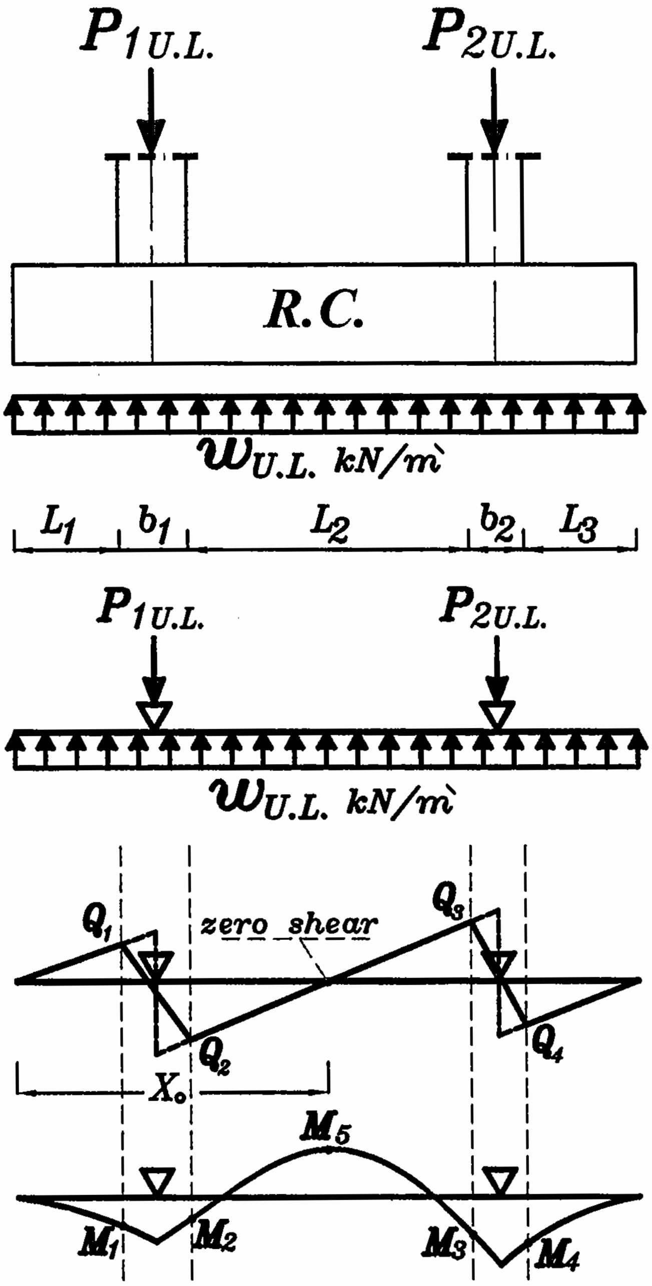
Ultimate Uniform Load on R.C. Footing

نعتبر أن القاعده عباره عن كمره مقلوبة بعرض $B_{R.C.}$

$$w_{U.L.} = \frac{R_{U.L.}}{L_{R.C.}} \quad (kN/m')$$



نقوم بعد ذلك برسم ال **BMD & SFD** كأنها كمرة عرضها $B_{R.C.}$.



يتم حساب قيم *B.M.* ، *S.F.*
على وش الاعمده .

لتحديد أكبر **moment** فى منتصف القاعدة M_3 يتم تحديد مكان نقطة **zero shear** أى حساب المسافه X_o

$$P_{1U.L.} = w_{U.L.} * X_o$$

$$X_o = \checkmark \longrightarrow \quad M_5 = \checkmark$$

Calculations :

$$Q_1 = w_u * l_1$$

$$Q_2 = P_{1UL} - w_u(l_1 + b_1)$$

$$Q_3 = P_{2UL} - w_u(l_3 + b_2)$$

$$Q_4 = w_u * l_3$$

$$M_1 = w_u * \frac{(l_1)^2}{2}$$

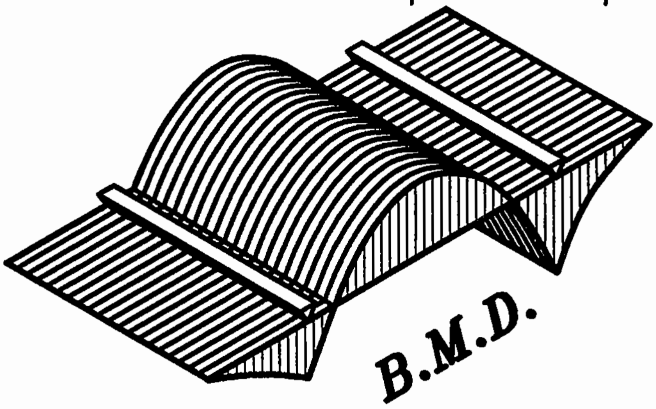
$$M_2 = w_u * \frac{(l_1 + b_1)^2}{2} - P_{1UL} * \frac{b_1}{2}$$

$$M_3 = w_u * \frac{(l_3+b_2)^2}{2} - P_{2_{UL}} * \frac{b_2}{2}$$

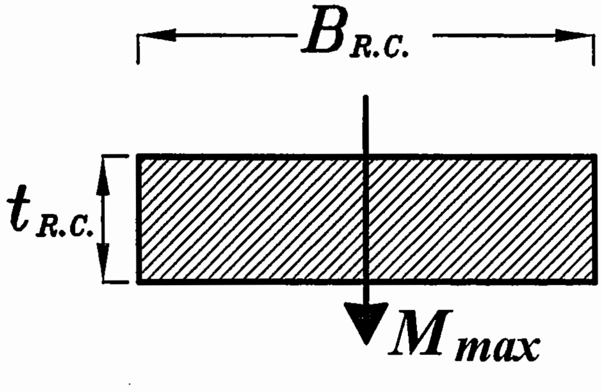
$$M_4 = w_u * \frac{(l_3)^2}{2}$$

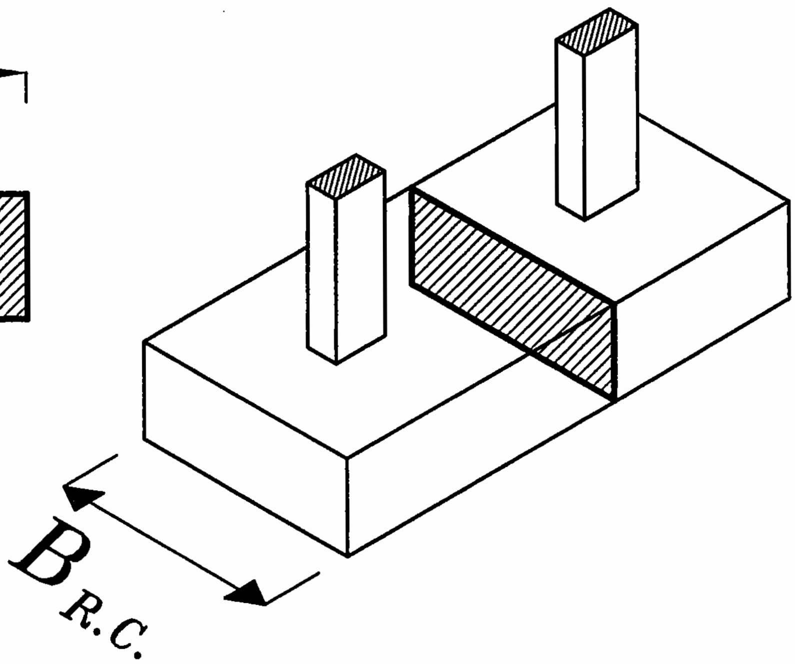
$$M_5 = P_{1_{UL}} \left[X_\circ - \left(l_1 + \frac{b_1}{2} \right) \right] - w_u * \frac{(X_\circ)^2}{2}$$

فى الامتحان تتم جميع الحسابات السابقة على الالة الحاسبة بسرعة ودقة ونكتفى فقط بكتابة القيم على الرسم لتوفير الوقت .



M_{max} *is the biggest moment of* M_1, M_2, M_3, M_4, M_5





$$d_{(mm)} = C_1 \sqrt{\frac{M_{max\,(kN.m)} * 10^6}{F_{cu\,(N/mm^2)} * B_{R.C.\,(mm)}}}$$

Choose $C_1 = (3.5 \rightarrow \boxed{5.0})$

Get $d = \checkmark\checkmark$ (mm)

Take **cover** = 70 mm

$t_{R.C.} = d$ + **cover** (70 mm)

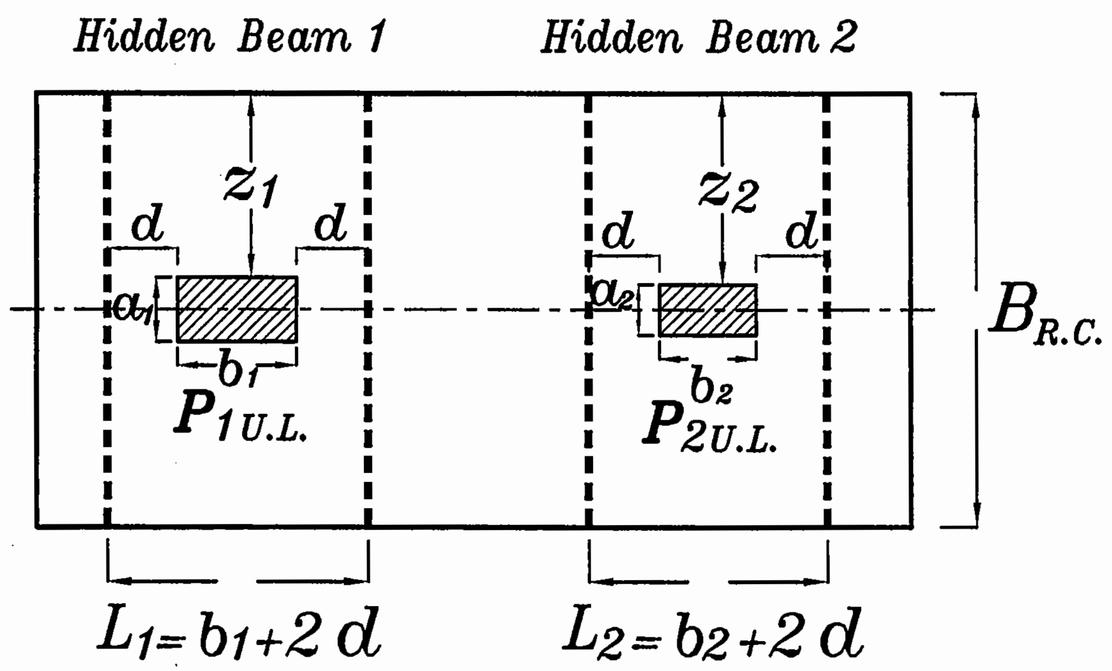
تقرب لاقرب ٥٠ مم بالزياده

Check depth in Transverse direction. (Short direction.)

As a Hidden Beam.

نعتبر القاعده أسفل كل عمود كأنها كمره مدفونه (***Hidden Beam***)

أبعادها أسفل العمود $L * B_{R.C.}$



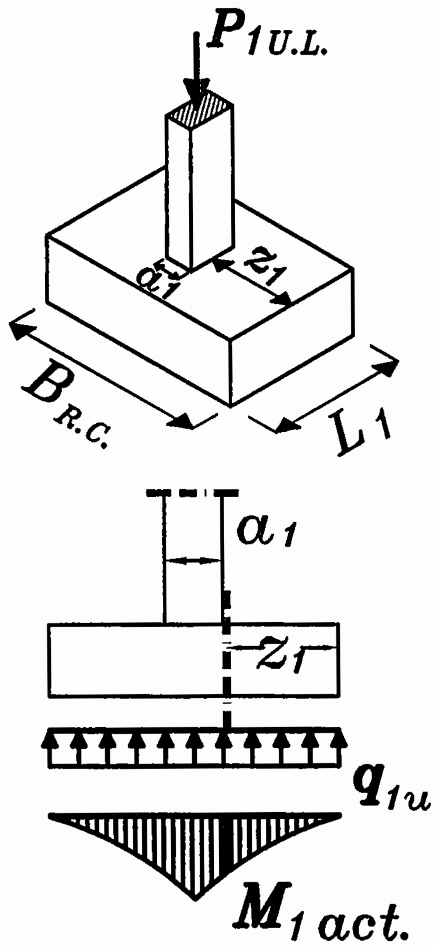
Hidden Beam 1

$$q_{1u} = \frac{P_{1\,U.L.}}{B_{R.C.} * L_1} \quad (kN/m^2)$$

$$Z_1 = \frac{B_{R.C.} - a_1}{2} \quad (m)$$

$$M_{1act.} = (q_{1u} * Z_1 * 1.0\,m)\ \frac{Z_1}{2}$$

$(kN.m/1.0\,m)$



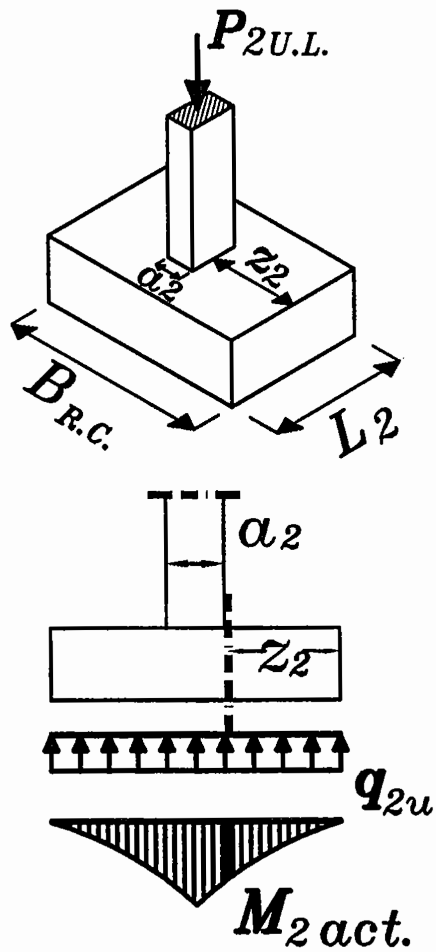
Hidden Beam 2

$$q_{2u} = \frac{P_{2\,U.L.}}{B_{R.C.} * L_2} \quad (kN/m^2)$$

$$Z_2 = \frac{B_{R.C.} - a_2}{2} \quad (m)$$

$$M_{2act.} = (q_{2u} * Z_2 * 1.0\,m)\ \frac{Z_2}{2}$$

$(kN.m/1.0\,m)$



Choose M_{bigger} The bigger value of $M_{1act.}$ & $M_{2act.}$

$$d = C_1 \sqrt{\frac{M_{bigger} * 10^6}{F_{cu} * 1000}} \xrightarrow{Get} C_1$$

Then Check on $C_1 \not< 2.8$

IF $C_1 < 2.8 \longrightarrow$ take $C_1 = 2.8$

and Calculate d

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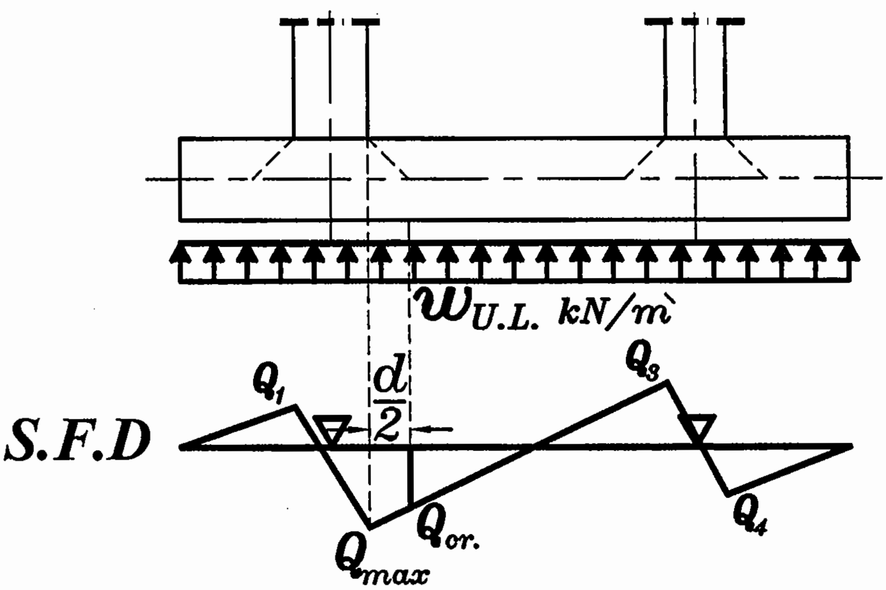
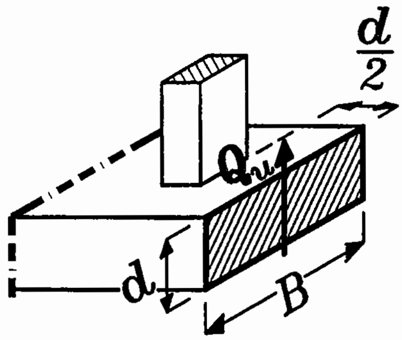
3 – Check Shear. at long direction

$Q_{max.}$ القطاع الحرج على بعد $d/2$ من وش العمود اللى عنده



$$Q_{cr.} = Q_{max.} - w_{U.L.} * \frac{d}{2}$$

$$q_{su} = \frac{Q_{cr.\,(kN)} * 10^3}{B\,(mm) * d\,(mm)} \quad (N/mm^2)$$



$$q_{scu} = 0.16 \sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$

IF $q_{su} \leqslant q_{scu} \longrightarrow$ *Safe shear stresses*

IF $q_{su} > q_{scu} \longrightarrow$ *UnSafe shear stresses*
We have to increase dimensions.

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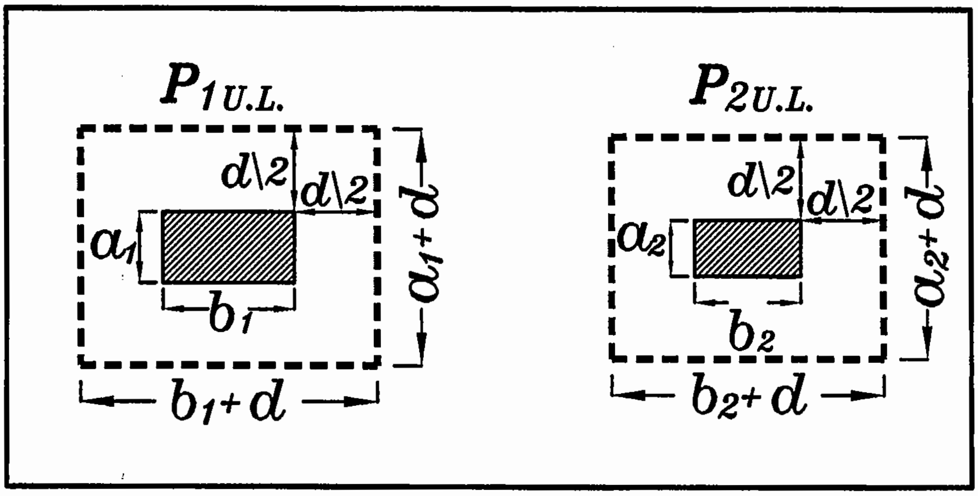
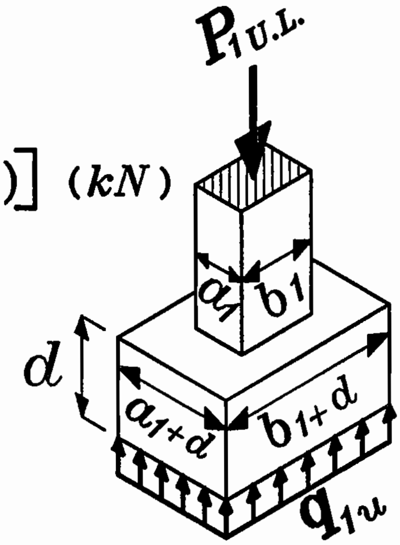
4 – Check Punching Shear.



Column 1

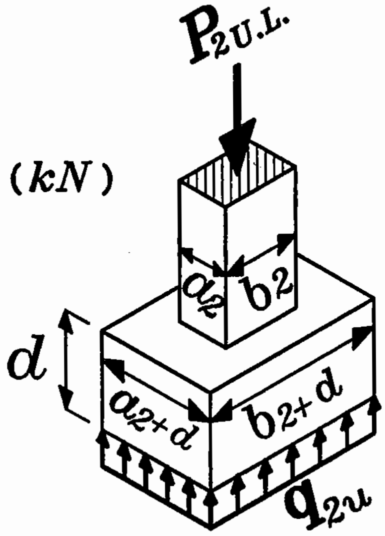


$$Q_{pu1} = P_{1\,U.L.} - (q_{1u}) \left[(a_1+d)(b_1+d)\right] \quad (kN)$$

$$A_{1p} = \underbrace{\left[2(a_1+d) + 2(b_1+d)\right]}_{\text{المحيط}} * \underbrace{d}_{\text{العمق}} \quad (mm^2)$$

$$q_{pu1} = \frac{Q_{pu1}(kN) * 10^3}{[2(a_1+d)+2(b_1+d)] * d \ (mm^2)} \quad (N/mm^2)$$

Column 2



$$Q_{pu2} = P_{2\,U.L.} - (q_{2u})\,[(a_2+d)(b_2+d)] \quad (kN)$$

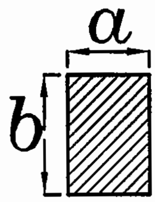
$$A_{2p} = [2(a_2+d)+2(b_2+d)] * d$$

المحيط — العمق

(mm^2)

$$q_{pu2} = \frac{Q_{pu2}(kN) * 10^3}{[2(a_2+d)+2(b_2+d)] * d \ (mm^2)} \quad (N/mm^2)$$

Choose q_{pumax} the bigger value of q_{pu1} & q_{pu2}



$$q_{pcu} = 0.316\left(0.5+\frac{a}{b}\right)\sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$$

IF $\left(0.5+\frac{a}{b}\right) \geq 1.0 \xrightarrow{\text{Take}} q_{pcu} = 0.316\sqrt{\frac{F_{cu}}{\gamma_c}} \quad (N/mm^2)$

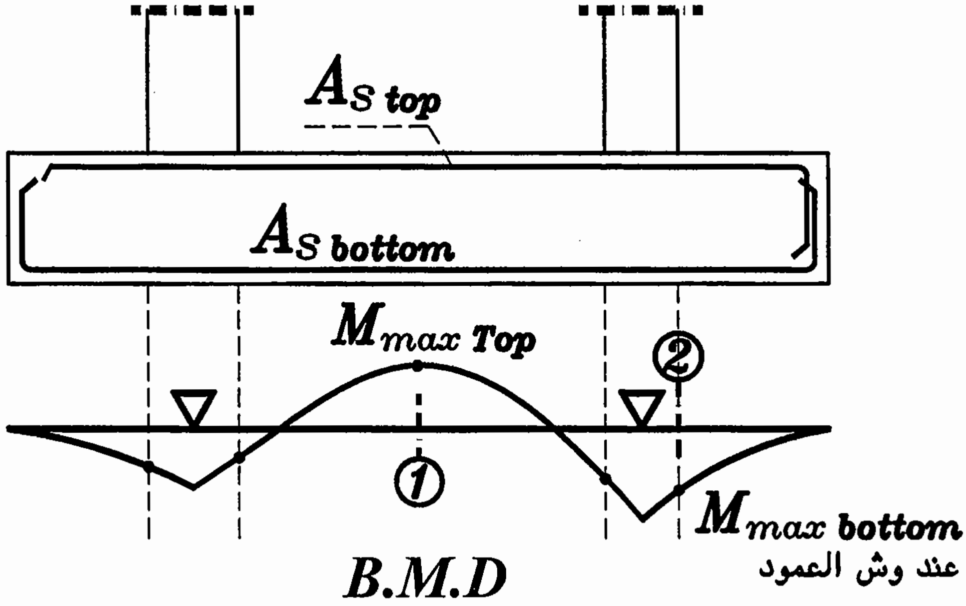
ال a , b يكونان للعمود اللى عنده اكبر اجهاد للقص الثاقب q_{pumax}

IF $q_{pumax} \leq q_{pcu} \longrightarrow$ **Safe punching shear.**

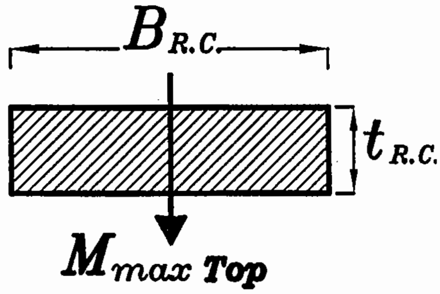
IF $q_{pumax} > q_{pcu} \longrightarrow$ **UnSafe punching shear.**
We have to increase dimensions.

5- Reinforcement of the Footing.

Longitudinal direction.



Sec. ①

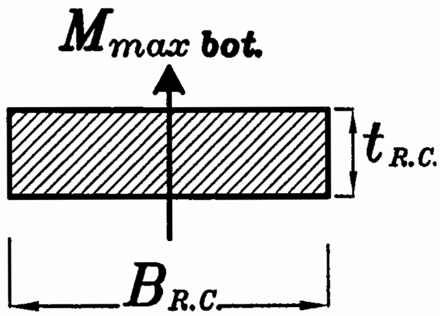


From $d = C_1 \sqrt{\dfrac{M_{max\ Top}}{F_{cu} * B_{R.C.}}}$

Get $C_1 \longrightarrow J$

$$A_{S\ top} = \frac{M_{max\ Top}}{J\ F_y\ d}\ (mm^2) \geqslant A_{S\ min}$$

Sec. ②



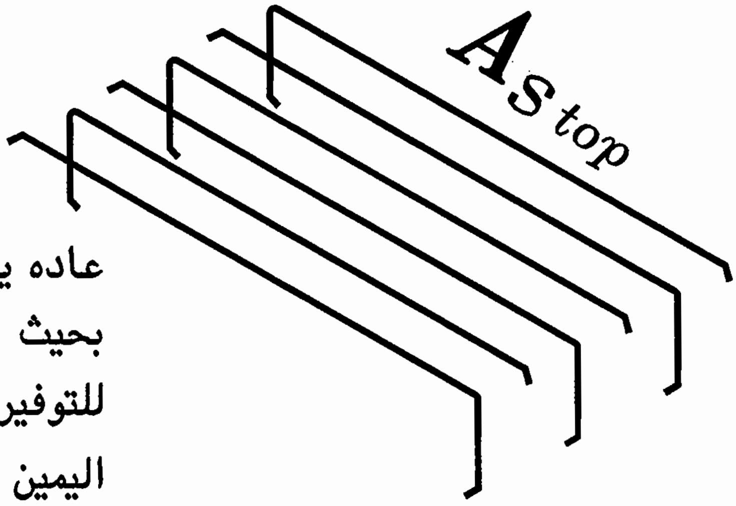
From $d = C_1 \sqrt{\dfrac{M_{max\ bot.}}{F_{cu} * B_{R.C.}}}$

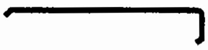
Get $C_1 \longrightarrow J$

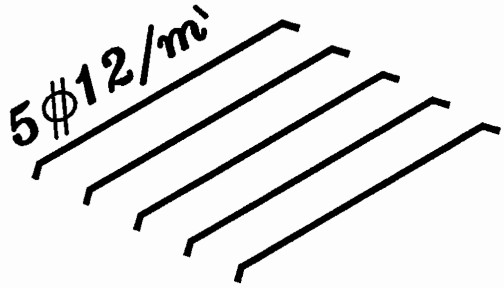
$$A_{S\ bot.} = \frac{M_{max\ bot.}}{J\ F_y\ d}\ (mm^2) \geqslant A_{S\ min}$$

Check $A_s \geq A_{s_{min}}$

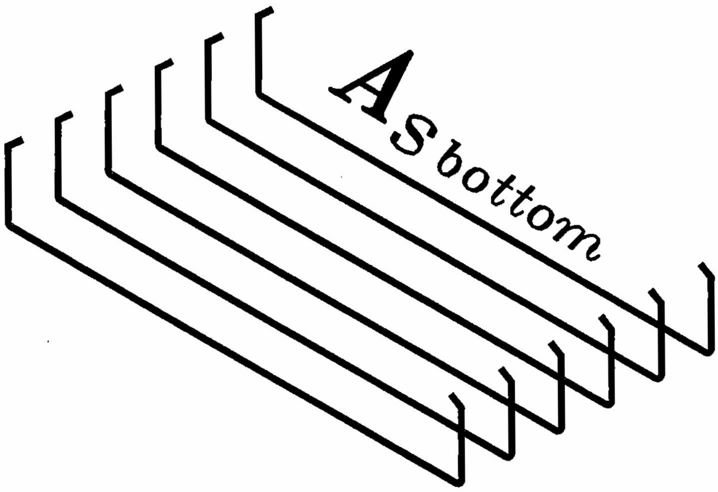
$$A_{s_{min}} \; (mm^2/m) = \begin{cases} 1.5\,d \; (mm) \\ 5\phi 12/m' \end{cases} \text{الأكبر}$$



عاده يتم رص الحديد العلوى فى القواعد
بحيث يتم عمل ركبه من جهه واحده فقط
للتوفير بحيث تكون الركبه مره من جهه
اليمين  و السيخ التالى تكون
الركبه جهه اليسار 

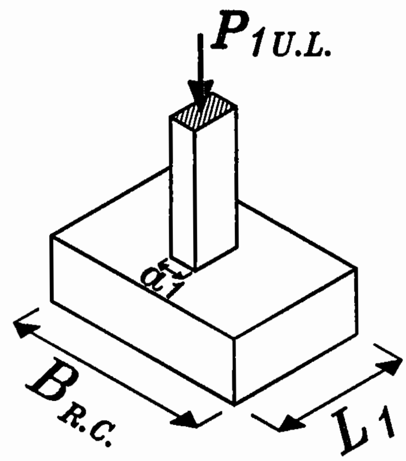


يوضع تسليح علوى ثانوى قيمته $5\phi 12/m'$



الحديد السفلى فى القواعد
يفضل أن يتم عمل ركبه من الجهتين

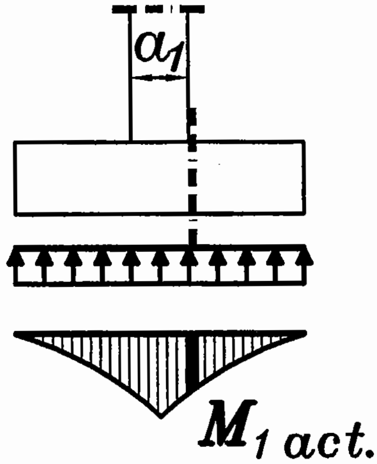
Transverse direction. Short direction.



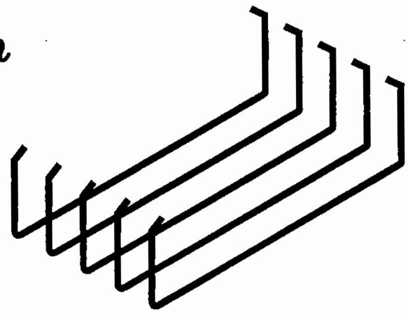
Hidden Beam 1

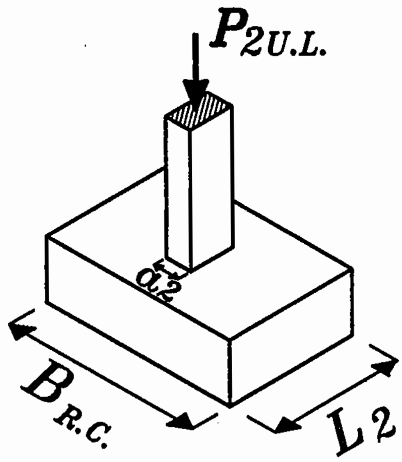
$$d = C_1 \sqrt{\frac{M_{1act.}}{F_{cu} * 1000}} \qquad C_1 \longrightarrow J$$

$$A_{S1} = \frac{M_{1act.}}{J\, F_y\, d} \qquad (mm^2/m')$$



Check $A_{s\,min}$

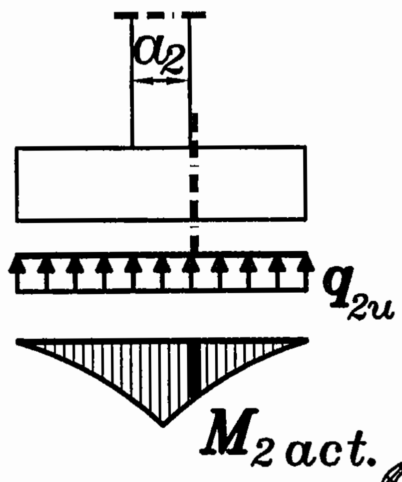




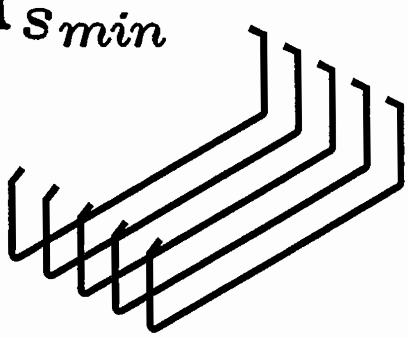
Hidden Beam 2

$$d = C_1 \sqrt{\frac{M_{2act.}}{F_{cu} * 1000}} \qquad C_1 \longrightarrow J$$

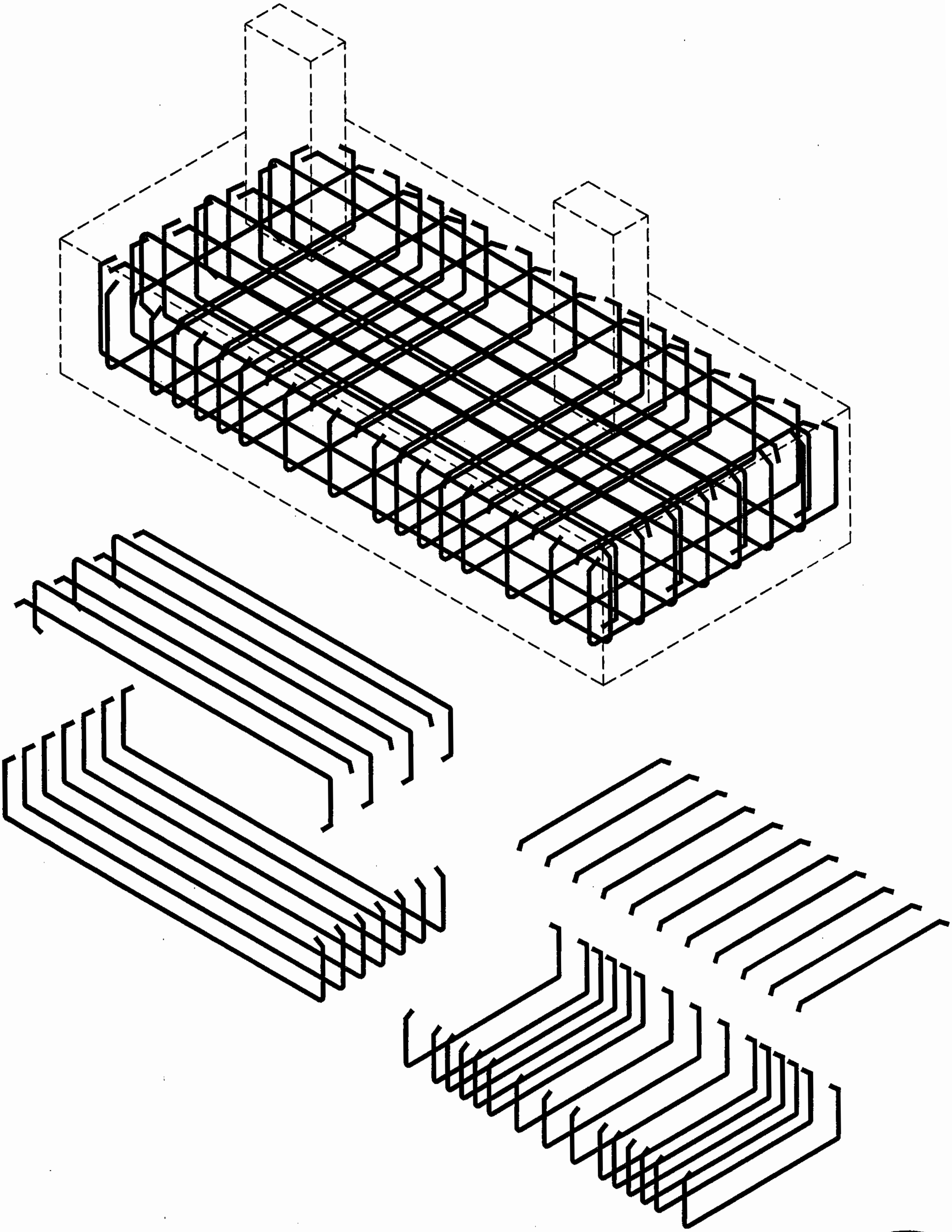
$$A_{S2} = \frac{M_{2act.}}{J\, F_y\, d} \qquad (mm^2/m')$$

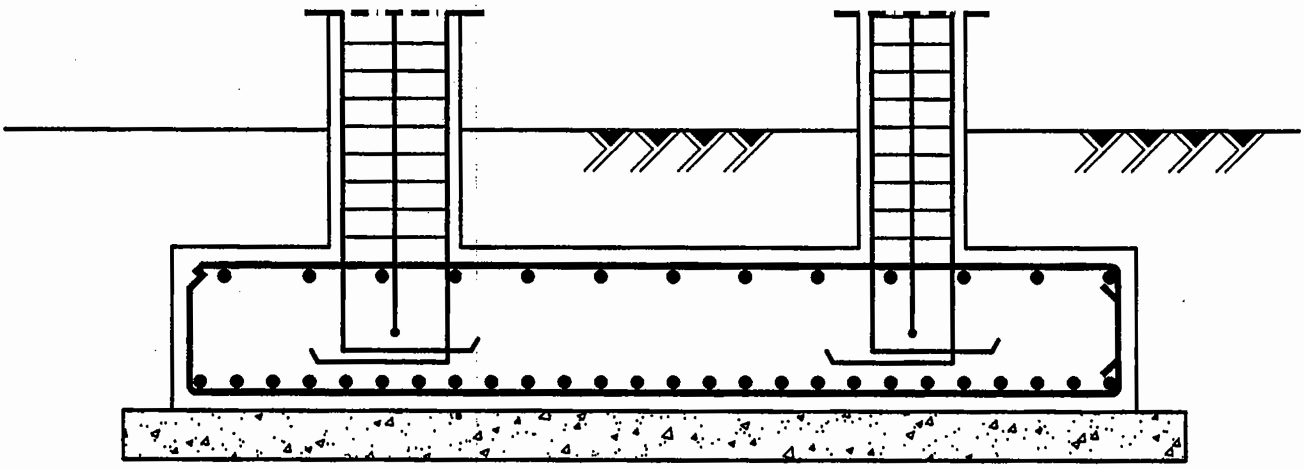


Check $A_{s\,min}$

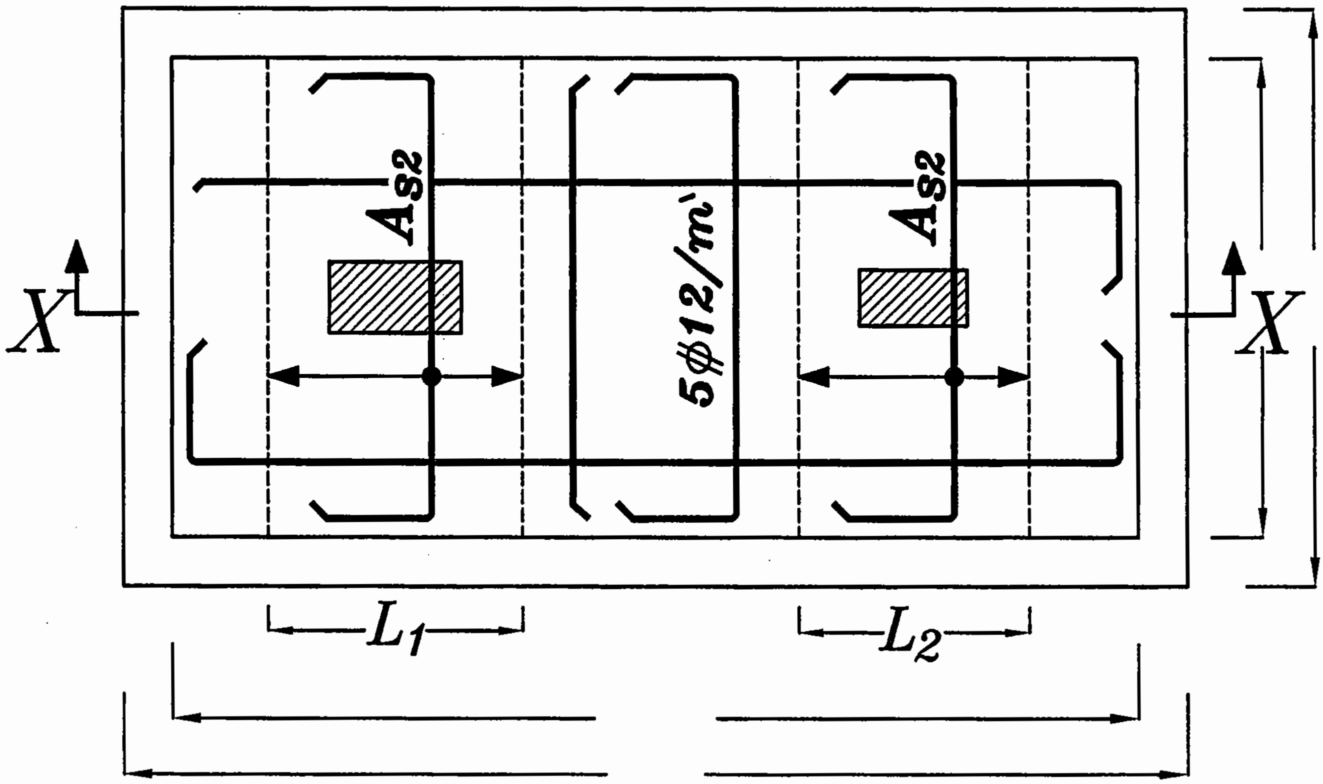


6 – Details of Reinforcement.





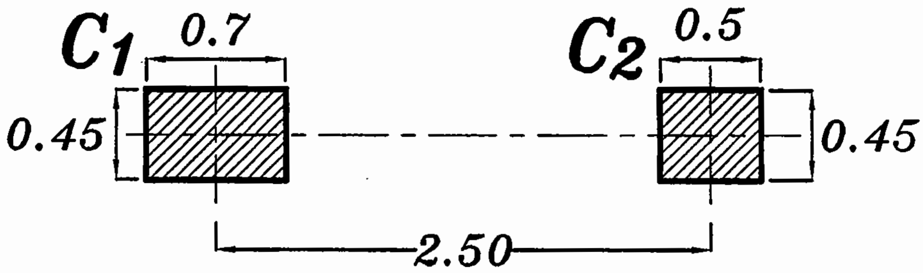
Sec X–X



Plan

Example (1):

*It is required to design Footings to support a R.C. column C_1 (45 * 70) cm. and carrying working load **2400 kN** and column C_2 (45 * 50) cm. and carrying working load **1800 kN** the spacing between the C.L. of the two columns is **2.50 m** as shown*



and the allowable net bearing capacity in the Footing site is **150 kN/m²**. ($F_{cu} = 25$ N/mm², $F_y = 360$ N/mm²).
and draw details of RFT. to scale **1:50**

Solution:

Data given:

Column C_1 dimensions (450 * 700) mm

P_1 (working) = 2400 kN $\quad$ P_1 (U.L.) = 2400 * 1.5 = 3600 kN

Column C_2 dimensions (450 * 500) mm

P_2 (working) = 1800 kN $\quad$ P_2 (U.L.) = 1800 * 1.5 = 2700 kN

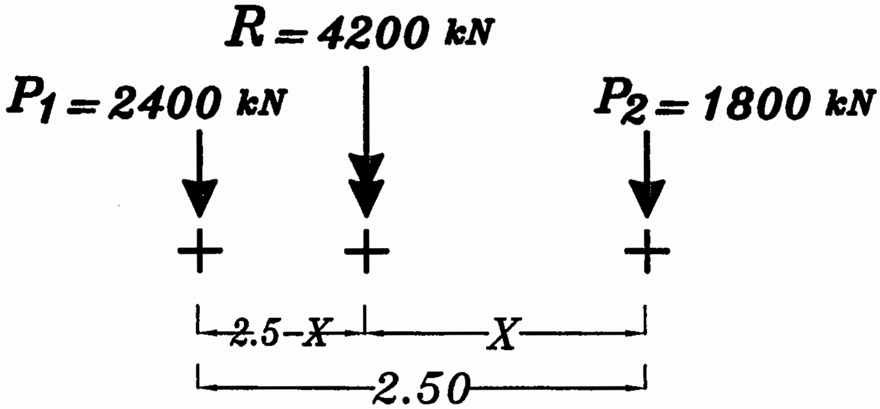
$R_{(working)} = P_1 + P_2 = 4200$ kN

$R_{(U.L.)} = 1.5 * 4200 = 6300$ kN

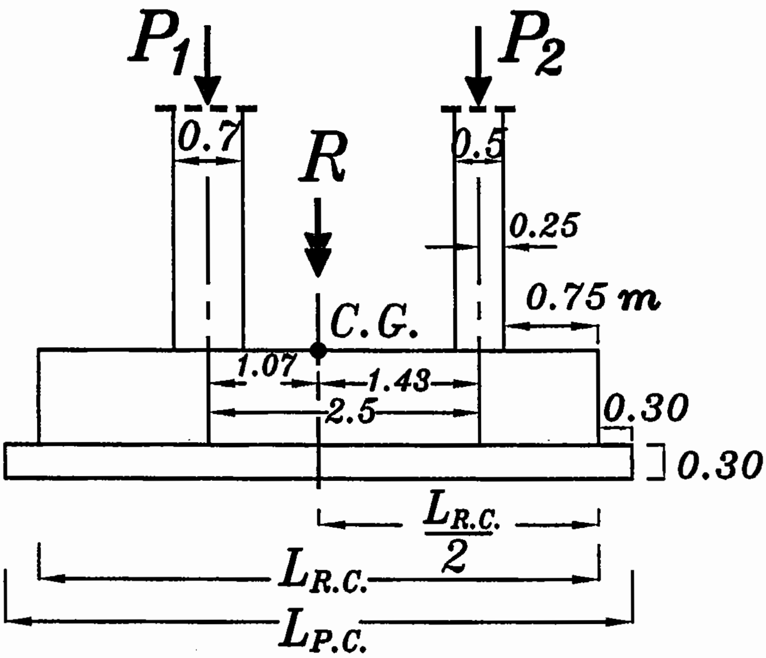
Bearing capacity of the soil = $q_{all} = 150$ kN/m²

$F_{cu} = 25$ N/mm² $\quad$ $F_y = 360$ N/mm²

1– Calculate the Footing area. *(Width & Length of R.C. Footing.)*



$$X = \frac{P_1}{R} * S = \frac{2400}{4200} * 2.5 = 1.43\ m$$



$$\frac{L_{R.C.}}{2} = (X) + \frac{a_2}{2} + (0.50 \rightarrow 1.0)\ m$$

$$\frac{L_{R.C.}}{2} = (1.43) + \frac{0.5}{2} + 0.75 \longrightarrow L_{R.C.} = 4.86$$

$$\boxed{L_{R.C.} = 4.90\,m}$$

$$L_{P.C.} = L_{R.C.} + 2\,t_{P.C.} = 4.90 + 2(0.3) = 4.80\,m$$

$$\boxed{L_{P.C.} = 5.50\,m}$$

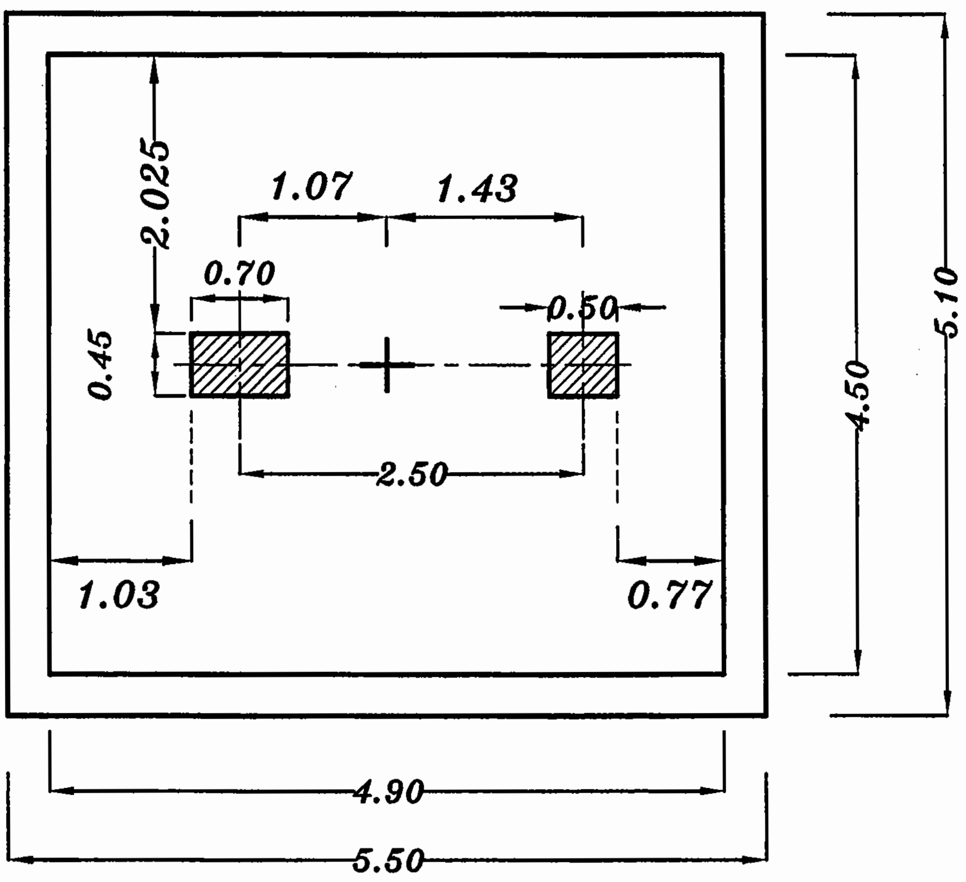
$$A_{P.C.} = \frac{R_w}{q_{all}} = \frac{4200}{150} = 28.0\ m^2$$

$$A_{P.C.} = 28.0 = B_{P.C.} * L_{P.C.} = B_{P.C.} * 5.50 \longrightarrow B_{P.C.} = 5.09\ m$$

$$\boxed{B_{P.C.} = 5.10\ m}$$

$$\boxed{B_{P.C.} = 5.10\ m} \qquad \boxed{L_{P.C.} = 5.50\ m}$$

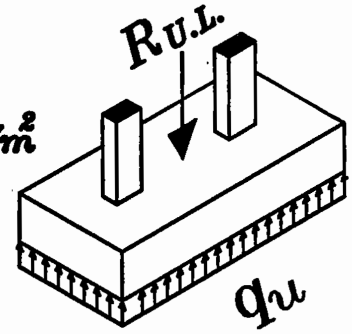
$$\boxed{B_{R.C.} = 4.50\ m} \qquad \boxed{L_{R.C.} = 4.90\ m}$$



2– Design the critical sections For moment. (Depth of R.C. Footing.)

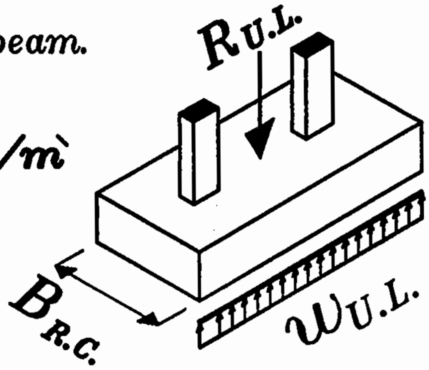
– Actual Normal stress on R.C. Footing (U.L.)

$$q_u = \frac{R_{U.L.}}{B_{R.C.} * L_{R.C.}} = \frac{6300}{4.5 * 4.9} = 285.7 \text{ kN/m}^2$$



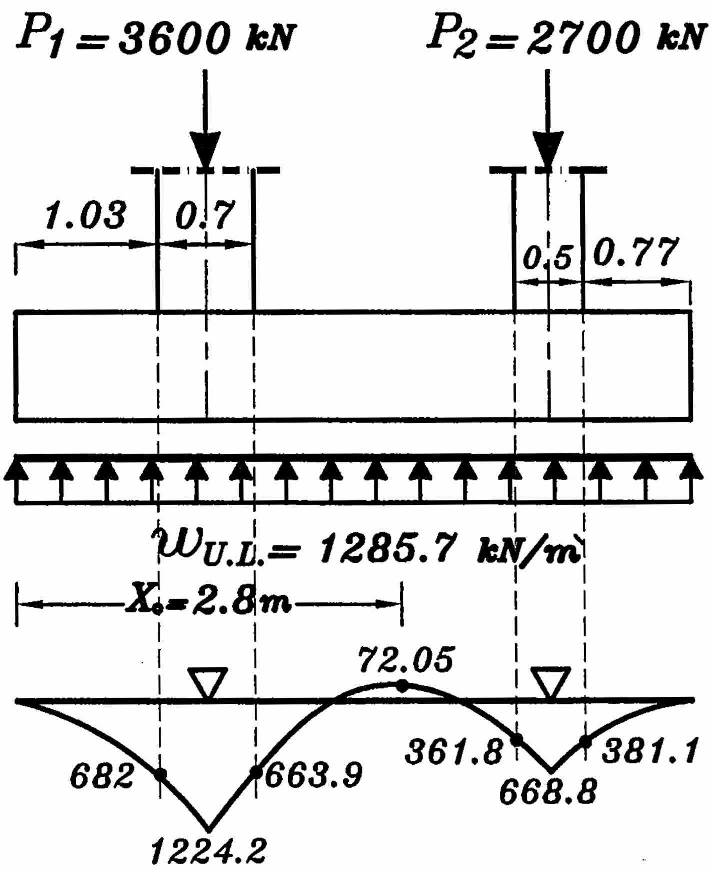
– Actual Uniform Load on R.C. Footing (U.L.) as a beam.

$$w_{U.L.} = \frac{R_{U.L.}}{L_{R.C.}} = \frac{6300}{4.9} = 1285.7 \text{ kN/m}'$$



Drawing U.L. B.M.D. on all R.C. Footing. Longitudinal direction.

$$\text{Point of Zero Shear } (X_o) = \frac{3600}{1285.7} = 2.80 \text{ m}$$



$M_{max.} = 682$ kN.m

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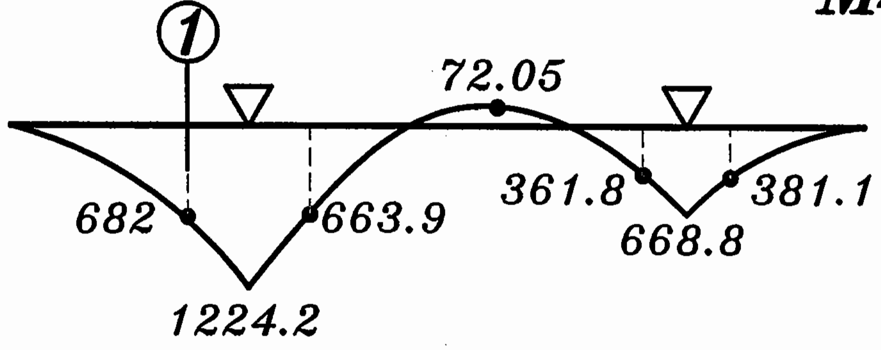
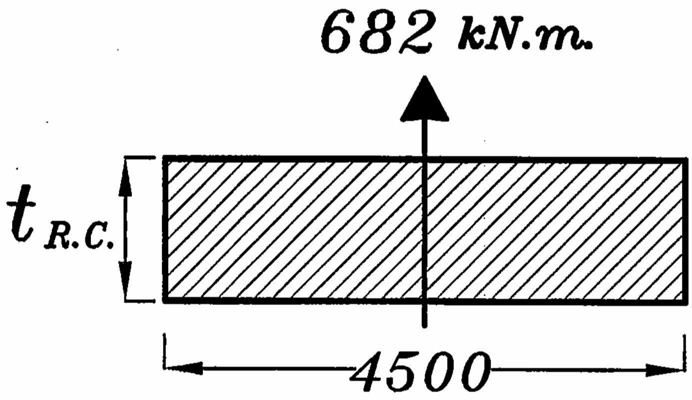
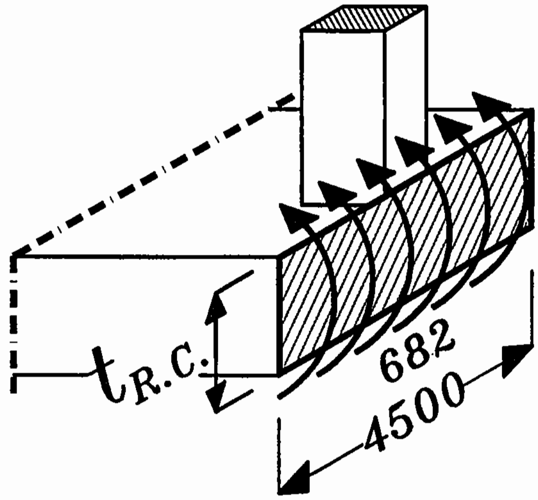






$$\because \; d = C_1 \sqrt{\frac{M_{act.}}{F_{cu} * b}}$$

Choose $C_1 = 5.0$

$$\therefore \; d = 5.0 \sqrt{\frac{682 * 10^6}{25 * 4500}} = 389.3 \text{ mm}$$

$$t_{R.C.} = d + 70 \text{ mm} = 389.3 + 70 = 459.3 \text{ mm}$$

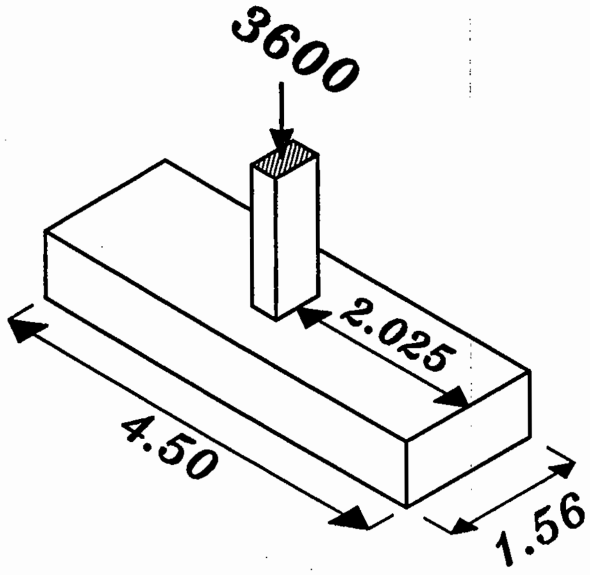
$t_{R.C.} = 500$ mm

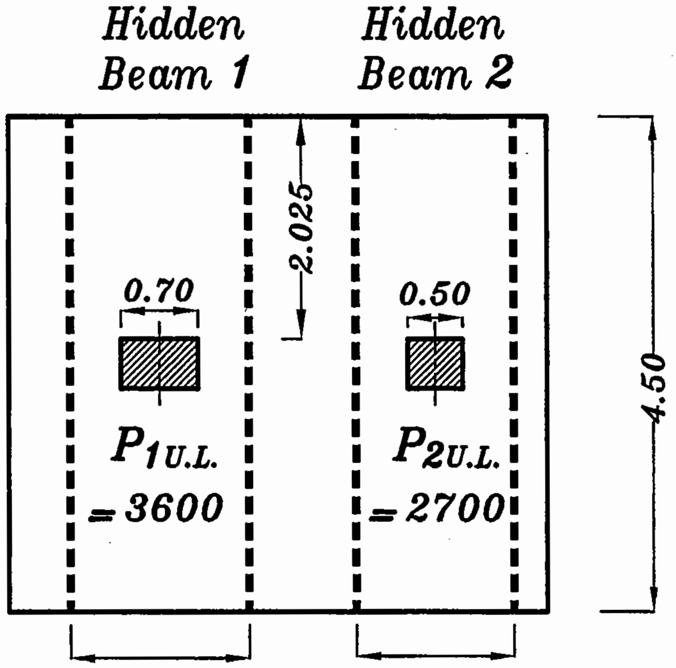
$d = 430$ mm

Check depth in Transverse direction.

As a Hidden Beam.

Hidden Beam 1

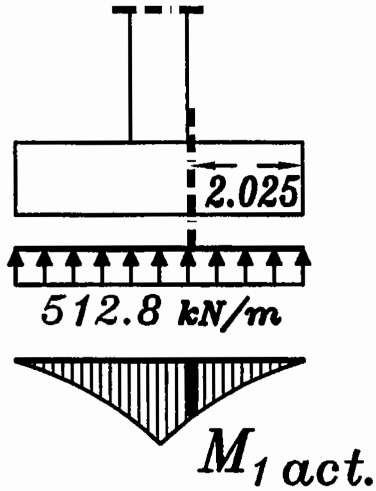




$L_1 = b_1 + 2d$
$= 0.7 + 2(0.43)$
$= 1.56\ m$

$L_2 = b_2 + 2d$
$= 0.5 + 2(0.43)$
$= 1.36\ m$

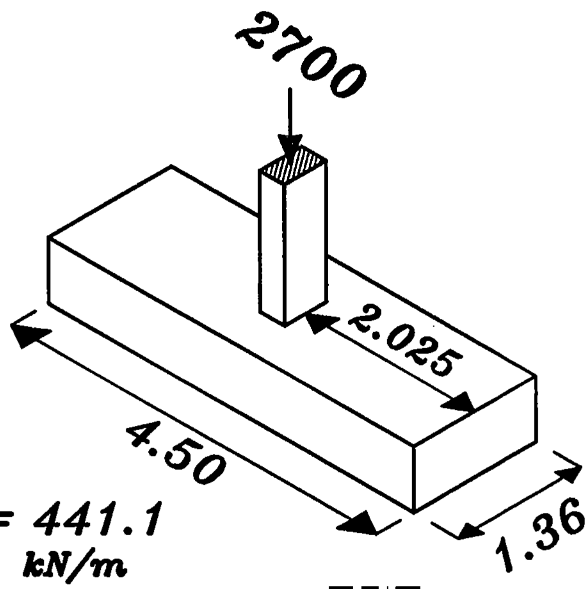
$$q_{1UL} = \frac{P_{1U.L.}}{B_{R.C.} * L_1} = \frac{3600}{4.5 * 1.56} = 512.8 \text{ kN/m}$$



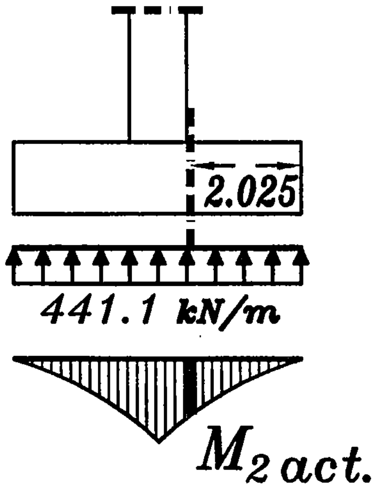
$$M_{1act.} = (512.8 * 2.025 * 1.0m)\ \frac{2.025}{2}$$

$$\boxed{M_{1act.} = 1051.4 \text{ kN.m/m}}$$

Hidden Beam 2



$$q_{2UL} = \frac{P_{2U.L.}}{B_{R.C.} * L_2} = \frac{2700}{4.5 * 1.36} = 441.1 \text{ kN/m}$$



$$M_{2act.} = (441.1 * 2.025 * 1.0m)\ \frac{2.025}{2}$$

$$\boxed{M_{2act.} = 904.4 \text{ kN.m/m}}$$

M_{bigger} From $M_{1act.}$ & $M_{2act.}$

$$\boxed{M_{bigger} = 1051.4 \text{ kN.m/m}}$$

$$430 = C_1 \sqrt{\frac{1051.4 * 10^6}{25 * 1000}} \longrightarrow C_1 = 2.09 < 2.8$$

∴ **We have to increase the depth**

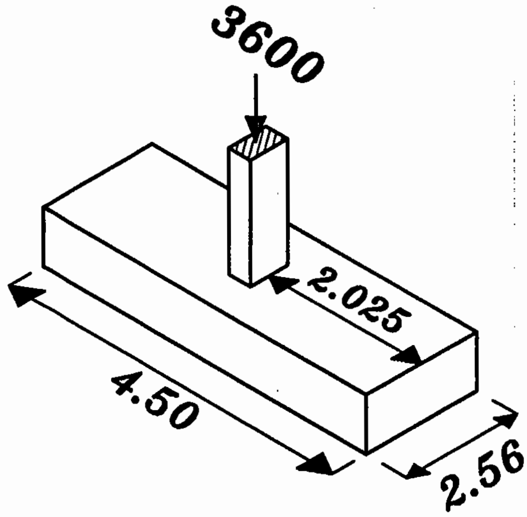
$$\therefore d = 4.5 \sqrt{\frac{1051.4 * 10^6}{25 * 1000}} = 922.8 \text{ mm}$$

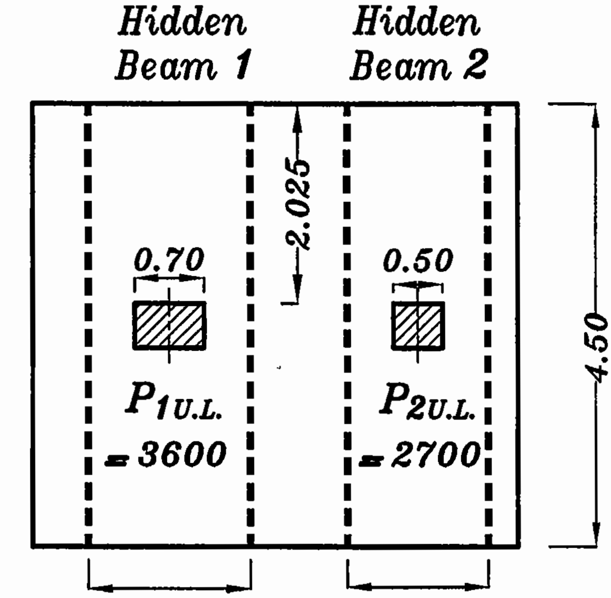
$$t_{R.C.} = d + 70 \text{ mm} = 922.8 + 70 = 992.8 \text{ mm}$$

$$\boxed{t_{R.C.} = 1000 \text{ mm}} \qquad \boxed{d = 930 \text{ mm}}$$

Recalculate the B.M. For Transverse direction with the new depth.

Hidden Beam 1





$$L_1 = b_1 + 2d = 0.7 + 2(0.93) = 2.56\ m$$

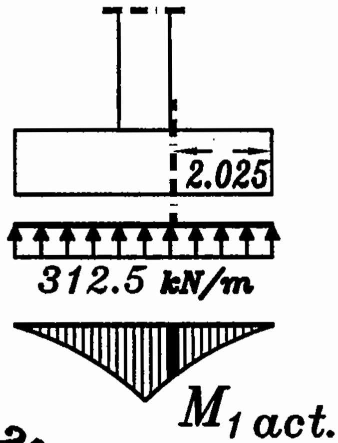
$$L_2 = b_2 + 2d = 0.5 + 2(0.93) = 2.36\ m$$

$$q_{1UL} = \frac{P_{1U.L.}}{B_{R.C.} * L_1}$$

$$= \frac{3600}{4.5 * 2.56} = 312.5\ kN/m$$

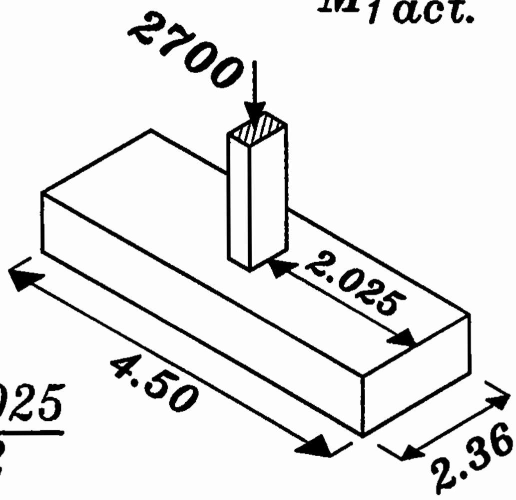
$$M_{1act.} = (312.5 * 2.025 * 1.0m)\ \frac{2.025}{2}$$

$$\boxed{M_{1act.} = 640.7\ kN.m/m}$$



Hidden Beam 2

$$q_{2UL} = \frac{P_{2U.L.}}{B_{R.C.} * L_2} = \frac{2700}{4.5 * 2.36} = 254.2\ kN/m$$

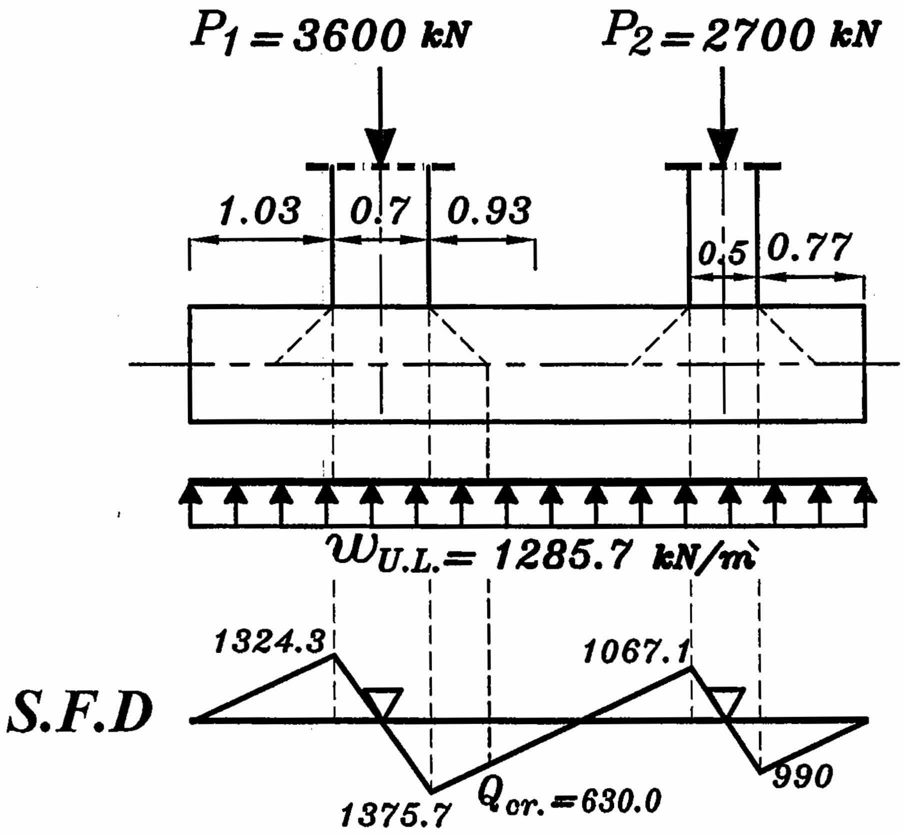


$$M_{2act.} = (254.2 * 2.025 * 1.0m)\ \frac{2.025}{2}$$

$$\boxed{M_{2act.} = 521.2\ kN.m/m}$$

3 – Check Shear. *at long direction*

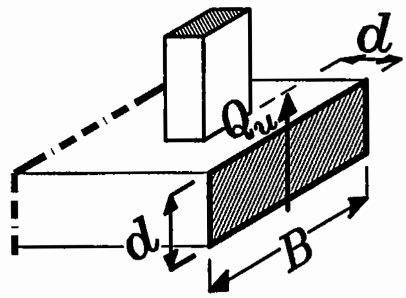
Critical section For Shear.



$$Q_{cr.} = Q_{max.} - w_{U.L.} * \frac{d}{2} = 1375.7 - 1285.7 * \frac{0.93}{2} = 777.8 \text{ kN}$$

* *Calculate Actual shear stress.* (q_u)

$$q_{cu} = \frac{Q_{cr.}}{B * d} = \frac{777.8 * 10^3}{4500 * 930} = 0.186 \text{ kN/m}^2$$

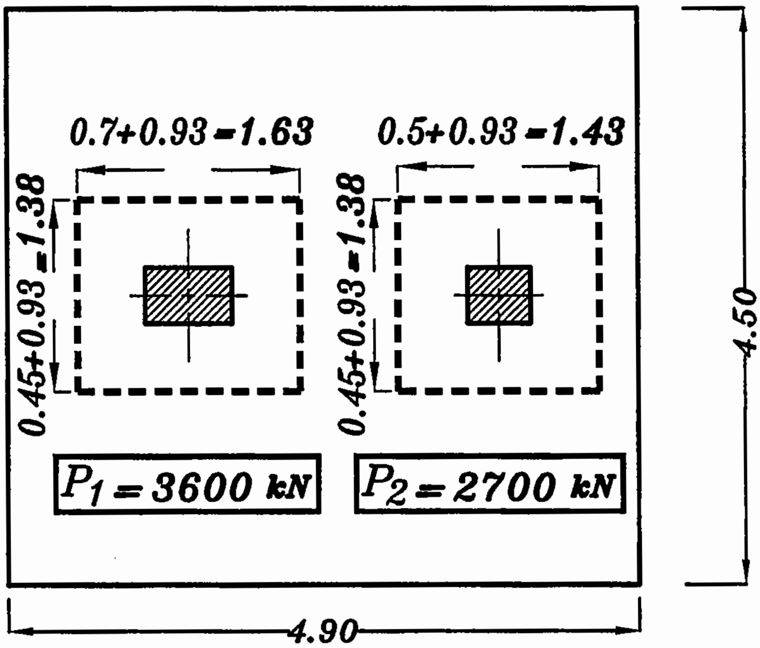


* *Allowable shear stress.* (q_{su})

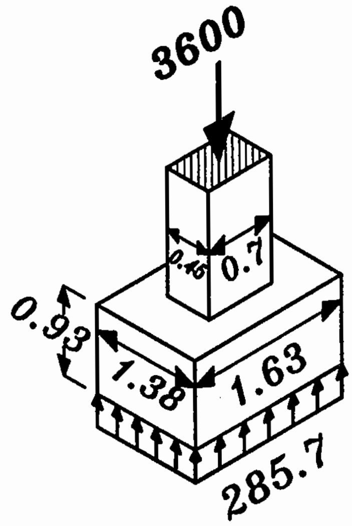
$$q_{su} = 0.16\sqrt{\frac{F_{cu}}{\gamma_c}} = 0.16\sqrt{\frac{25}{1.5}} = 0.653 \text{ N/mm}^2$$

$\boxed{q_{cu} < q_{scu}}$ → *Safe shear stresses*
No need to increase dimensions.

4 – Check Punching Shear.



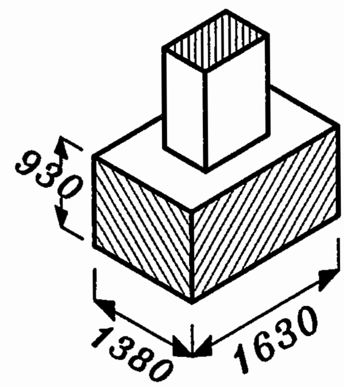
Column 1



* Calculate Punching Force. (Q_{1p})

$$Q_{1p} = 3600 - 285.7\ (1.38 * 1.63)$$
$$= 2957.3 \text{ kN}$$

$$A_{1p} = [2(1380) + 2(1630)] * 930$$
$$= 5598600 \text{ mm}^2$$

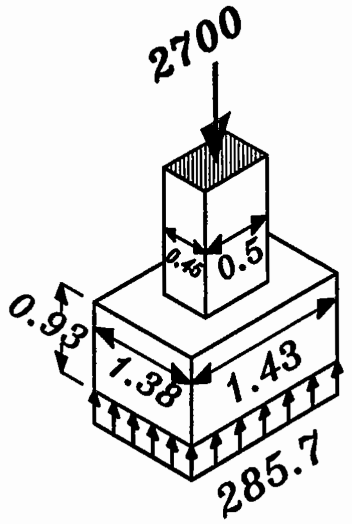


* Calculate Actual Punching shear stress. q_{1pu}

$$q_{1pu} = \frac{2957.3 * 10^3}{5598600} = 0.528 \text{ N/mm}^2$$

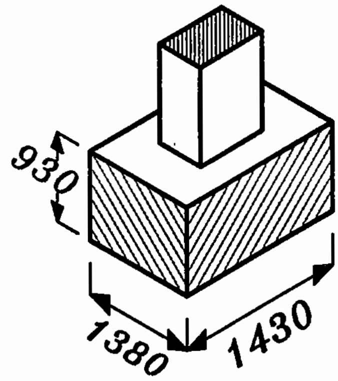
Column 2

* *Calculate Punching Force.* (Q_{2p})



$$Q_{2p} = 2700 - 285.7\ (1.38 * 1.43)$$
$$= 2136.2\ kN$$

$$A_{2p} = \left[2(1380) + 2(1430)\right] * 930$$
$$= 5226600\ mm^2$$



* *Calculate Actual Punching shear stress.* q_{2pu}

$$q_{2pu} = \frac{2136.2 * 10^3}{5226600} = 0.408\ N/mm^2$$

q_{pumax} the bigger q_{1pu} & $q_{2pu} = 0.528\ N/mm^2$

* *Calculate allowable Punching shear stress.* q_{pcu}

$$\boxed{q_{pcu} = 0.316\ (0.5 + \frac{a}{b})\sqrt{\frac{F_{cu}}{\gamma_c}}}$$

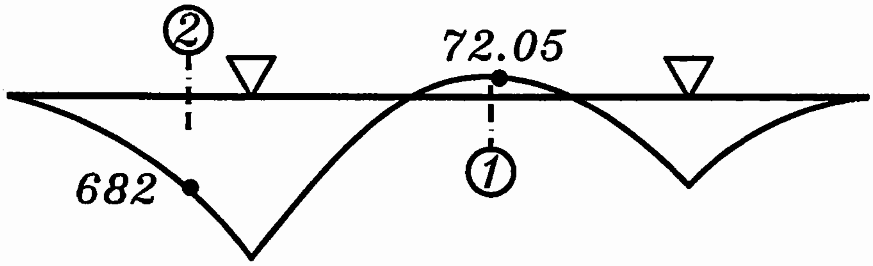
$$(0.5 + \frac{a}{b}) = (0.5 + \frac{0.45}{0.70}) = 1.14 > 1.0$$

$$\therefore\ q_{pcu} = 0.316\sqrt{\frac{F_{cu}}{\gamma_c}} = 0.316\sqrt{\frac{25}{1.5}} = 1.29\ N/mm^2$$

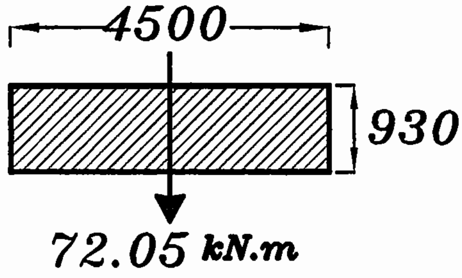
$q_{pu} \leqslant q_{pcu} \longrightarrow$	*Safe punching shear.* *No need to increase dimensions.*

5- Reinforcement of the Footing.

Longitudinal direction.



Sec. ①



$$930 = C_1 \sqrt{\frac{72.05 * 10^6}{25 \ * 4500}}$$

$$\longrightarrow C_1 = 36.7 \longrightarrow J = 0.826$$

$$A_S = \frac{M_{act.}}{J \ F_y \ d} = \frac{72.05 * 10^6}{0.826 * 360 * 930} = 260.53 \ mm^2$$

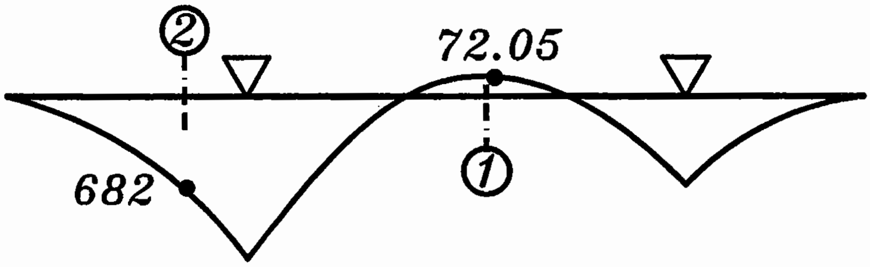
$$A_S \ (mm^2/m) = \frac{A_S}{B_{R.C.}} = \frac{260.53}{4.50} = 57.9 \ mm^2/m`$$

Check $A_{S\,min}$

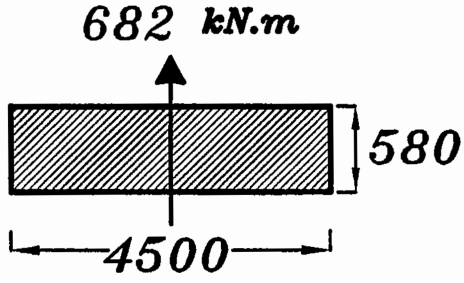
$$A_{S\,min} = \left\{ \begin{array}{l} 1.5\,d = 1.5 * 930 = 1395 \\ 5 \phi 12/m` = 565 \end{array} \right\} 1395 \ mm^2$$

$$\therefore A_S < A_{S\,min} \longrightarrow Take \ A_S = 1395 \ mm^2$$

$$\boxed{7 \phi 16/m`}$$



Sec. ②



$$930 = C_1 \sqrt{\frac{682 * 10^6}{25 * 4500}}$$

$$\longrightarrow C_1 = 11.9 \longrightarrow J = 0.826$$

$$A_s = \frac{M_{act.}}{J\, F_y\, d} = \frac{682 * 10^6}{0.826 * 360 * 930} = 2466.1 \text{ mm}^2$$

$$A_{s\,(mm^2/m)} = \frac{A_s}{B_{R.C.}} = \frac{2466.1}{4.50} = 548.0 \text{ mm}^2/m'$$

Check $A_{s\,min}$

$$A_{s\,min} = \left\{ \begin{array}{l} 1.5\, d = 1.5 * 930 = 1395 \\ 5 \phi 12/m' = 565 \end{array} \right\} 1395 \text{ mm}^2$$

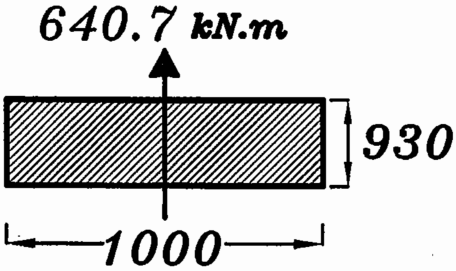
$$\therefore A_s < A_{s\,min} \longrightarrow \text{Take } A_s = 1395 \text{ mm}^2$$

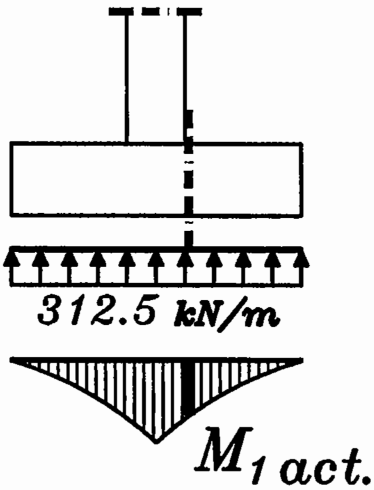
$$\boxed{7 \phi 16/m'}$$

Transverse direction. Short direction.

Hidden Beam 1

$$\boxed{M_{1act.} = 640.7 \ kN.m/m}$$





$$930 = C_1 \sqrt{\frac{640.7 * 10^6}{25 \ * 1000}} \longrightarrow C_1 = 5.81 \longrightarrow J = 0.826$$

$$A_S = \frac{M_{act.}}{J \ F_y \ d} = \frac{640.7 * 10^6}{0.826 * 360 * 930} = 2316.8 \ mm^2/m`$$

Check $A_{s\,min}$

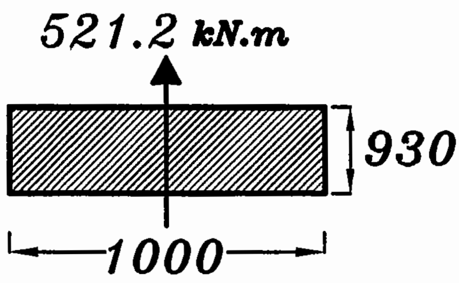
$$A_{s\,min} = \left\{ \begin{array}{l} 1.5\,d = 1.5 * 930 = 1395 \\ 5 \phi 12/m` = 565 \end{array} \right\} 1395 \ mm^2$$

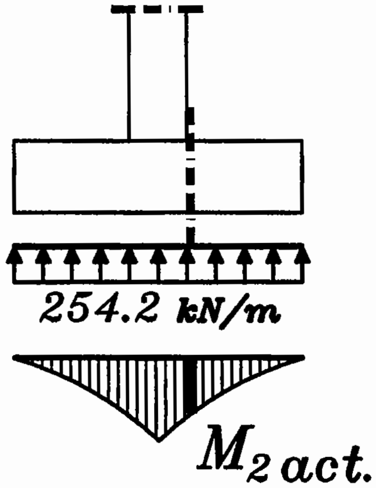
$$\therefore \ A_S > A_{s\,min} \longrightarrow o.k.$$

$$A_S = 2316.8 \ mm^2 \qquad \boxed{7 \phi 22/m`}$$

Hidden Beam 2

$$M_{2act.} = 521.2 \ kN.m/m$$





$$930 = C_1 \sqrt{\frac{521.2 * 10^6}{25 \ * 1000}} \longrightarrow C_1 = 6.44 \longrightarrow J = 0.826$$

$$A_S = \frac{M_{act.}}{J \ F_y \ d} = \frac{521.2 * 10^6}{0.826 * 360 * 930} = 1884.7 \ mm^2/m'$$

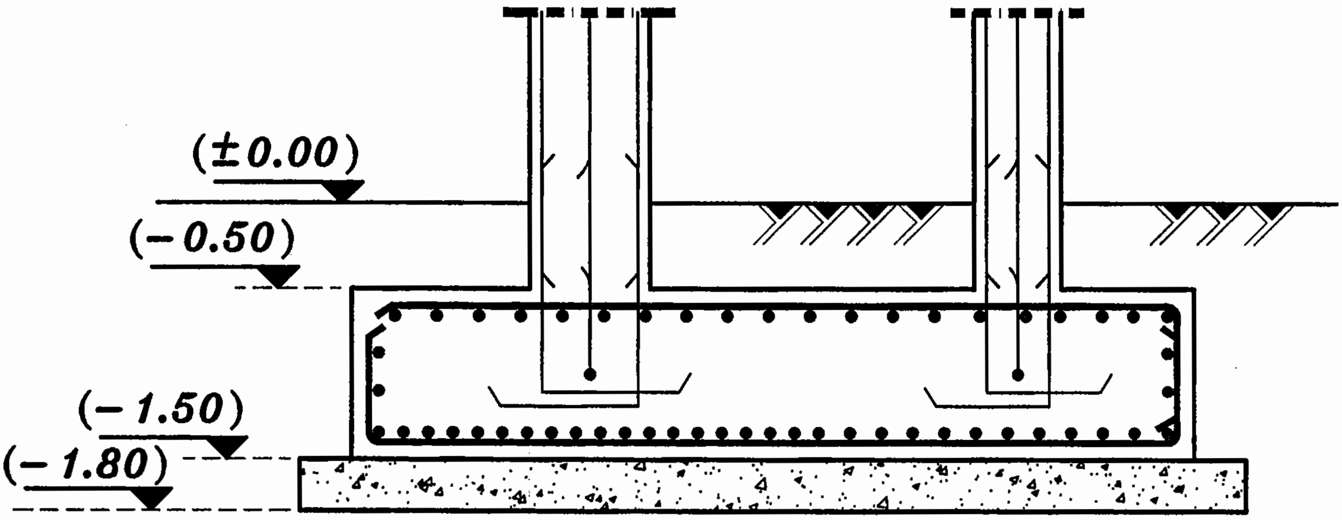
Check $A_{S_{min}}$

$$A_{S_{min}} = \left\{ \begin{array}{l} 1.5\,d = 1.5 * 930 = 1395 \\ 5 \phi 12/m' = 565 \end{array} \right\} 1395 \ mm^2$$

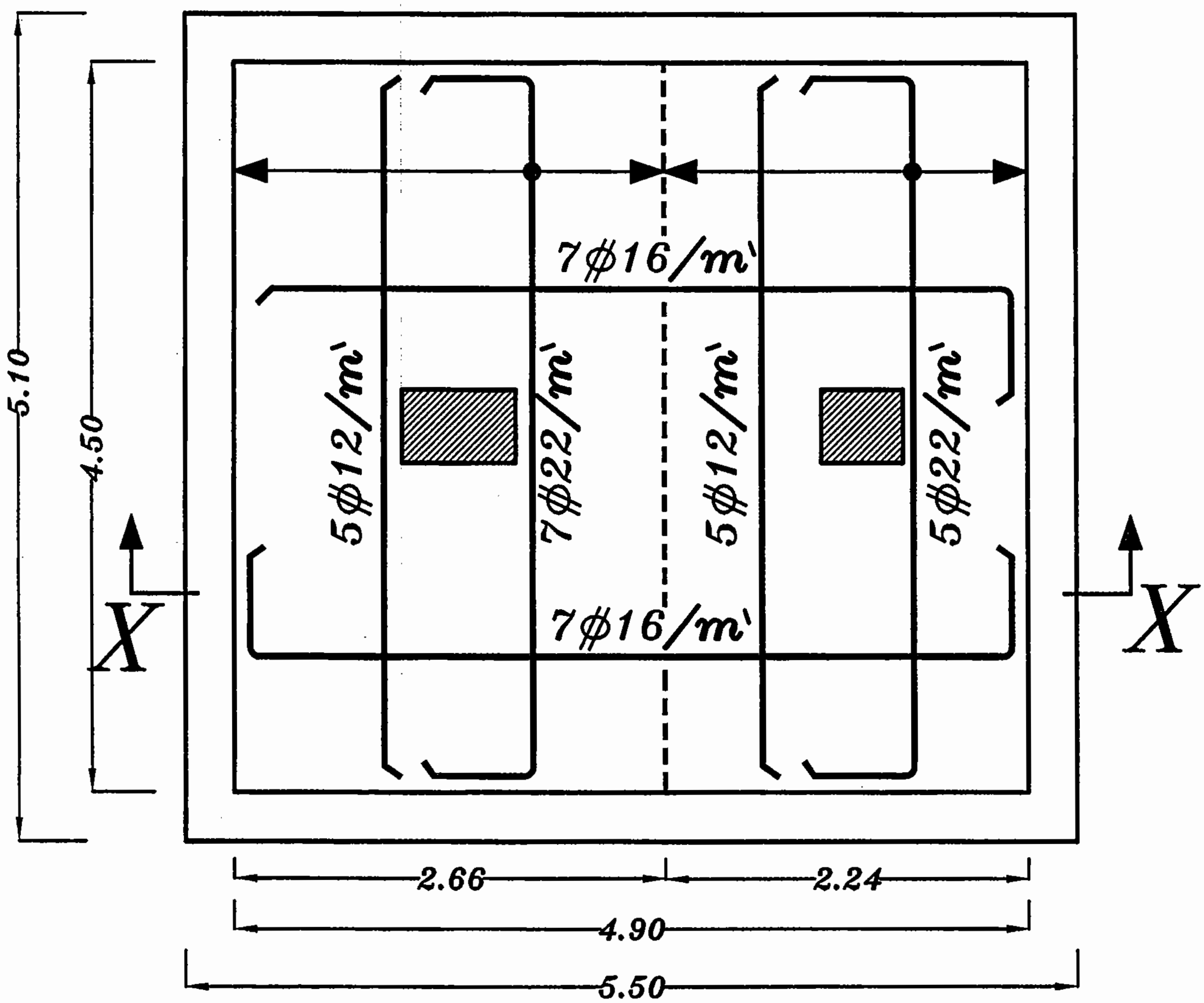
$$\therefore A_S > A_{S_{min}} \longrightarrow o.k.$$

$A_S = 1884.7 \ mm^2$ **$5 \phi 22/m'$**

6- Details of Reinforcement.



Sec X-X



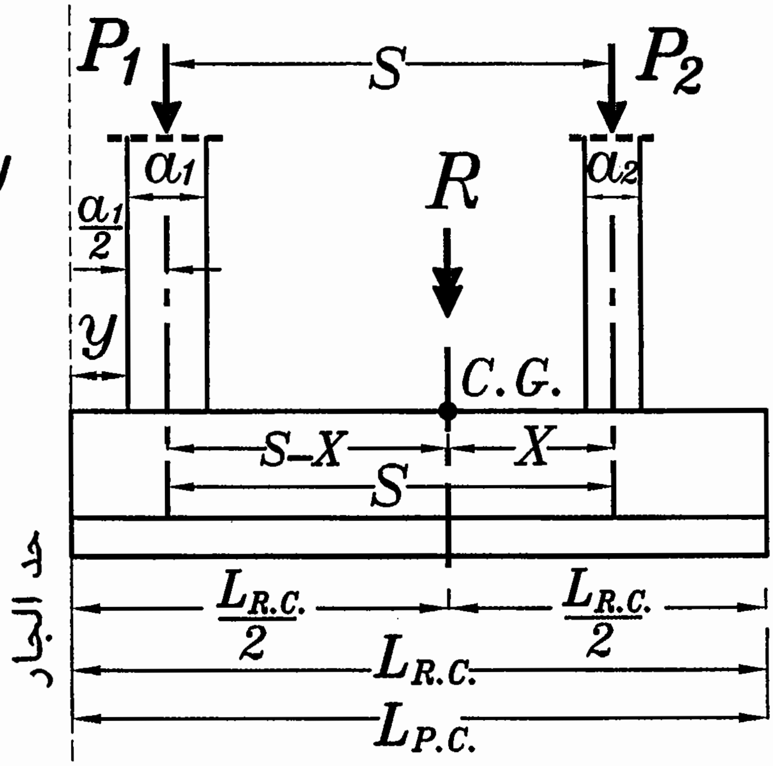
فى حالة قاعدة مشتركة بجوار حد الجار

فى حالة وقوع أحد عمودى القاعدة المشتركة بجانب حد الجار تختلف بعض مراحل التصميم عن ما سبق وهى

Calculate the Footing area.

$$\frac{L_{R.C.}}{2} = (S-X) + \frac{a_1}{2} + y$$

→ $L_{R.C.} = \checkmark$



IF y = 0

وش العمود ملاصق لحد الجار

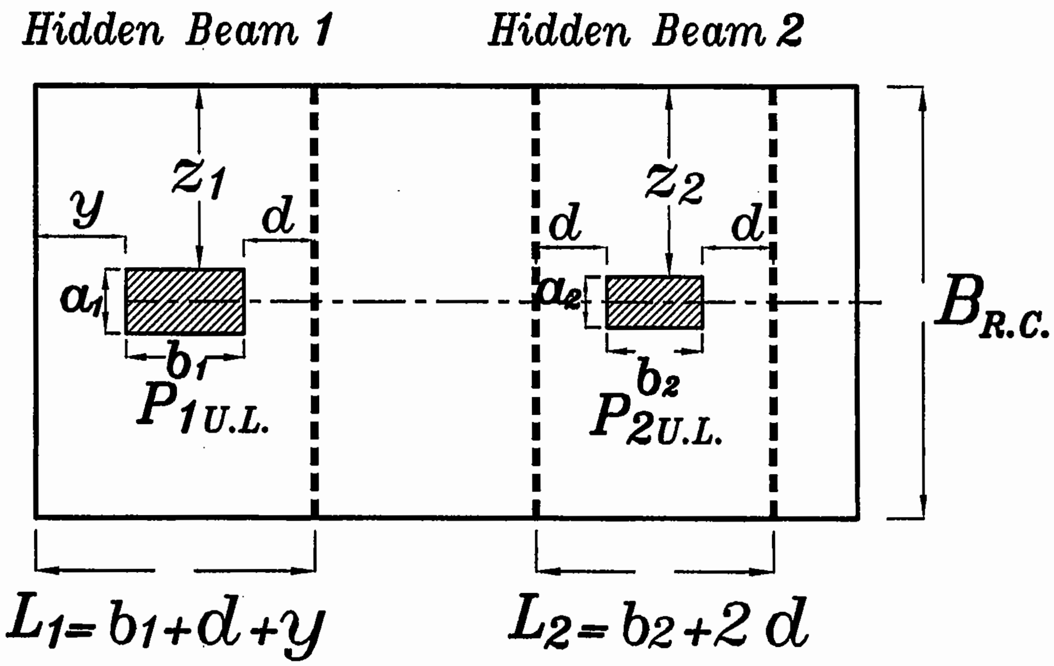
$$\rightarrow \frac{L_{R.C.}}{2} = (S-X) + \frac{a_1}{2}$$

و ذلك لانه غير مسموح ببروز ال **P.C.** عن ال **R.C.** من جهه الجار و بالتالى غير مسموح بالبروز من الجهه الاخرى حتى يظل **$C.G._{R.C.}$ at $C.G._{P.C.}$ at $C.G._{R}$**

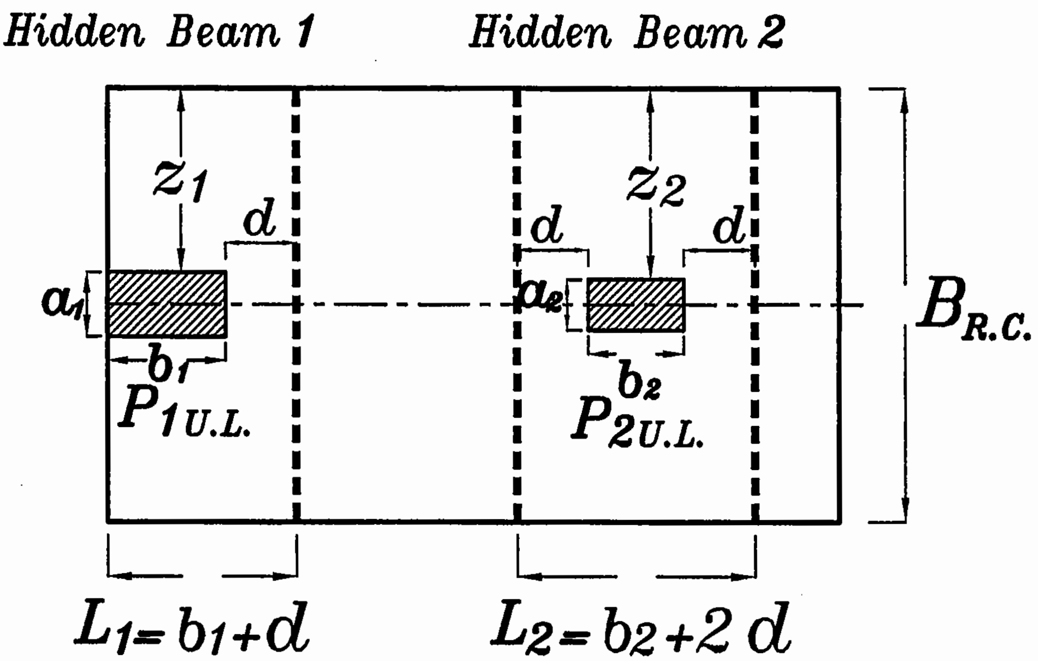
$$L_{P.C.} = L_{R.C.}$$

أبعاد الـ (*Hidden Beam*)

للعمود بجوار حد الجار **IF $y < d$**

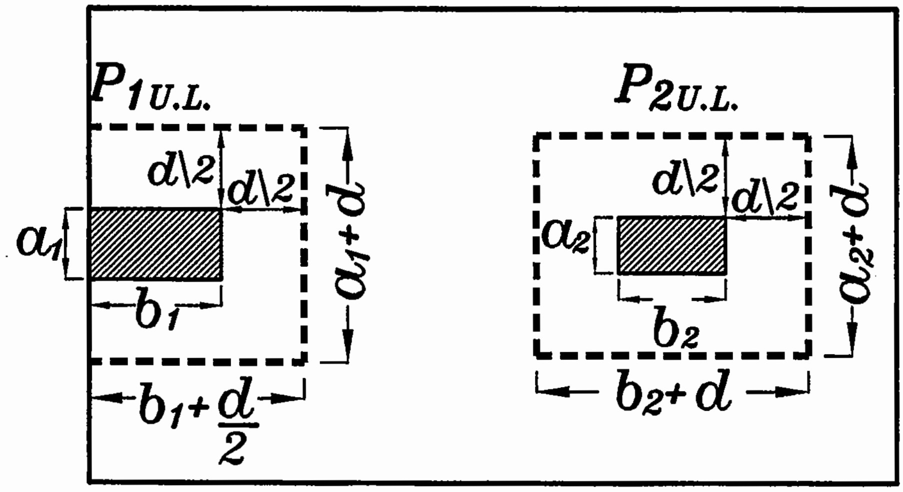


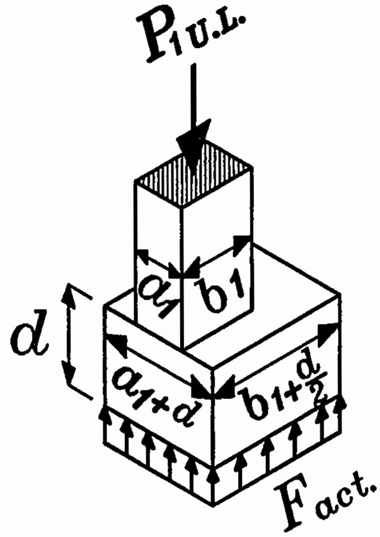
IF $y = 0$



فى مرحلة **Check Punching**

اذا وقع اى ضلع من اضلاع القطاع الحرج خارج القاعدة نكتفى فقط بباقى الاضلاع الواقعة داخل حدود القاعدة.





$$Q_{1p}=P_{1\,U.L.}-(F_{act.})\left[(a_1+d)(b_1+\frac{d}{2})\right]$$

(kN)

المحيط العمق

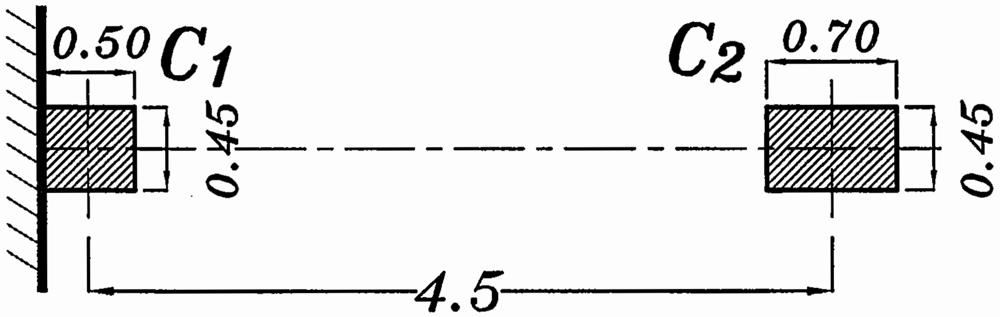
$$A_{1p}=\left[(a_1+d)+2(b_1+\frac{d}{2})\right]*d$$

(mm^2)

$$q_{1pu}=\frac{Q_{1p\,(kN)}*10^3}{\left[(a_1+d)+2(b_1+\frac{d}{2})\right]*d\ (mm^2)}\quad (N/mm^2)$$

Example (2):

*It is required to design Footings to support a proterty line column C_1 (45*50) cm. and carrying working load 1000 kN and interior column C_2 (45*70) cm. and carrying working load 2200 kN the spacing between the C.L. of the two columns is 4.5 m as shown*



and the allowable net bearing capacity in the Footing site is 200 kN/m². (F_{cu} = 25 N/mm², F_y = 360 N/mm²).
and draw details of RFT. to scale 1:50

Solution.

Data given:

Column C_1 dimensions (450*500) mm

P_1 (working) = 1000 kN $\quad$ P_1 (U.L.) = 1000*1.5 = 1500 kN

Column C_2 dimensions (450*700) mm

P_2 (working) = 2200 kN $\quad$ P_2 (U.L.) = 2200*1.5 = 3300 kN

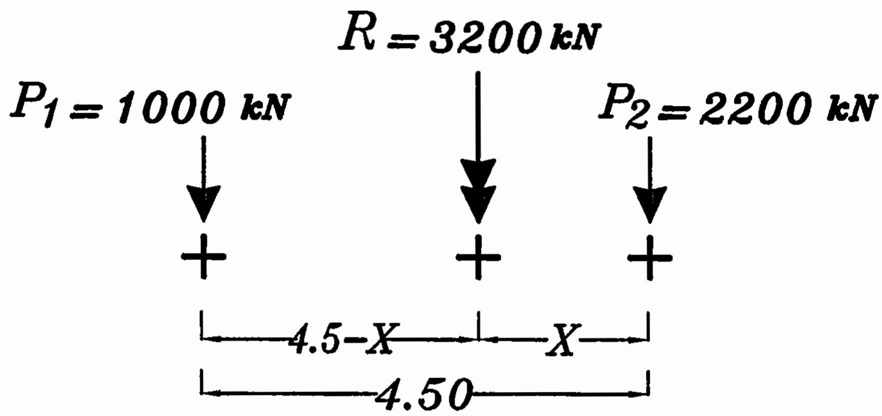
$R_{(working)} = P_1 + P_2 = 3200$ kN

$R_{(U.L.)} = 1.5 * 3200 = 4800$ kN

Bearing capacity of the soil = q_{all} = 200 kN/m²

F_{cu} = 25 N/mm² $\quad$ F_y = 360 N/mm²

1– Calculate the Footing area. (Width & Length of R.C. Footing.)



$$X = \frac{P_1}{R} * S = \frac{1000}{3200} * 4.5 = 1.40 \ m$$

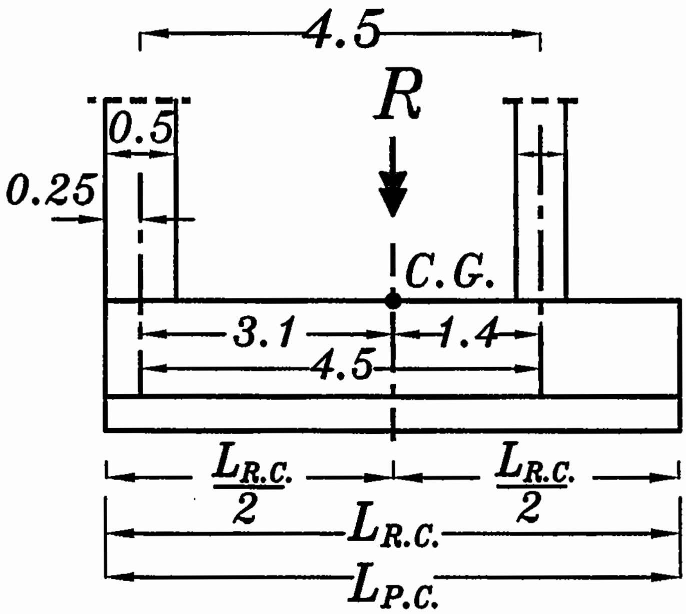
$$R = P_1 + P_2 = 1000 + 2200 = 3200 \ kN$$

$$L_{R.C.} = 2(3.1 + 0.25)$$

$$= 6.70 \ m$$

$$\boxed{L_{R.C.} = 6.70 \ m}$$

$$\boxed{L_{P.C.} = 6.70 \ m}$$



Calculate the width of the Footing. B

$$A_{P.C.} = \frac{R_w}{q_{all}} = \frac{3200}{200} = 16.0 \ m^2 = B_{P.C.} * L_{P.C.} = B_{P.C.} * 6.70$$

$$B_{P.C.} = 2.39 \ m$$

$$\boxed{B_{P.C.} = 2.40 \ m} \qquad \boxed{B_{R.C.} = 1.80 \ m}$$

2– Design the critical sections For moment. (Depth of R.C. Footing.)

$P_{1U.L.} = 1.5 * 1000 = 1500$ kN

$P_{2U.L.} = 1.5 * 2200 = 3300$ kN

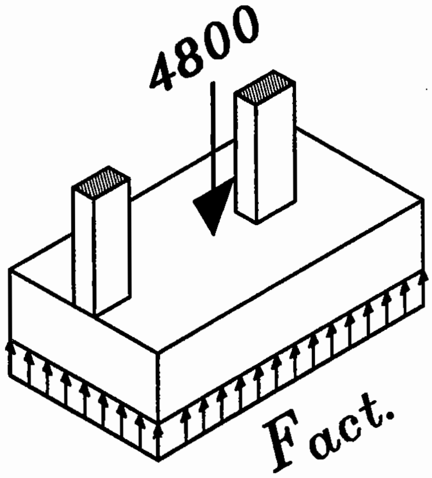
$R_{U.L.} = 1.5 * 3200 = 4800$ kN

– Actual Normal stress on R.C. Footing (U.L.)

$$q_{UL} = \frac{R_{U.L.}}{B_{R.C.} * L_{R.C.}}$$

$$q_{UL} = \frac{4800}{1.8 * 6.7} = 398.0 \text{ kN/m}^2$$

$$\boxed{q_{UL} = 398.0} \text{ kN/m}^2$$

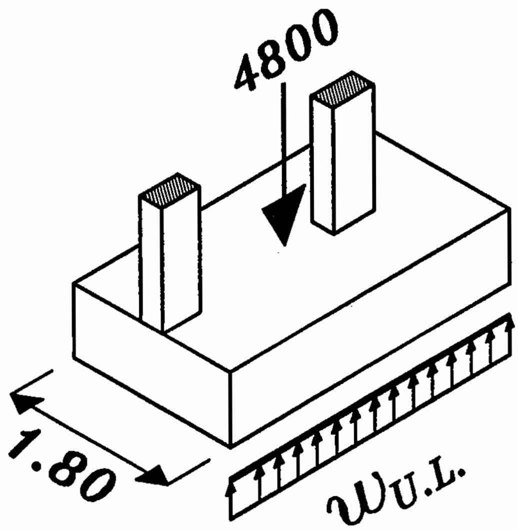


– Actual Uniform Load on R.C. Footing (U.L.) as a beam.

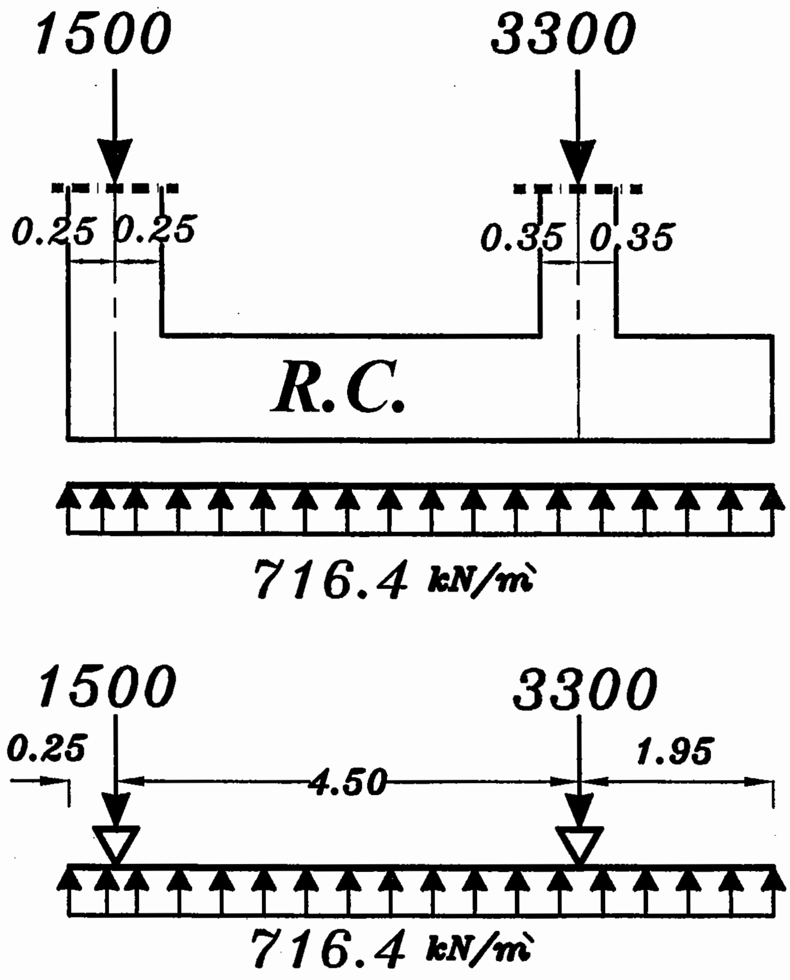
$$w_{U.L.} = \frac{R_{U.L.}}{L_{R.C.}} \quad (\text{kN/m}')$$

$$w_{U.L.} = \frac{4800}{6.7} = 716.4 \text{ kN/m}'$$

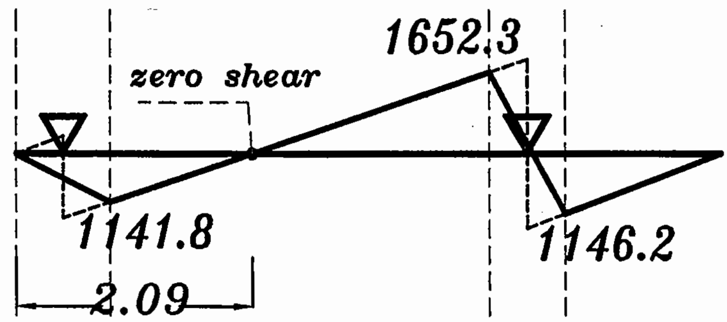
$$\boxed{w_{U.L.} = 716.4} \text{ kN/m}'$$



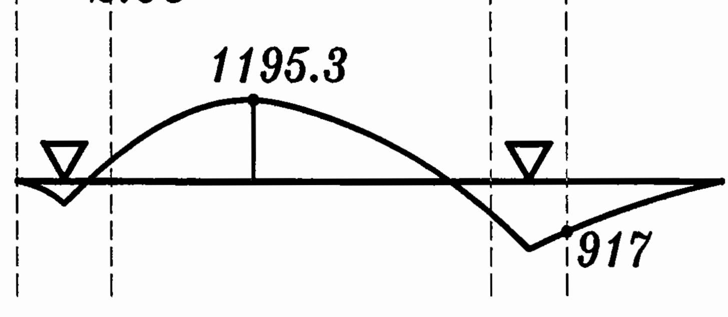
Longitudinal direction.



S.F.D



B.M.D



$$\because\ d = C_1 \sqrt{\frac{M_{act.}}{F_{cu} * b}}$$

Choose $C_1 = 5.0$

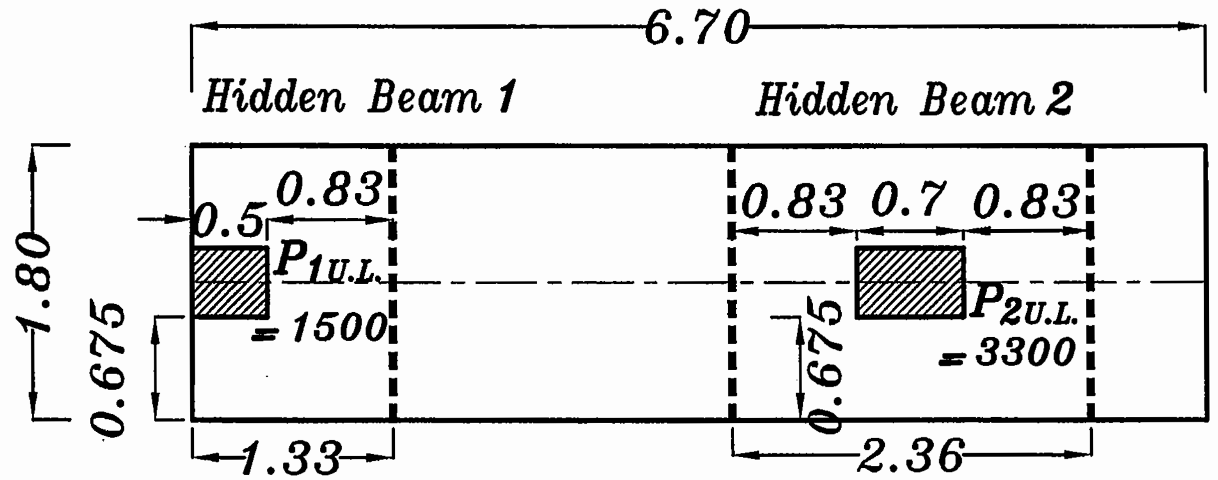
$$\therefore\ d = 5.0 \sqrt{\frac{1195.3 * 10^6}{25 * 1800}} = 814.9\ mm$$

$$t_{R.C.} = d + 70\ mm = 814.9 + 70 = 884.9\ mm$$

$t_{R.C.} = 900\ mm$ $\quad$ $d = 830\ mm$

Check depth in Transverse direction.

As a Hidden Beam.



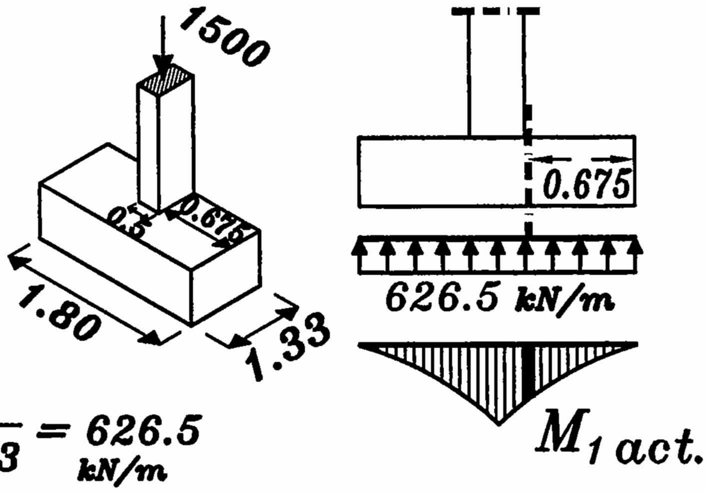
$L_1 = 0.5 + 0.83$

$L_1 = 1.33\ m$

$L_2 = 0.7 + 2 * 0.83$

$L_2 = 2.36\ m$

Hidden Beam 1

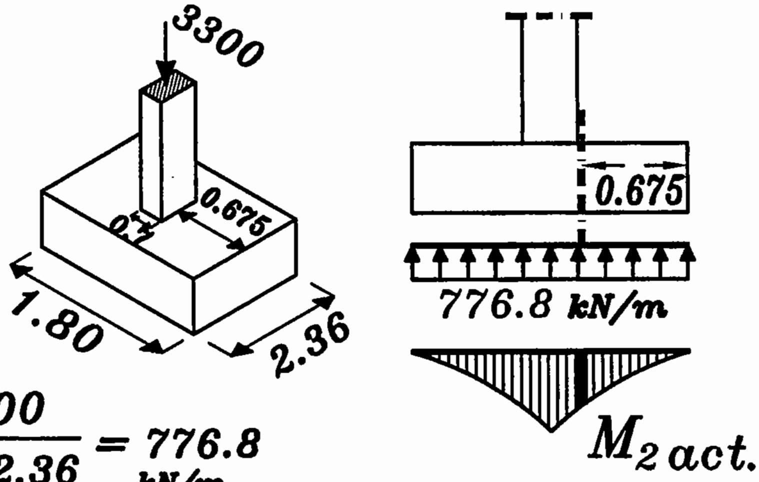


$$q_{1UL} = \frac{P_{1U.L.}}{B_{R.C.} * L_1} = \frac{1500}{1.8 * 1.33} = 626.5 \; kN/m$$

$$M_{1act.} = (626.5 * 0.675 * 1.0m) \frac{0.675}{2}$$

$$\boxed{M_{1act.} = 142.7 \; kN.m/m}$$

Hidden Beam 2



$$q_{2UL} = \frac{P_{2U.L.}}{B_{R.C.} * L_2} = \frac{3300}{1.8 * 2.36} = 776.8 \; kN/m$$

$$M_{2act.} = (776.8 * 0.675 * 1.0m) \frac{0.675}{2}$$

$$\boxed{M_{2act.} = 176.9 \; kN.m/m}$$

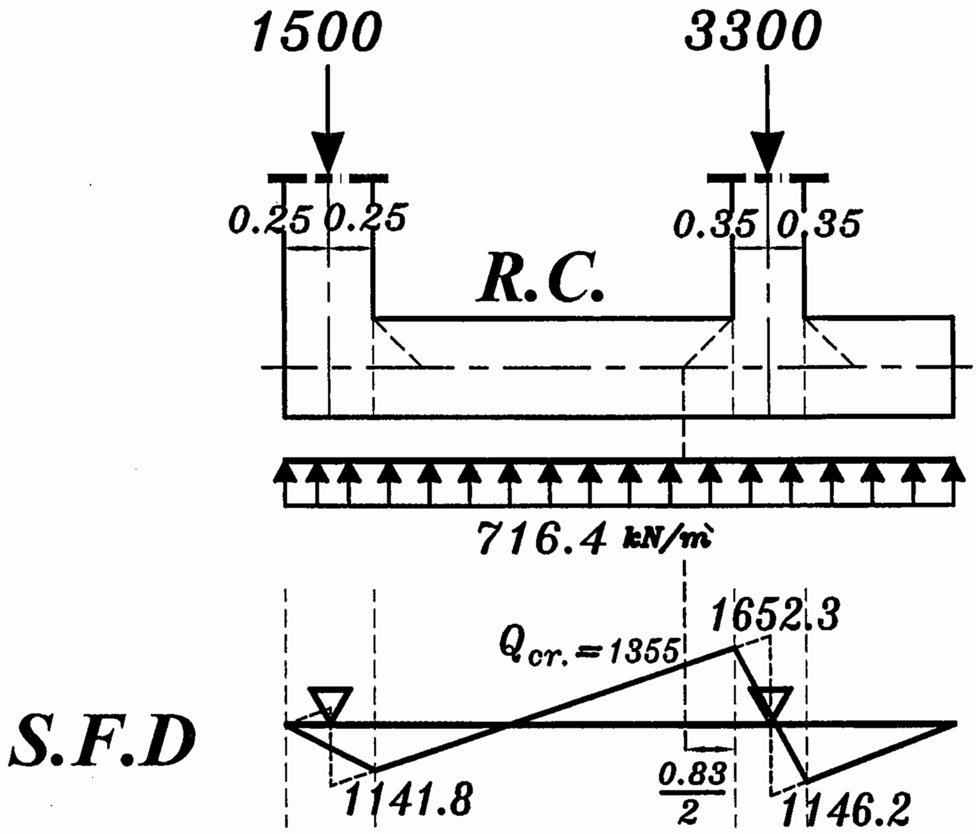
M_{bigger} From $M_{1act.}$ & $M_{2act.}$

$$\boxed{M_{bigger} = 176.9 \; kN.m/m}$$

$$830 = C_1 \sqrt{\frac{176.9 * 10^6}{25 \; * 1000}} \longrightarrow C_1 = 9.86 > 2.8 \; \therefore ok.$$

3 – Check Shear. at long direction

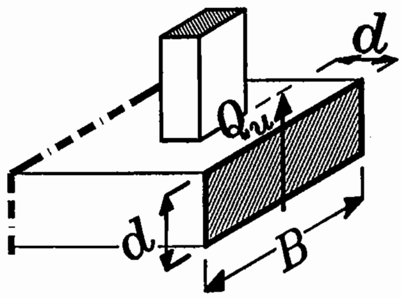
Critical section For Shear.



$$Q_{cr.} = Q_{max.} - w_{U.L.} * \frac{d}{2} = 1652.3 - 716.4 * \frac{0.83}{2} = 1355\ kN$$

* Calculate Actual shear stress.

$$q_{su} = \frac{Q_{cr.}}{B * d} = \frac{1355 * 10^3}{1800 * 830} = 0.907\ kN/m^2$$



* Allowable shear stress.

$$q_{scu} = 0.16\sqrt{\frac{F_{cu}}{\gamma_c}} = 0.16\sqrt{\frac{25}{1.5}} = 0.653\ N/mm^2$$

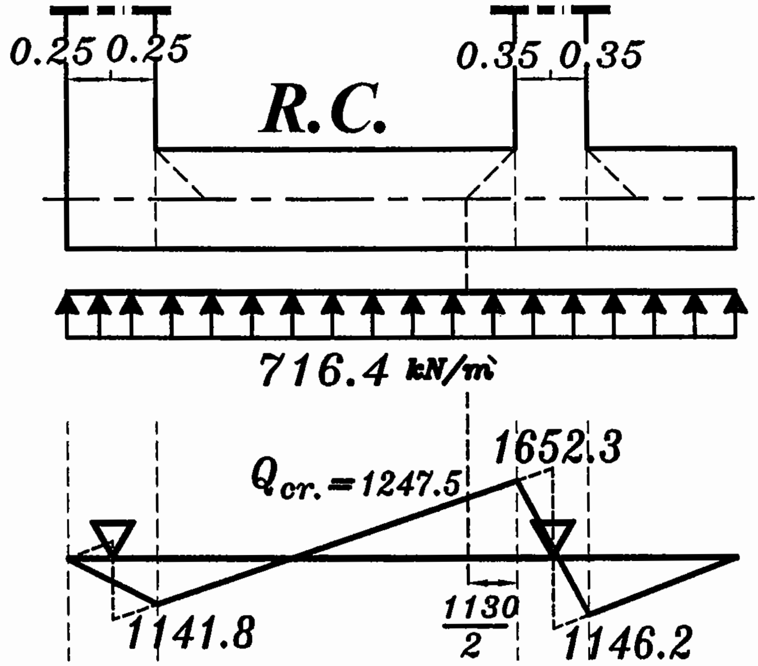
$$\boxed{q_{cu} > q_{scu}}$$ ⟶ UnSafe shear stresses

We have to increase Depth

Increase the depth of the Footing.

يتم زياده depth القاعده ١٠ سم ثم يتم عمل Check Shear

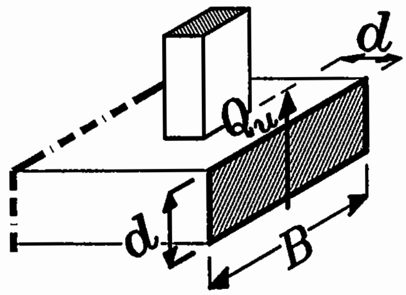
Take $t_{R.C.} = 1200\ mm$ $d = 1130\ mm$



S.F.D

$$Q_{cr.} = Q_{max.} - w_{U.L.} * \frac{d}{2} = 1652.3 - 716.4 * \frac{1.13}{2} = 1247.5\ kN$$

* Calculate Actual shear stress.



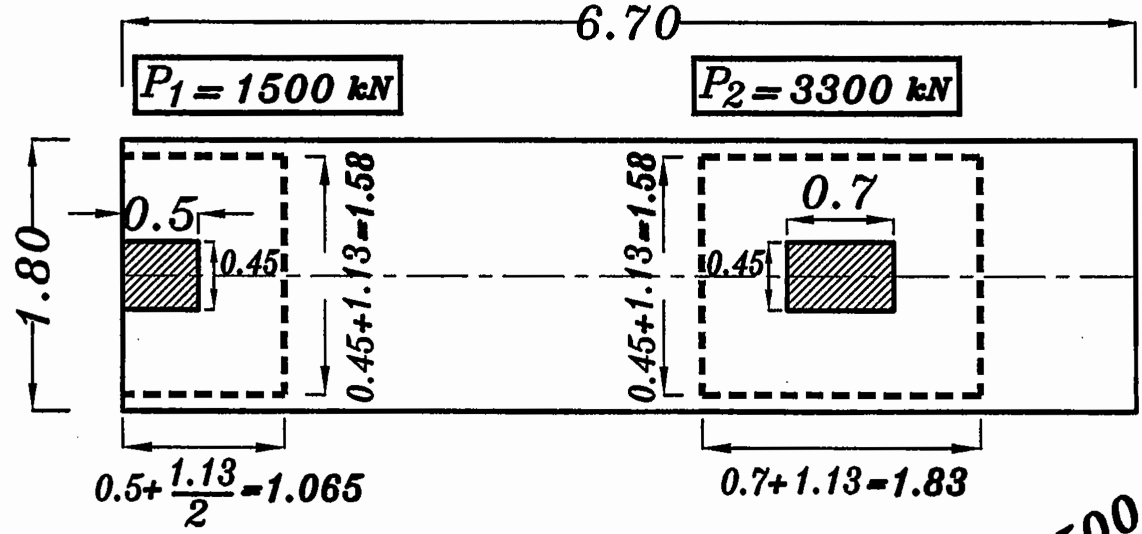
$$q_{cu} = \frac{Q_{cr.}}{B * d} = \frac{1247.5 * 10^3}{1800 * 1130} = 0.613\ kN/m^2$$

* Allowable shear stress. (q_{su})

$$q_{scu} = 0.16\sqrt{\frac{F_{cu}}{\gamma_c}} = 0.16\sqrt{\frac{25}{1.5}} = 0.653\ N/mm^2$$

$q_{cu} < q_{scu}$ ⟶ Safe shear stresses

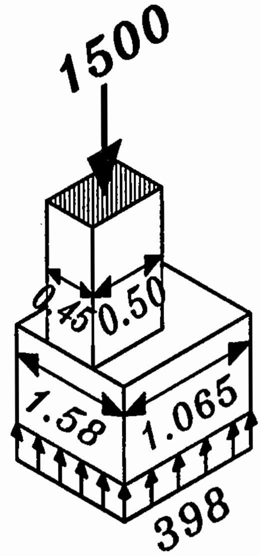
4 – Check Punching Shear.



Column 1

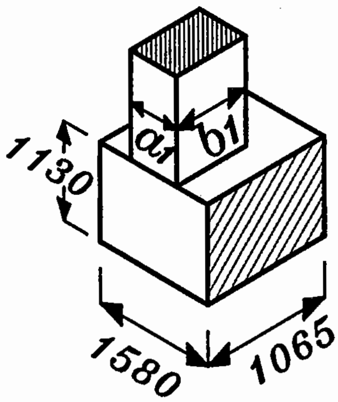
* Calculate Punching Force. (Q_{1p})

$$Q_{1p} = 1500 - 398\ (1.065 * 1.58) = 830.3\ kN$$



$$A_{1p} = [2\,(1065) + (1580)] * 1130$$

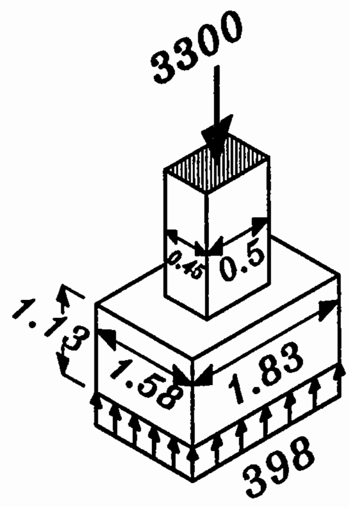
$$= 4192300\ mm^2$$



* Calculate Actual Punching shear stress. q_{1pu}

$$q_{1pu} = \frac{830.3 * 10^3}{4192300} = 0.198\ N/mm^2$$

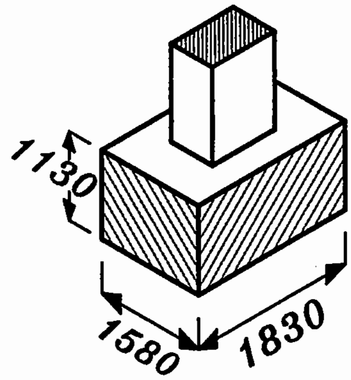
Column 2



* Calculate Punching Force. (Q_{2p})

$$Q_{2p} = 3300 - 398\ (1.83 * 1.58)$$
$$= 2149.2\ kN$$

$$A_{2p} = [2(1580) + 2(1830)] * 1130$$
$$= 7706600\ mm^2$$



* Calculate Actual Punching shear stress. q_{1pu}

$$q_{2pu} = \frac{2149.2 * 10^3}{7706600} = 0.279\ N/mm^2$$

q_{pumax} the bigger q_{1pu} & $q_{2pu} = 0.279\ N/mm^2$

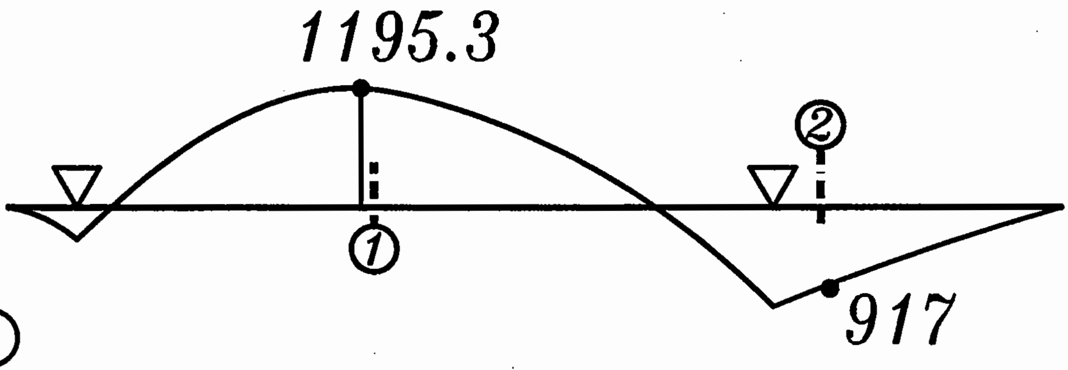
$$q_{pcu} = 0.316\ (0.5 + \frac{a}{b}) \sqrt{\frac{F_{cu}}{\delta_c}}$$

$$(0.5 + \frac{a}{b}) = (0.5 + \frac{0.45}{0.50}) = 1.40 > 1.0$$

$$\therefore q_{pcu} = 0.316 \sqrt{\frac{F_{cu}}{\delta_c}} = 0.316 \sqrt{\frac{25}{1.5}} = 1.29\ N/mm^2$$

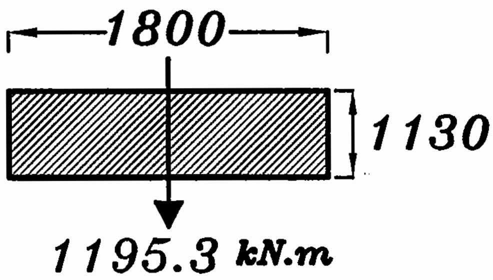
$q_{pu} \leqslant q_{pcu} \longrightarrow$ Safe punching shear.
No need to increase dimensions.

5- Reinforcement of the Footing.



Sec. ①

$$1130 = C_1 \sqrt{\frac{1195.3 * 10^6}{25 * 1800}}$$



$$\longrightarrow C_1 = 6.93 \longrightarrow J = 0.826$$

$$A_S = \frac{M_{act.}}{J\, F_y\, d} = \frac{1195.3 * 10^6}{0.826 * 360 * 1130} = 3557.2 \ mm^2$$

$$A_S \ (mm^2/m) = \frac{A_S}{B_{R.C.}} = \frac{3557.2}{1.80} = 1976.2 \ mm^2/m'$$

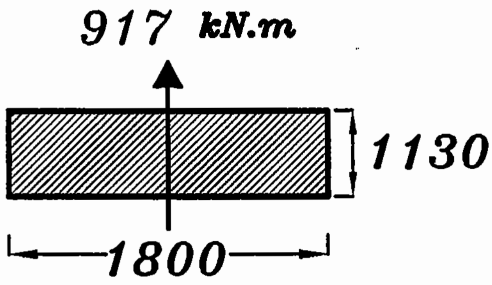
Check $A_{S_{min}}$

$$A_{S_{min}} = \left\{ \begin{array}{l} 1.5\, d = 1.5 * 1130 = 1695 \\ 5\phi 12/m' = 565 \end{array} \right\} 1395 \ mm^2$$

$$\therefore A_S > A_{S_{min}} \longrightarrow \text{Take } A_S = 1976.2 \ mm^2$$

$6\phi 22/m'$

Sec. ③



$$1130 = C_1 \sqrt{\frac{917 * 10^6}{25 * 1800}}$$

$$\longrightarrow C_1 = 7.91 \longrightarrow J = 0.826$$

$$A_S = \frac{M_{act.}}{J\, F_y\, d} = \frac{917 * 10^6}{0.826 * 360 * 1130} = 2729.0\ mm^2$$

$$A_S\ (mm^2/m) = \frac{A_S}{B_{R.C.}} = \frac{2729.0}{1.80} = 1516.1\ mm^2/m'$$

Check $A_{S_{min}}$

$$A_{S_{min}} = \left\{ \begin{array}{l} 1.5\, d = 1.5 * 1130 = 1695 \\ 5 \phi 12/m' = 565 \end{array} \right\} 1695\ mm^2$$

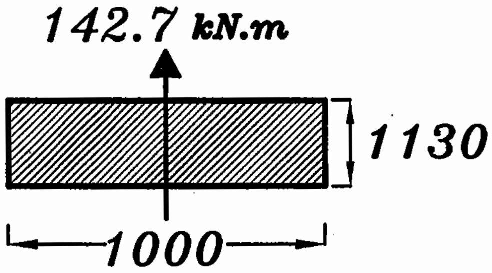
$$\therefore A_S > A_{S_{min}} \longrightarrow \text{Take } A_S = 1516.1\ mm^2$$

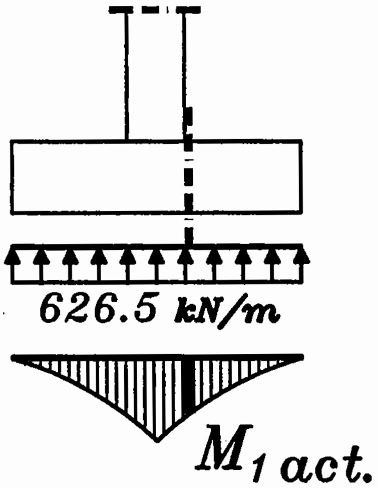
$5 \phi 20/m'$

Transverse direction. Short direction.

Hidden Beam 1

$$M_{1act.} = 142.7 \ kN.m/m$$





$$1130 = C_1 \sqrt{\frac{142.7 * 10^6}{25 \ * 1000}} \longrightarrow C_1 = 14.9 \longrightarrow J = 0.826$$

$$A_S = \frac{M_{act.}}{J \ F_y \ d} = \frac{142.7 * 10^6}{0.826 * 360 * 1130} = 424.7 \ mm^2/m`$$

Check $A_{S_{min}}$

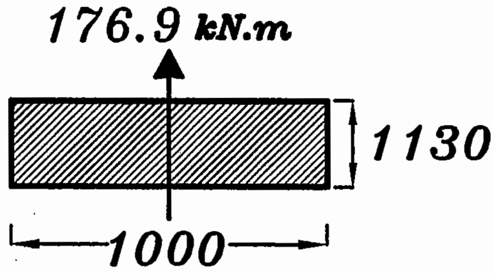
$$A_{S_{min}} = \left\{ \begin{array}{l} 1.5\,d = 1.5 * 1130 = 1695 \\ 5 \phi 12/m` = 565 \end{array} \right\} 1695 \ mm^2$$

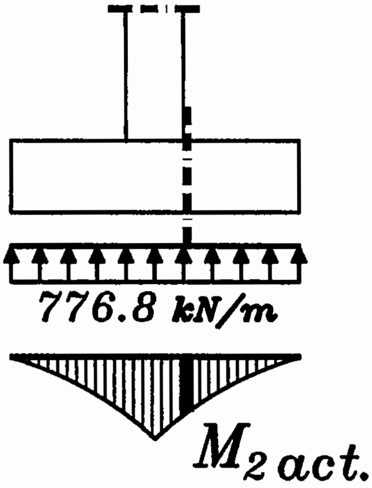
$$\therefore A_S < A_{S_{min}} \longrightarrow Take \ A_S = 1695 \ mm^2$$

$$\boxed{6 \phi 18/m`}$$

Hidden Beam 2

$$M_{2act.} = 176.9 \ kN.m/m$$





$$1130 = C_1 \sqrt{\frac{176.9 * 10^6}{25 \ * 1000}} \longrightarrow C_1 = 13.4 \longrightarrow J = 0.826$$

$$A_S = \frac{M_{act.}}{J \ F_y \ d} = \frac{176.9 * 10^6}{0.826 * 360 * 1130} = 526.4 \quad mm^2/m'$$

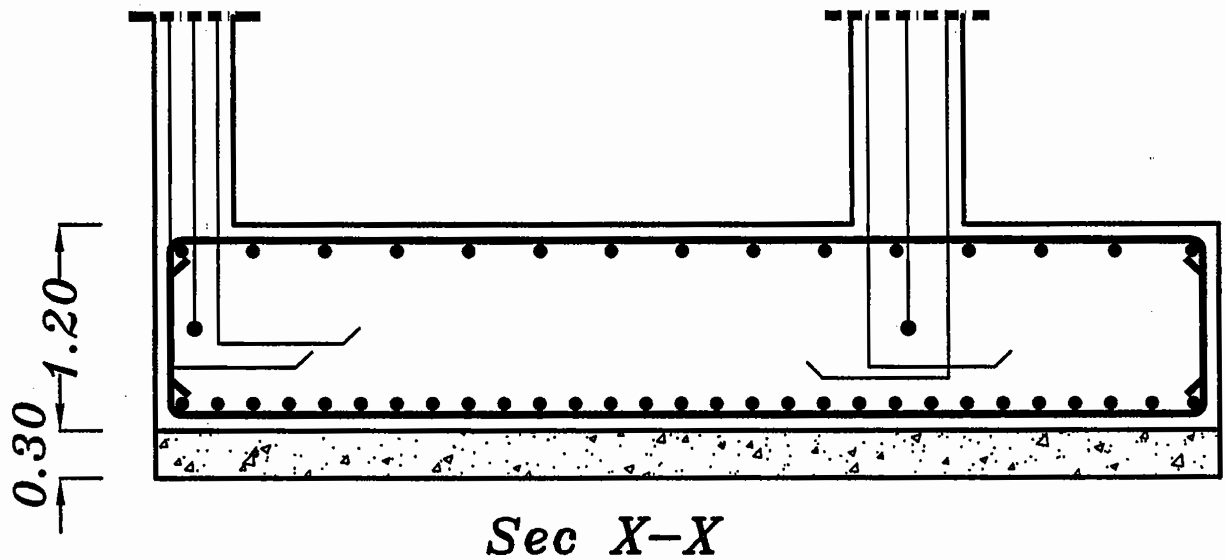
Check $A_{s_{min}}$

$$A_{s_{min}} = \begin{cases} 1.5\,d = 1.5 * 1130 = 1695 \\ 5\phi\,12/m' = 565 \end{cases} \quad 1695 \ mm^2$$

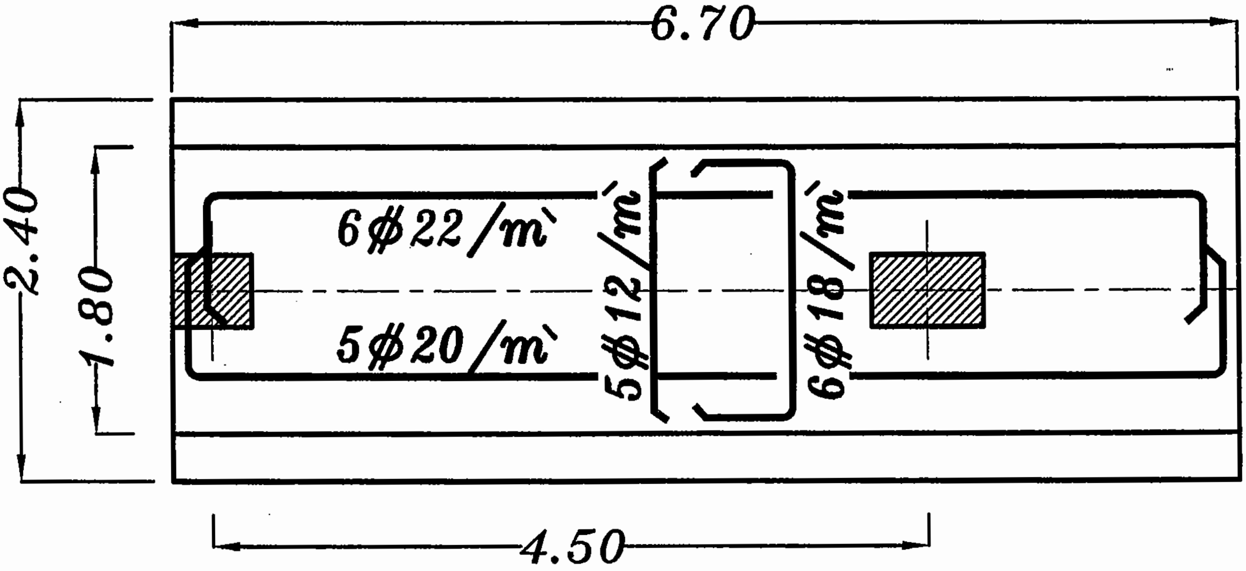
$$\therefore \ A_S < A_{s_{min}} \longrightarrow \text{Take} \ A_S = 1695 \ mm^2$$

$$\boxed{6\phi 18/m'}$$

6 – *Details of Reinforcement.*



Sec X–X



Plan

٥٠ قرش

Ain Shams University
Faculty of Engineering
Laboratory of Soil Mech. & Foundation Eng.
4th Year Civil – Public Works Department
Foundation Engineering
Academic year 2012 - 2013

جامعة عين شمس – كلية الهندسة
معمل ميكانيكا التربة وهندسة الأساسات
رابعة مدني – طلبة شعبة الأشغال العامة
هندسة الأساسات
العام الجامعي ٢٠١٢ – ٢٠١٣

ASSIGNMENT No. 1

DESIGN OF SHALLOW FOUNDATIONS

- Any missing data may reasonably be assumed

1) Design an isolated footing to support a circular column. The diameter of the circular column is 0.8 m, and it carries an axial load of 3500 KN. The suggested thickness of the plain concrete footing is 30 cm. The allowable net bearing capacity of the subsoil is 150 KPa (f_{cu} = 25 N/mm^2, Steel 36/52). Draw details for the designed footing in both plan and cross sectional elevation using scale 1:50.

2) [a] Design a rectangular isolated footing to support a column (40 x 90 cm) carries an axial load of 2500 KN. Consider the thickness of the plain concrete footing equals 40 cm. The allowable net bearing capacity of the subsoil is 150 KPa (f_{cu} = 25 N/mm^2, Steel 36/52). Draw details for the designed footing in both plan and cross sectional elevation using scale 1:50.
[b] Redesign the previous isolated foundation (2-a) assuming the thickness of the plain concrete footing is 10 cm.
[c] Compare between the designed isolated footings in (2-a) and (2-b), with respect to the volume of the plain concrete footings; the volume of the reinforced concrete footings; and the amount of the reinforcements.

3) Two internal square columns in a residential building are spaced two meters center to center. The two columns are subjected to normal forces of 1700 and 1900 kN, respectively. It is required to design a suitable foundation system to support the two columns.
Data:
$q_{all\ net}$ = 200 KN/m^2
$t_{p.c.}$=40 cm. (f_{cu} = 30 N/mm^2, Steel 36/52)

Example (3):

Two internal square columns in a residential building are spaced two meters center to center. the two columns are subjected to normal forces of 1700 and 1900 kN, respectively It is required to design a suitable foundation system to support the two columns.

DATA:

$q_{all\ net} = 200\ kN/m^2$

$F_{cu} = 30\ N/mm^2,\ F_y = 360\ N/mm^2$

$t_{p.c.} = 40\ cm$

Solution.

Data given:

P_1 (working) $= 1700\ kN$

P_2 (working) $= 1900\ kN$

R (working) $= P_1 + P_2 = 3600\ kN$

Bearing capacity of the soil $= q_{all} = 150\ kN/m^2$

$F_{cu} = 30\ N/mm^2$ $F_y = 360\ N/mm^2$

$t_{p.c.} = 40\ cm$

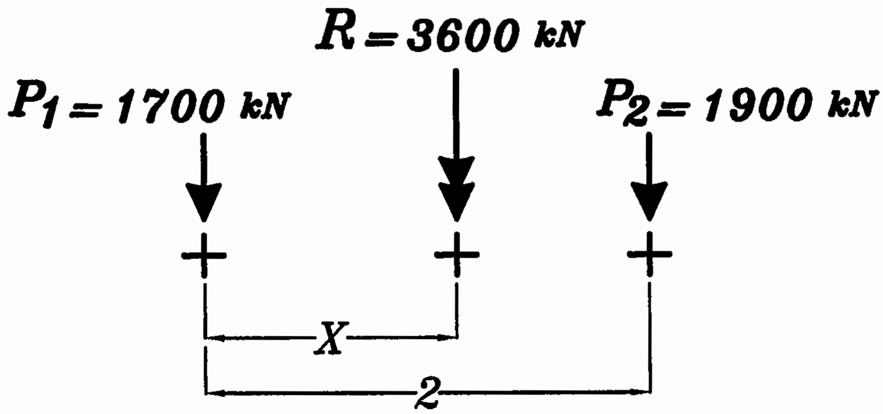
$$\text{Col. } C_1 \text{ Area} = \frac{P_1}{F_{co}} = \frac{1700*1000}{7} = 242857 \ mm^2$$

Take C_1 dimensions $(500*500)$ mm

$$\text{Col. } C_2 \text{ Area} = \frac{P_2}{F_{co}} = \frac{1900*1000}{7} = 271428 \ mm^2$$

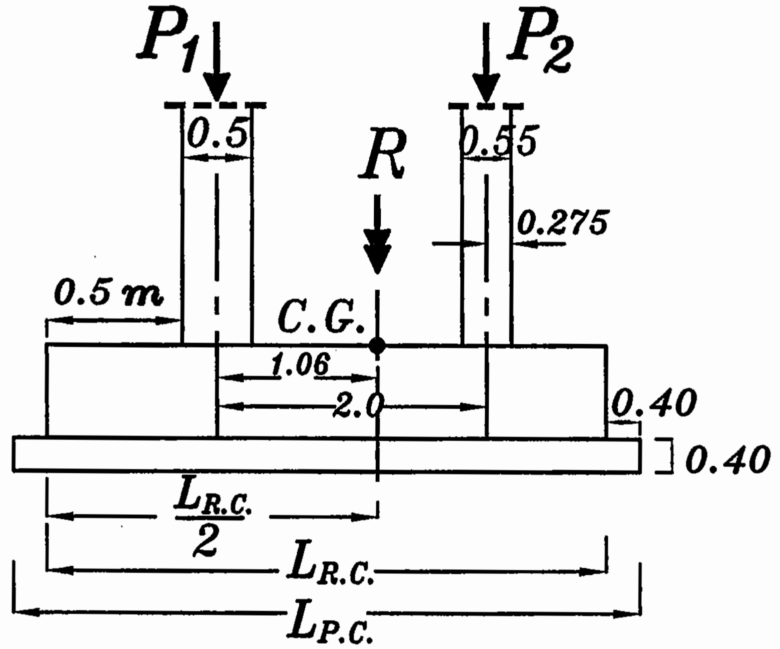
Take C_2 dimensions $(550*550)$ mm

1– Calculate the Footing area. (*Width & Length of R.C. Footing.*)



$$P_2 * S = R * X$$

$$X = \frac{P_2}{R} * S = \frac{1900}{3600} * 2 = 1.06 \ m$$



$$\frac{L_{R.C.}}{2} = (X) + \frac{a_1}{2} + (0.50 \rightarrow 1.0)\ m$$

$$\frac{L_{R.C.}}{2} = (1.06) + \frac{0.5}{2} + 0.50 \longrightarrow L_{R.C.} = 3.62$$

$$\boxed{L_{R.C.} = 3.65\,m}$$

$$L_{P.C.} = L_{R.C.} + 2\,t_{P.C.} = 3.65 + 2(0.4) = 4.45\,m$$

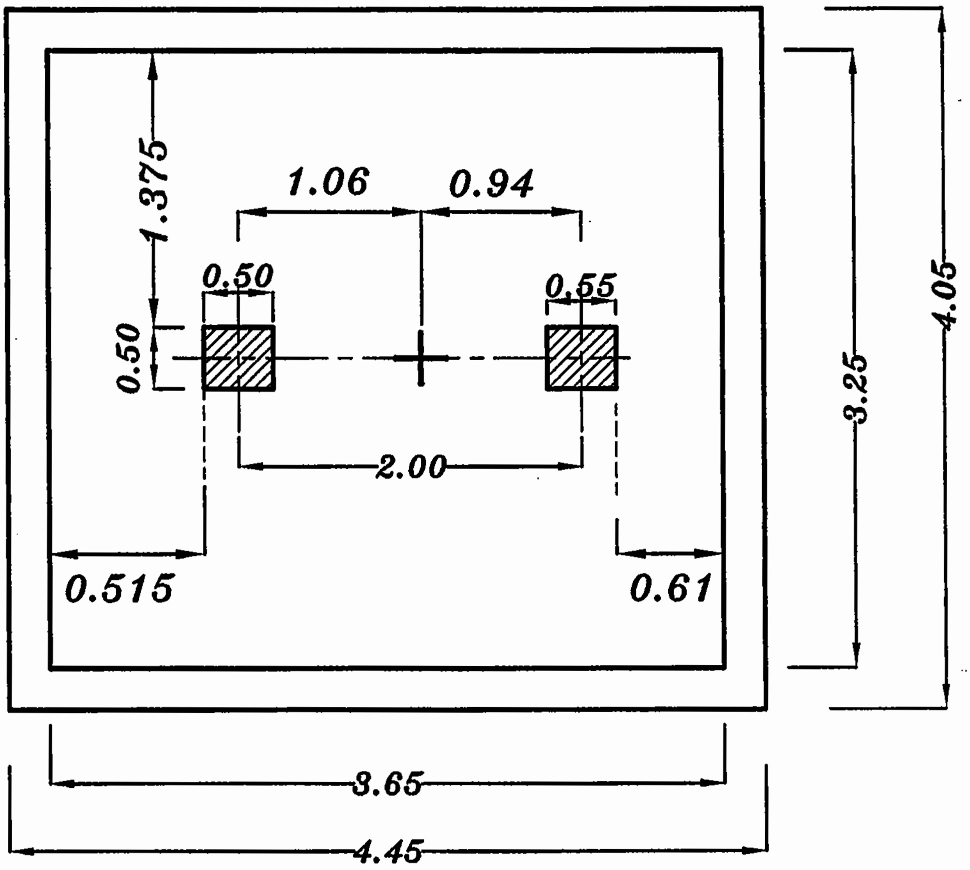
$$\boxed{L_{P.C.} = 4.45\,m}$$

$$A_{P.C.} = \frac{R_w}{q_{all}} = \frac{3600}{200} = 18\ m^2$$

$$A_{P.C.} = 18 = B_{P.C.} * L_{P.C.} = B_{P.C.} * 4.45 \longrightarrow B_{P.C.} = 4.04\,m$$

$$\boxed{B_{P.C.} = 4.05\ m} \qquad \boxed{L_{P.C.} = 4.45\ m}$$

$$\boxed{B_{R.C.} = 3.25\ m} \qquad \boxed{L_{R.C.} = 3.65\ m}$$



2– Design the critical sections For moment. (Depth of R.C. Footing.)

$P_{1\,U.L.} = 1.5 * 1700 = 2550$ kN

$P_{2\,U.L.} = 1.5 * 1900 = 2850$ kN

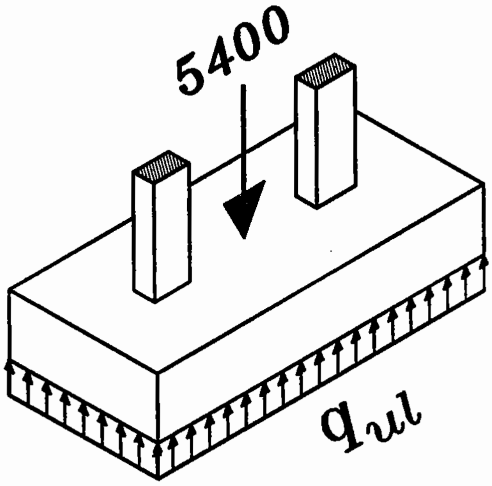
$R_{\,U.L.} = 1.5 * 3600 = 5400$ kN

- *Actual Normal stress on R.C. Footing* **(U.L.)**

$$q_{UL} = \frac{R_{U.L.}}{B_{R.C.} * L_{R.C.}}$$

$$q_{UL} = \frac{5400}{3.25 * 3.65} = 455 \quad kN/m^2$$

$$\boxed{q_{UL} = 455} \quad kN/m^2$$

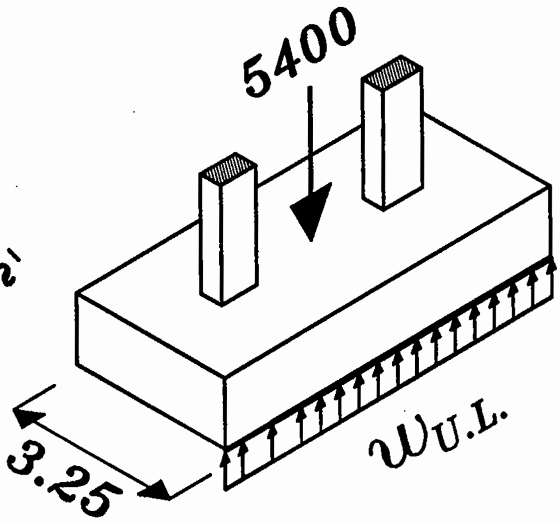


- *Actual Uniform Load on R.C. Footing* **(U.L.)** *as a beam.*

$$w_{U.L.} = \frac{R_{U.L.}}{L_{R.C.}} \quad (kN/m')$$

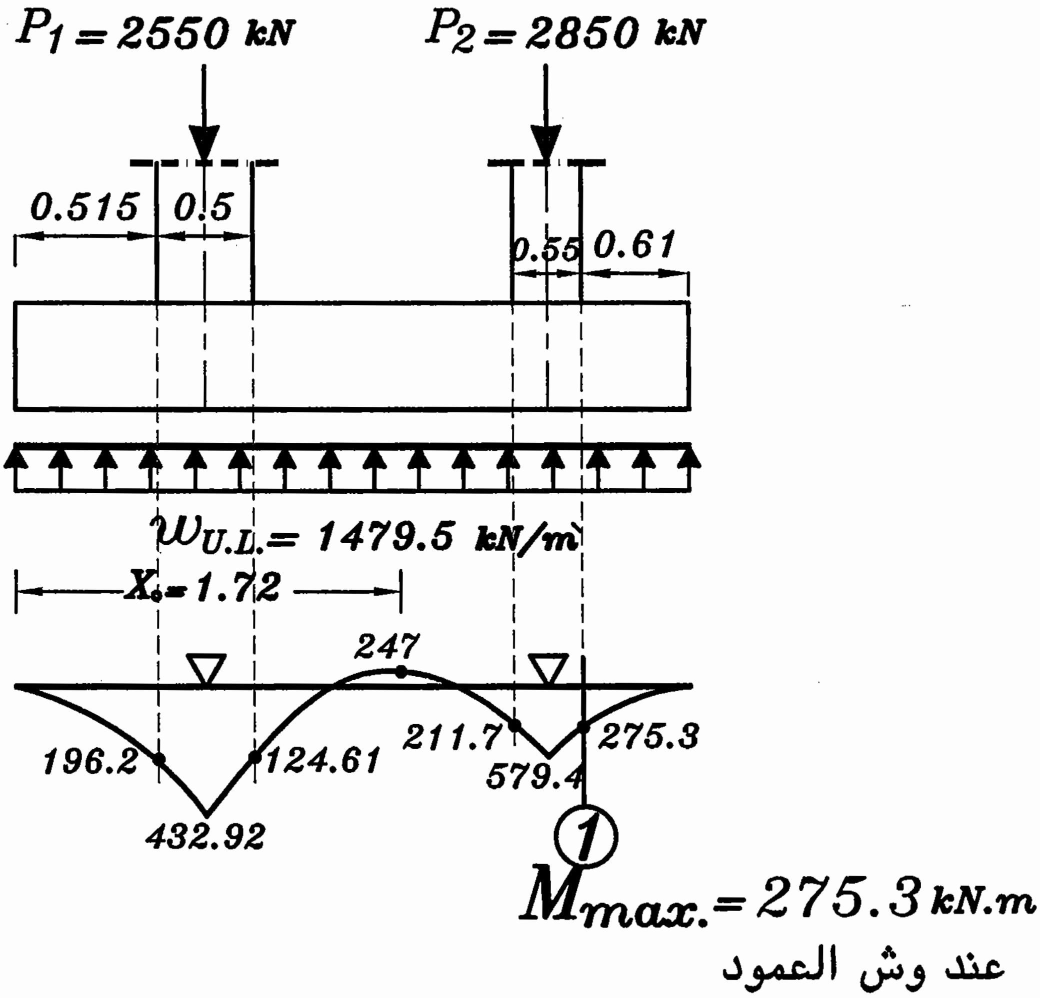
$$w_{U.L.} = \frac{5400}{3.65} = 1479.5 kN/m'$$

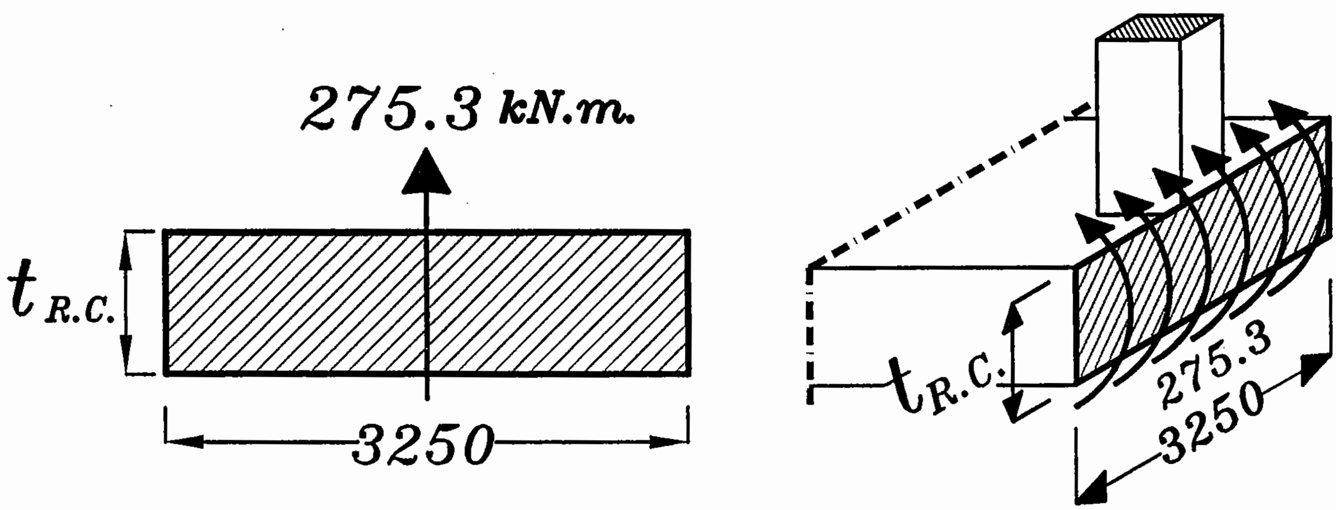
$$\boxed{w_{U.L.} = 1479.5} \; kN/m'$$



Drawing U.L. B.M.D. on all R.C. Footing. Longitudinal direction.

$$\text{Point of Zero Shear } (X_o) = \frac{2550}{1479.5} = 1.72 \text{ m}$$





$$\because \; d = C_1 \sqrt{\frac{M_{act.}}{F_{cu} * b}} \qquad \text{Choose } C_1 = 5.0$$

$$\therefore \; d = 5.0 \sqrt{\frac{275.3 * 10^6}{30 * 3250}} = 265.68 \text{ mm}$$

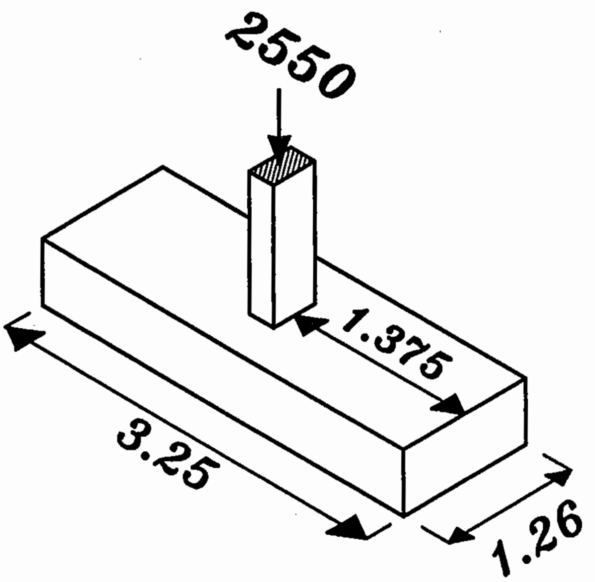
$$t_{R.C.} = d + 70 \text{ mm} = 265.68 + 70 = 335.68 \text{mm}$$

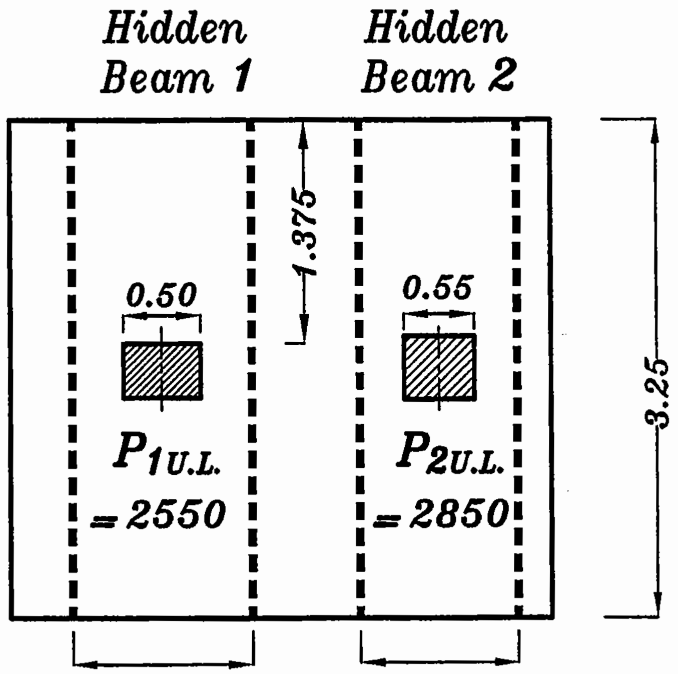
$$\boxed{t_{R.C.} = 450 \text{ mm}} \qquad \boxed{d = 380 \text{ mm}}$$

Check depth in Transverse direction.

As a Hidden Beam.

Hidden Beam 1

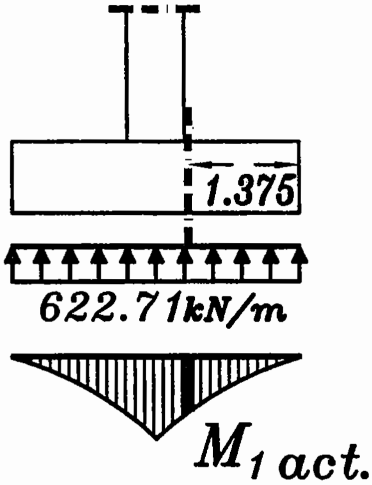




$$L_1 = b_1 + 2d = 0.5 + 2(0.38) = 1.26 \text{ m}$$

$$L_2 = b_2 + 2d = 0.55 + 2(0.38) = 1.31 \text{ m}$$

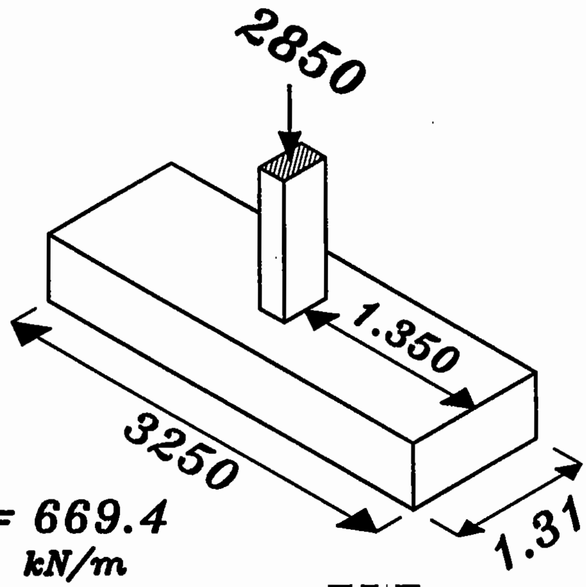
$$q_{1UL} = \frac{P_{1\,U.L.}}{B_{R.C.} * L_1} = \frac{2550}{3.25 * 1.26} = 622.71 \text{ kN/m}$$



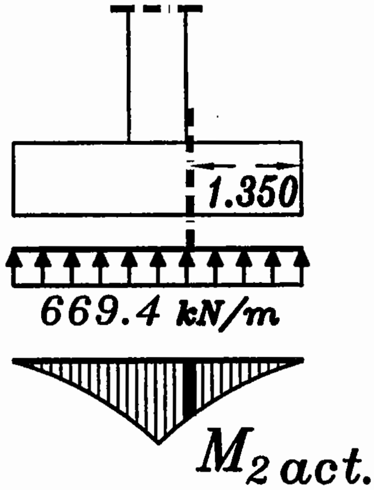
$$M_{1act.} = (622.71 * 1.375 * 1.0m)\,\frac{1.375}{2}$$

$$\boxed{M_{1act.} = 588.65 \text{ kN.m/m}}$$

Hidden Beam 2



$$q_{2UL} = \frac{P_{2\,U.L.}}{B_{R.C.} * L_2} = \frac{2850}{3.25 * 1.31} = 669.4 \text{ kN/m}$$



$$M_{2act.} = (669.4 * 1.350 * 1.0m)\,\frac{1.350}{2}$$

$$\boxed{M_{2act.} = 610 \text{ kN.m/m}}$$

M_{bigger} From $M_{1act.}$ & $M_{2act.}$

$$\boxed{M_{bigger} = 610 \text{ kN.m/m}}$$

$$380 = C_1 \sqrt{\frac{610 * 10^6}{30 * 1000}} \longrightarrow C_1 = 2.66 < 2.8$$

$\because$ **We have to increase the depth**

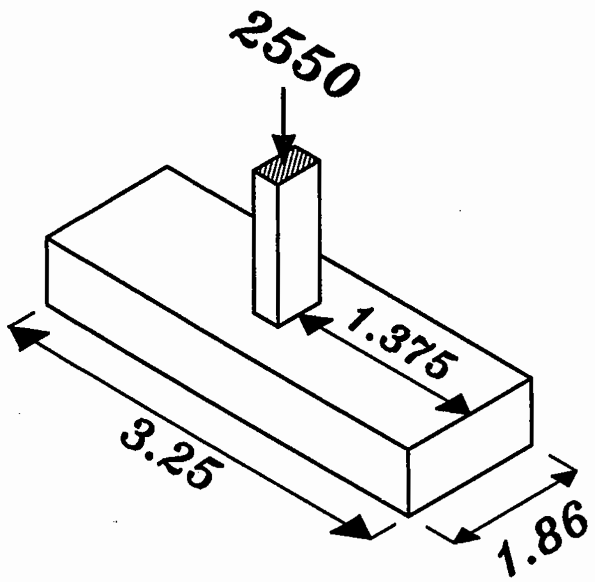
$$\therefore d = 4.5 \sqrt{\frac{610 * 10^6}{30 * 1000}} = 641.67 \ mm$$

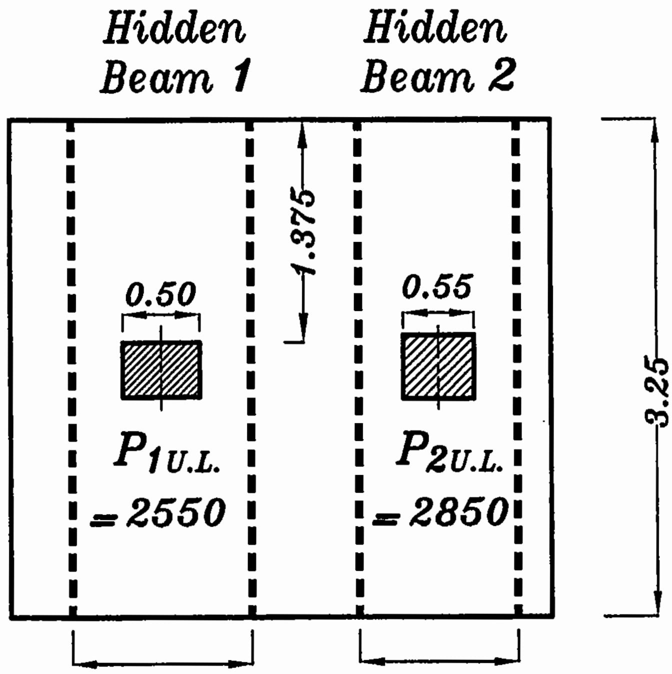
$$t_{R.C.} = d + 70 \ mm = 641.67 + 70 = 711.67 \ mm$$

$t_{R.C.} = 750 \ mm$ | $d = 680 \ mm$

Recalculate the B.M. For Transverse direction with the new depth.

Hidden Beam 1

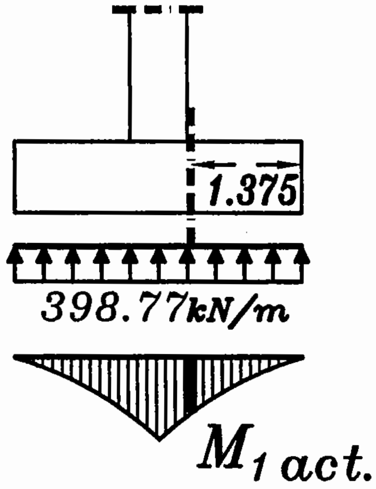




$$L_1 = b_1 + 2d = 0.5 + 2(0.68) = 1.86 \ m$$

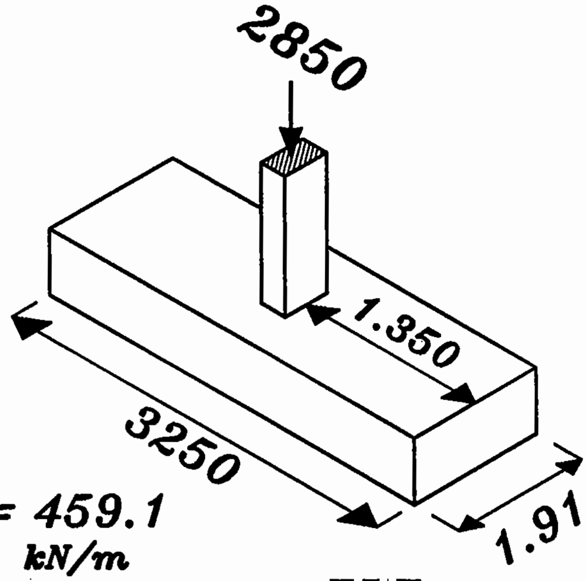
$$L_2 = b_2 + 2d = 0.55 + 2(0.68) = 1.91 \ m$$

$$q_{1UL} = \frac{P_{1\,U.L.}}{B_{R.C.} * L_1} = \frac{2550}{3.25 * 1.86} = 421.84 \text{ kN/m}$$



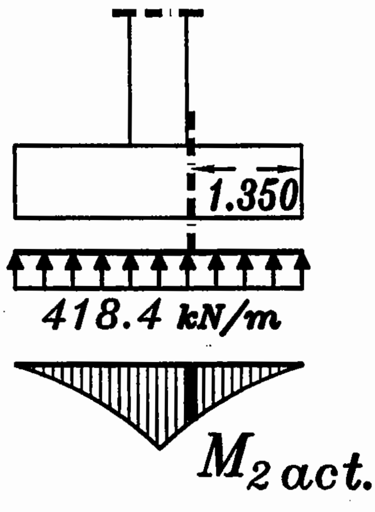
$$M_{1act.} = (421.84 * 1.375 * 1.0m)\,\frac{1.375}{2}$$

$$\boxed{M_{1act.} = 398.77 \text{ kN.m/m}}$$



Hidden Beam 2

$$q_{2UL} = \frac{P_{2\,U.L.}}{B_{R.C.} * L_2} = \frac{2850}{3.25 * 1.91} = 459.1 \text{ kN/m}$$



$$M_{2act.} = (459.1 * 1.350 * 1.0m)\,\frac{1.350}{2}$$

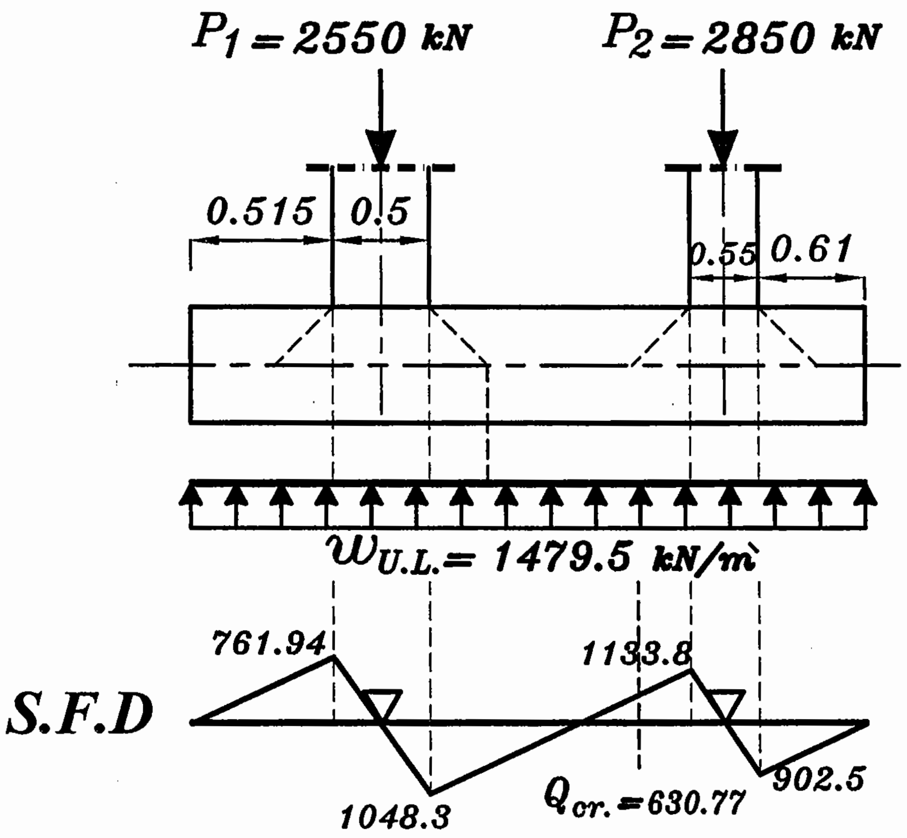
$$\boxed{M_{2act.} = 418.4 \text{ kN.m/m}}$$

M_{bigger} From $M_{1act.}$ & $M_{2act.}$

$$\boxed{M_{bigger} = 418.4 \text{ kN.m/m}}$$

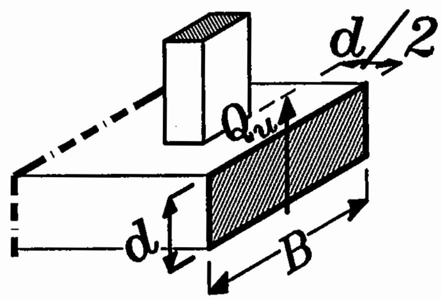
3 – Check Shear. *at long direction*

Critical section For Shear.



$$Q_{cr.} = Q_{max.} - W_{U.L.} * \frac{d}{2} = 1133.8 - 1479.5 * \frac{0.68}{2} = 630.77 kN$$

* Calculate Actual shear stress. (q_u)



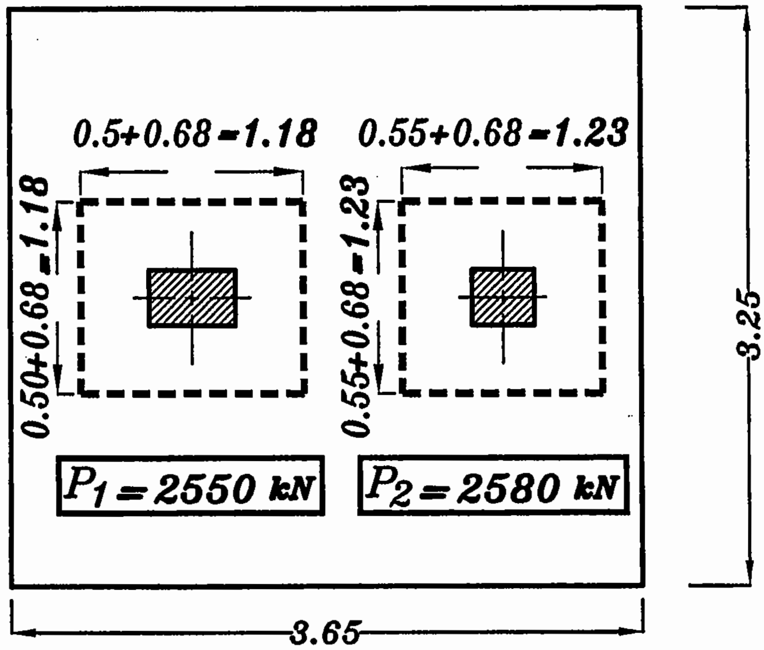
$$q_{cu} = \frac{Q_{cr.}}{B * d} = \frac{630.77 * 10^3}{3250 * 680} = 0.285 \ kN/m^2$$

* Allowable shear stress. (q_{su})

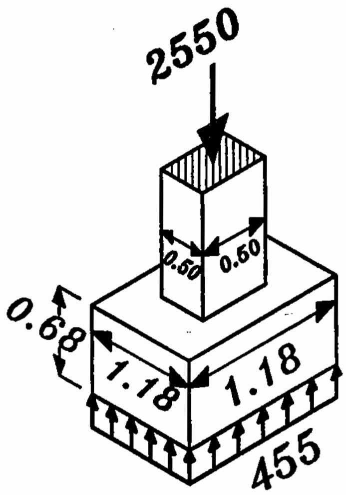
$$q_{su} = 0.16 \sqrt{\frac{F_{cu}}{\gamma_c}} = 0.16 \sqrt{\frac{30}{1.5}} = 0.716 \ N/mm^2$$

$q_{cu} < q_{scu}$ ⟶ Safe shear stresses
No need to increase dimensions.

4- Check Punching Shear.



Column 1



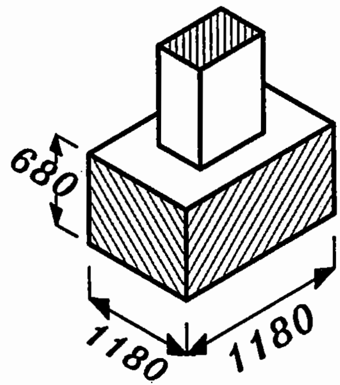
* Calculate Punching Force. (Q_{1p})

$$Q_{1p} = 2550 - 455\ (1.18 * 1.18)$$

$$= 1916.5\ kN$$

$$A_{1p} = [2(1180) + 2(1180)] * 680$$

$$= 3209600\ mm^2$$

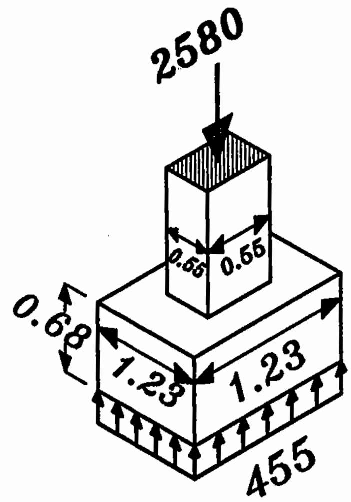


* Calculate Actual Punching shear stress. q_{1pu}

$$q_{1pu} = \frac{1916.5 * 10^3}{3209600} = 0.597\ N/mm^2$$

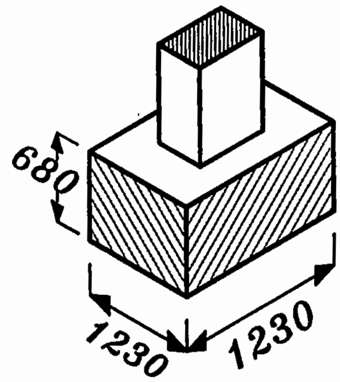
Column 2

* Calculate Punching Force. (Q_{2p})



$$Q_{2p} = 2580 - 455\ (1.23 * 1.23)$$
$$= 1891.6\ kN$$

$$A_{2p} = [2(1230) + 2(1230)] * 680$$
$$= 3345600\ mm^2$$



* Calculate Actual Punching shear stress. q_{2pu}

$$q_{2pu} = \frac{1891.6 * 10^3}{3345600} = 0.565\ N/mm^2$$

q_{pumax} the bigger q_{1pu} & $q_{2pu} = 0.597\ N/mm^2$

* Calculate allowable Punching shear stress. q_{pcu}

$$q_{pcu} = 0.316\ (0.5 + \frac{a}{b}) \sqrt{\frac{F_{cu}}{\gamma_c}}$$

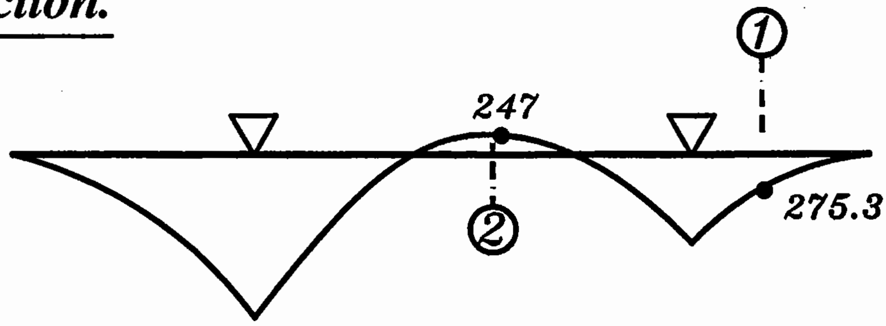
$$(0.5 + \frac{a}{b}) = (0.5 + \frac{0.50}{0.50}) = 1.50 > 1.0$$

$$\therefore\ q_{pcu} = 0.316 \sqrt{\frac{F_{cu}}{\gamma_c}} = 0.316 \sqrt{\frac{30}{1.5}} = 1.41\ N/mm^2$$

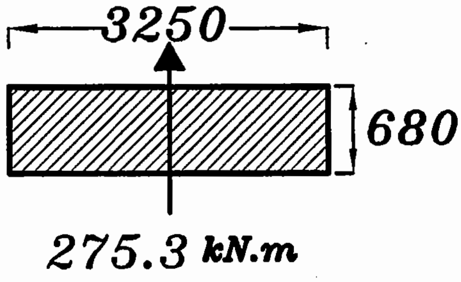
$q_{pu} \leqslant q_{pcu} \longrightarrow$	Safe punching shear. No need to increase dimensions.

5- Reinforcement of the Footing.

Longitudinal direction.



Sec. ①



$$680 = C_1 \sqrt{\frac{275.3 * 10^6}{30 * 3250}}$$

$$\longrightarrow C_1 = 12.79 \longrightarrow J = 0.826$$

$$A_S = \frac{M_{act.}}{J\, F_y\, d} = \frac{275.3 * 10^6}{0.826 * 360 * 680} = 1361.5 \ mm^2$$

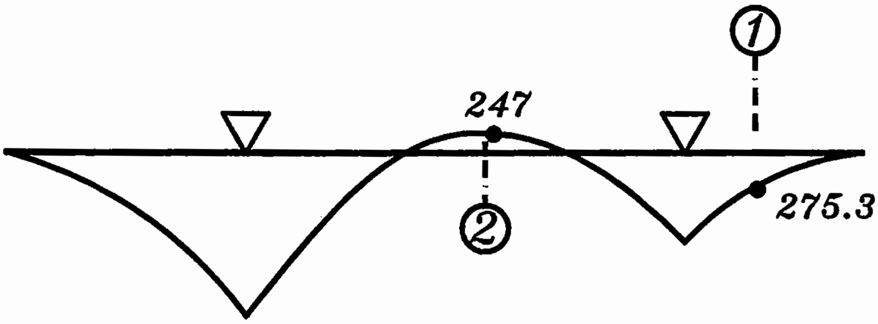
$$A_{S\ (mm^2/m)} = \frac{A_S}{B_{R.C.}} = \frac{1361.5}{3.25} = 419 \ mm^2/m'$$

Check $A_{S_{min}}$

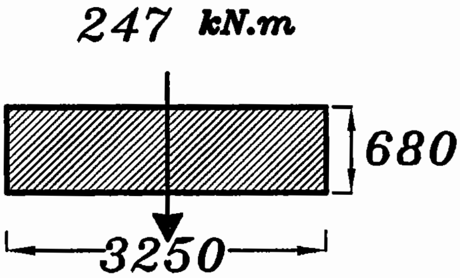
$$A_{S_{min}} = \left\{ \begin{array}{l} 1.5\, d = 1.5 * 680 = 1020 \\ 5 \phi 12/m' = 565 \end{array} \right\} 1020 \ mm^2$$

$$\therefore A_S < A_{S_{min}} \longrightarrow \text{Take } A_S = 1020 \ mm^2$$

$$\boxed{6 \phi 16/m'}$$



Sec. ②



$$680 = C_1 \sqrt{\frac{247 * 10^6}{30 * 3250}}$$

$$\longrightarrow C_1 = 13.5 \longrightarrow J = 0.826$$

$$A_S = \frac{M_{act.}}{J\, F_y\, d} = \frac{247 * 10^6}{0.826 * 360 * 680} = 1221.5\ mm^2$$

$$A_S\ (mm^2/m) = \frac{A_S}{B_{R.C.}} = \frac{1221.5}{3.25} = 375.9\ mm^2/m'$$

Check $A_{S_{min}}$

$$A_{S_{min}} = \left\{ \begin{array}{l} 1.5\, d = 1.5 * 680 = 1020 \\ 5 \phi 12/m' = 565 \end{array} \right\} 1020\ mm^2$$

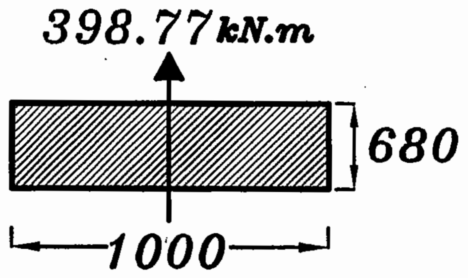
$$\therefore A_S < A_{S_{min}} \longrightarrow \text{Take } A_S = 1020\ mm^2$$

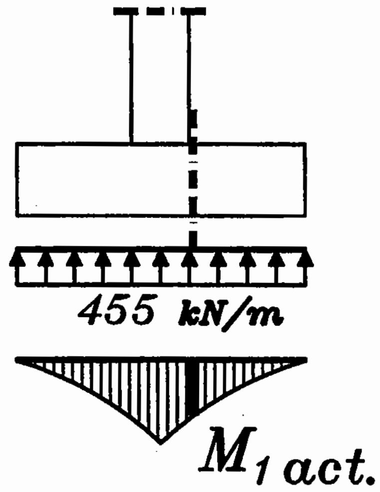
$$\boxed{6 \phi 16/m'}$$

Transverse direction. Short direction.

Hidden Beam 1

$$M_{1act.} = 398.77 \; kN.m/m$$





$$680 = C_1 \sqrt{\frac{398.77 * 10^6}{30 * 1000}} \longrightarrow C_1 = 5.81 \longrightarrow J = 0.826$$

$$A_s = \frac{M_{act.}}{J \, F_y \, d} = \frac{398.77 * 10^6}{0.826 * 360 * 680} = 1972.1 \; mm^2/m'$$

Check $A_{s\,min}$

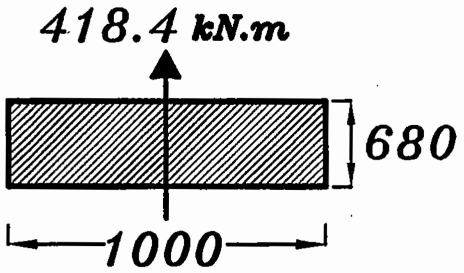
$$A_{s\,min} = \begin{cases} 1.5\, d = 1.5 * 680 = 1020 \\ 5 \phi 12/m' = 565 \end{cases} \; 1020 \; mm^2$$

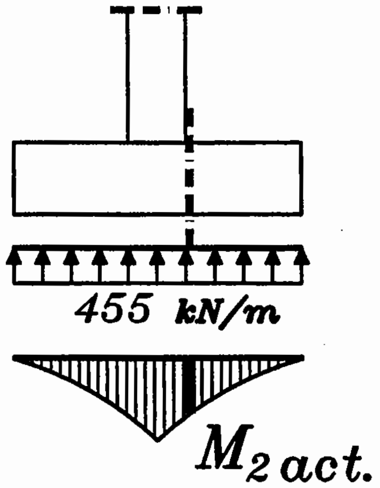
$$\therefore \; A_s > A_{s\,min} \longrightarrow o.k.$$

$$A_s = 1972.1 \; mm^2 \qquad \boxed{6 \phi 22/m'}$$

Hidden Beam 2

$$M_{2act.} = 418.4\ kN.m/m$$





$$680 = C_1 \sqrt{\frac{418.4 * 10^6}{30 * 1000}} \longrightarrow C_1 = 5.75 \longrightarrow J = 0.826$$

$$A_S = \frac{M_{act.}}{J\ F_y\ d} = \frac{418.4 * 10^6}{0.826 * 360 * 680} = 2069.2\ mm^2/m'$$

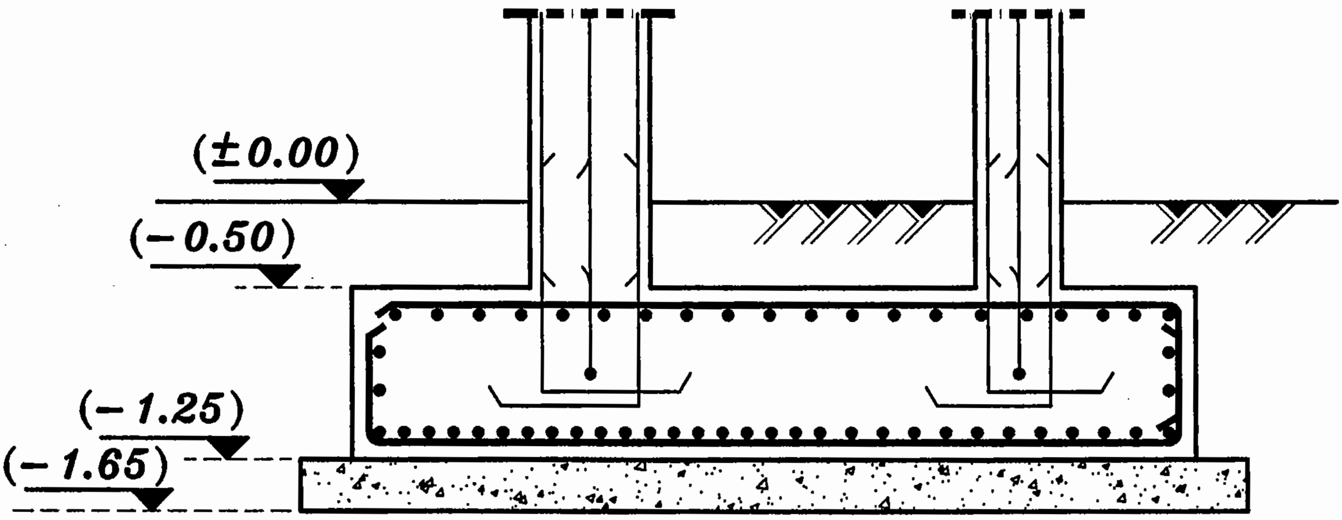
Check $A_{s_{min}}$

$$A_{s_{min}} = \begin{cases} 1.5\,d = 1.5 * 680 = 1020 \\ 5\phi\,12/m' = 565 \end{cases} 1020\ mm^2$$

$$\therefore\ A_S > A_{S_{min}} \longrightarrow o.k.$$

$$A_S = 2069.2\ mm^2 \qquad \boxed{6\phi 22/m'}$$

6 – Details of Reinforcement.



Sec X–X