أشغال ٣

م/الطيب

4th Year Civil - Public works

Foundation Design

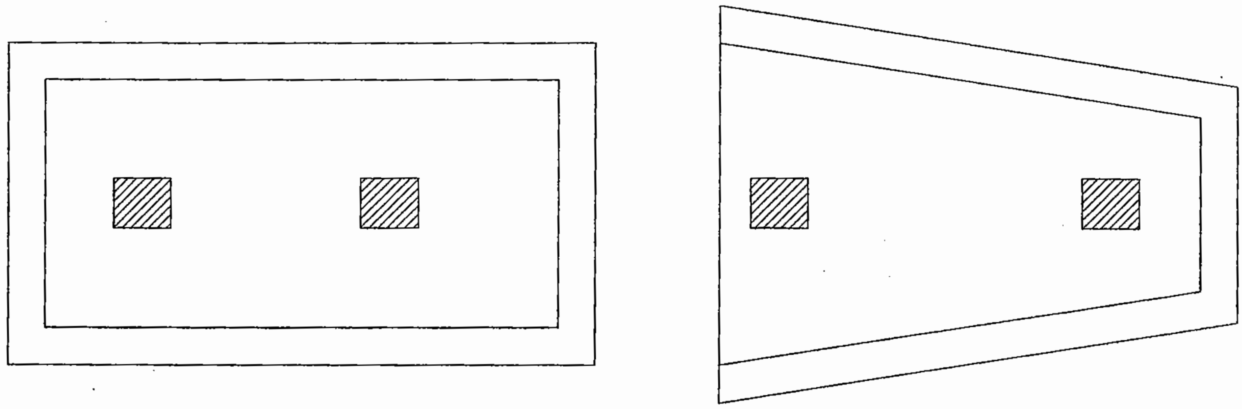
(3)

Shallow Foundations

3- Design of combined footing

Design of Combined footing

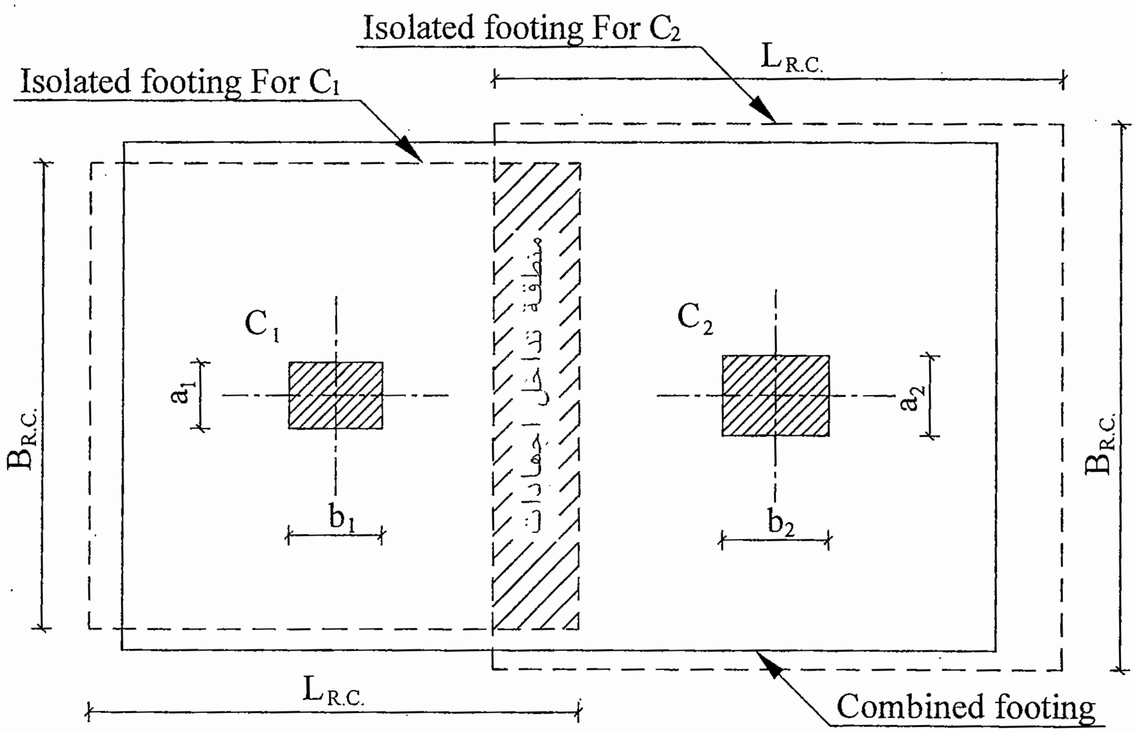
- القاعدة الشتركة Combined footing هى قاعدة تحمل عمودين فقط ويوجد منها نوعان:-



1- Rectangular footing   2- Trapezoidal footing

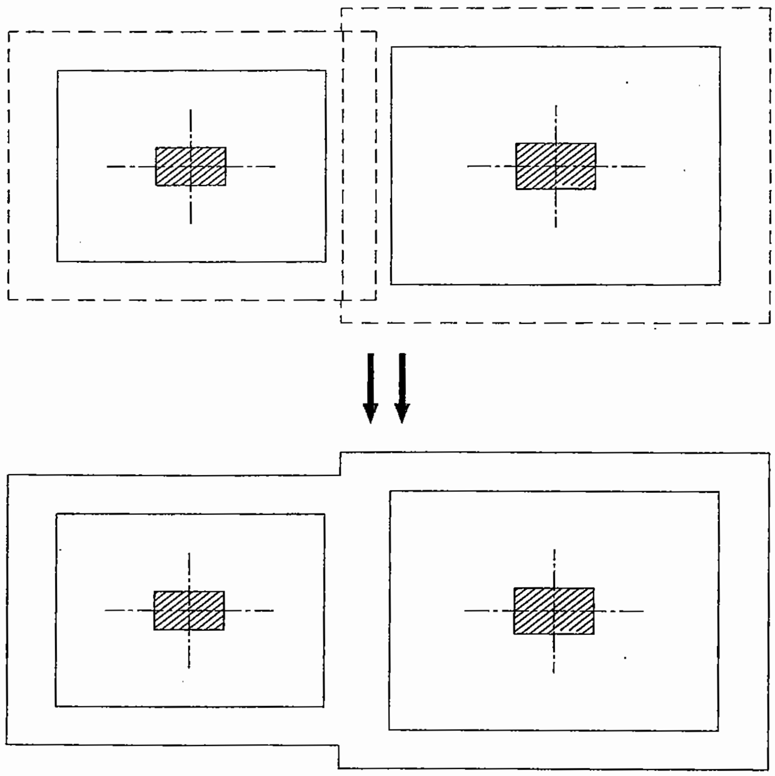
- نلجأ لاستخدام القواعد المشتركة عندما لا نستطيع استخدام قاعدة منفصلة أسفل كل عمود ويحدث ذلك فى حالتين:-

الحالة الأولى:- عند توقيع أبعاد الخرسانة المسلحة لقاعدتين منفصلتين لعمودين متجاورين على الرسم ووجد أن القاعدتين متداخلتان مما يعنى حدوث تداخل فى الإجهادات أسفل القاعدتين مما يعنى زيادة قيمة الإجهادات فى المنطقة المشتركة عن (q_{all}) وفى هذه الحاله يكون حل استخدام قاعدتين منفصلتين مرفوض ويجب استخدام Rectangular combined footing.



- ملاحظة هامة:-

- فى حالة حدوث تداخل فى الخرسانة العادية لعمودين متجاورين وليس فى الخرسانة المسلحة يمكن استخدام قاعدة عادية واحدة للعمودين بينما تكون القاعدة المسلحة لكل عمود منفصلة مع مراعاة الشروط التالية:-



١- المسافة بين القاعدتين المسلحتين لا تقل عن 20 cm وذلك حتى يمكن تنفيذ الشدة الخشبية.

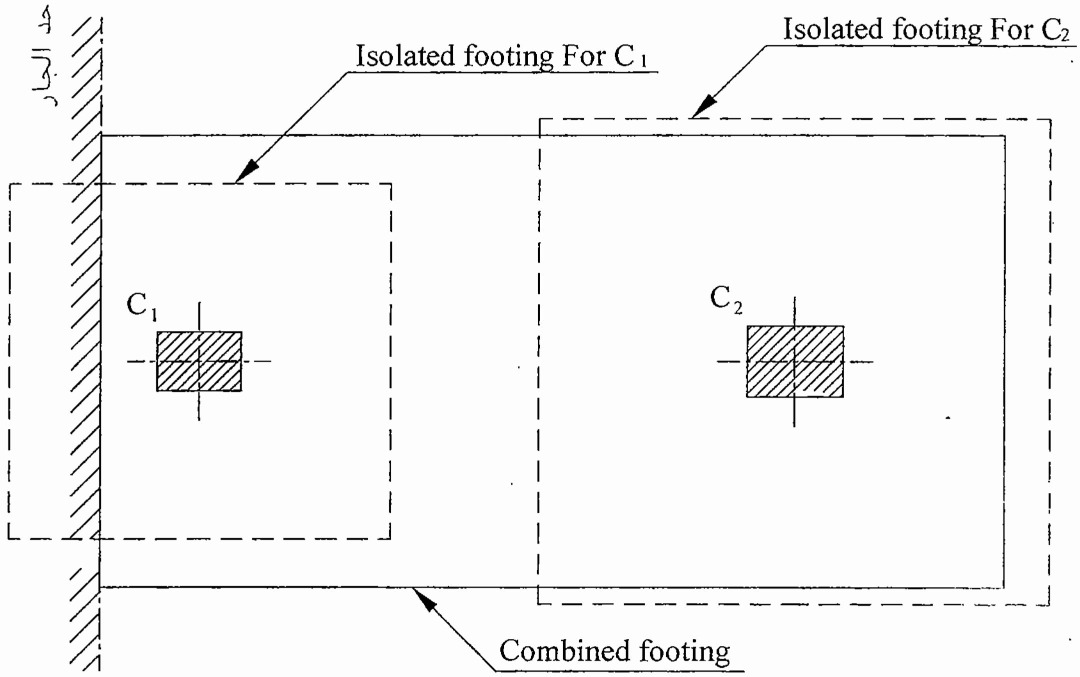
٢- إذا كان سمك العادية $t_{P.C.} > 20cm$ يجب عمل check على أن الاجهادات أسفل العادية لا تزيد عن q_{all}.

- For $t_{P.C.} > 20$ cm:-
- Check that:-

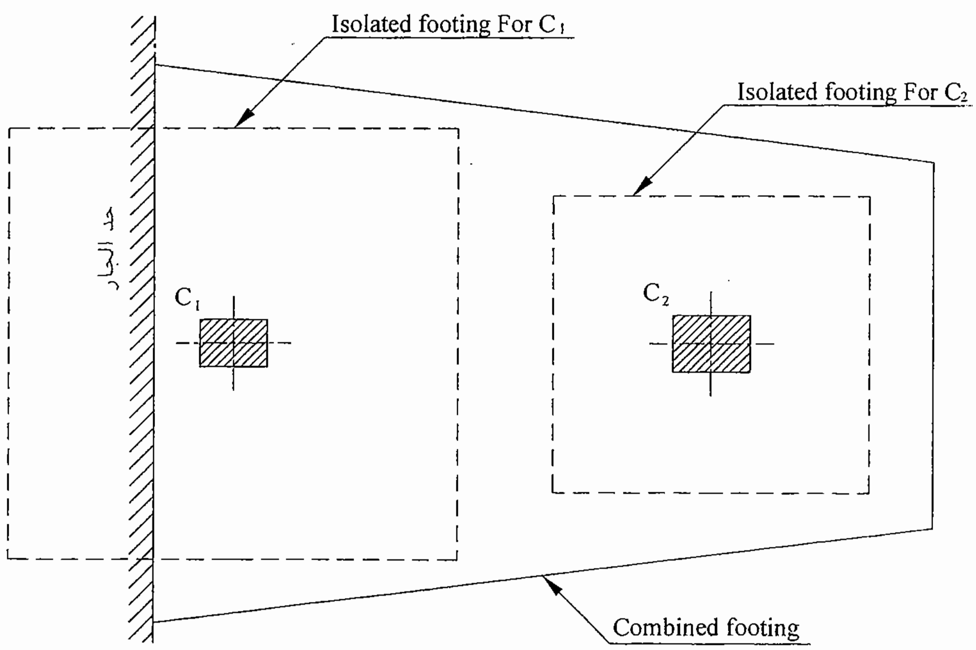
$$\frac{P_1 + P_2}{A_{P.C.}} \le q_{all}$$

الحالة الثانية:- عند توقيع أبعاد الخرسانة العادية لقاعدة منفصلة لعمود قريب من حد الجار Property line ووجد أن جزء من القاعدة تعدت حد الجار وهذا مرفوض لذلك نلجأ لعمل قاعدة مشتركة Combined footing مع أقرب عمود داخلى من عمود الجار حيث:-

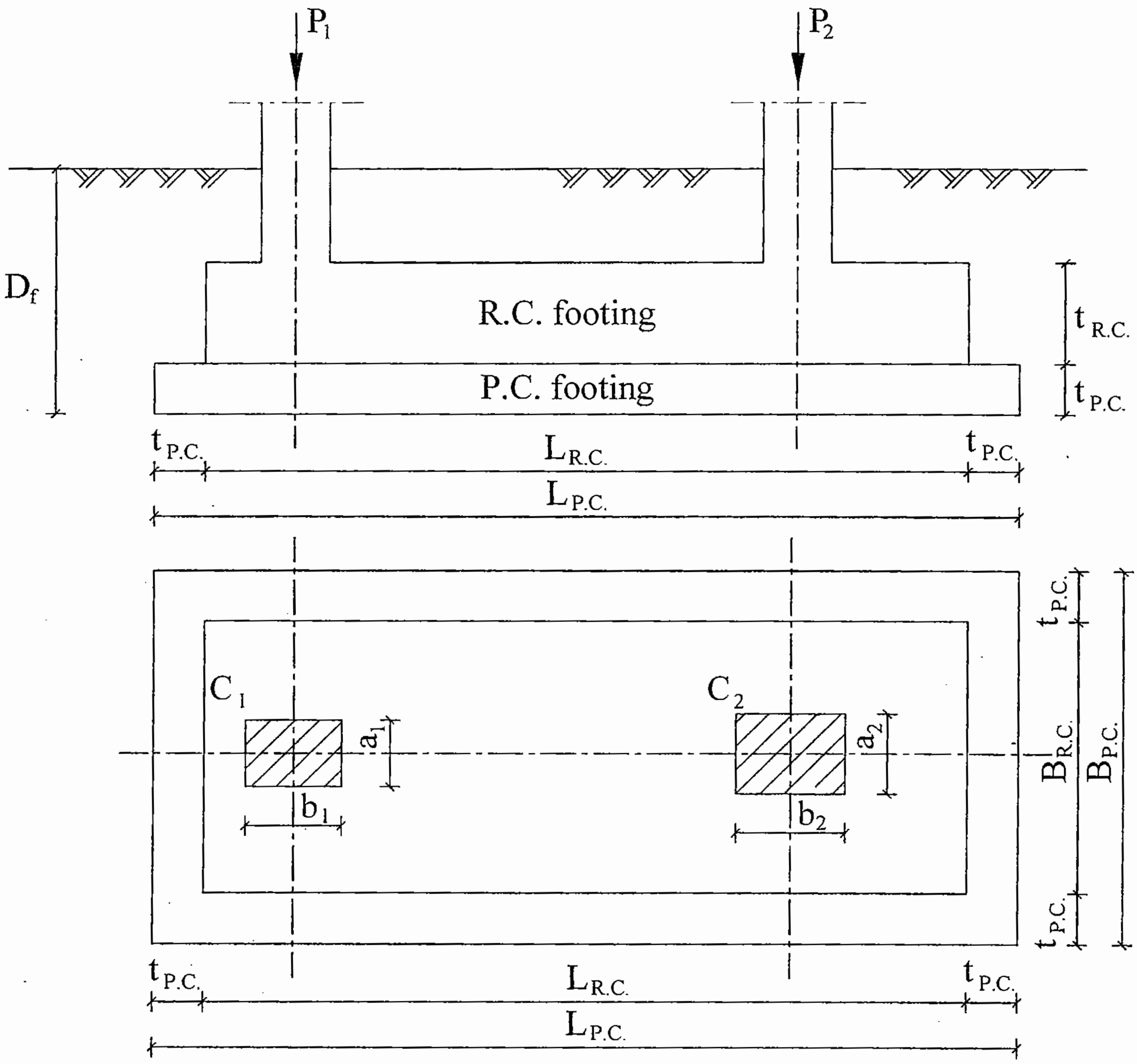
١- إذا كان حمل عمود الجار Exterior column أقل من حمل العمود الداخلى Interior column نستخدم Rectangular combined footing.



٢- إذا كان حمل عمود الجار Exterior column أكبر من حمل العمود الداخلى Interior column نستخدم Trapezoidal combined footing.



Design of Rectangular Combined Footing

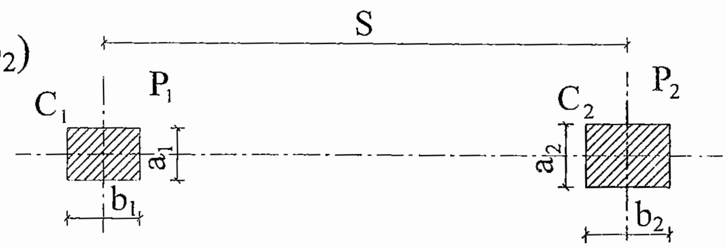


الفكرة الأساسية لتصميم القاعدة المشتركة:-

- يجب أن يكون مركز ثقل c.g. لمحصلة حمل العمودين هو نفسه مركز ثقل القاعدة حتى يكون توزيع الإجهادات أسفل القاعدة منتظم.

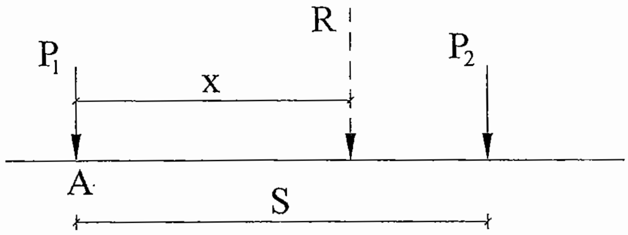
Given:-

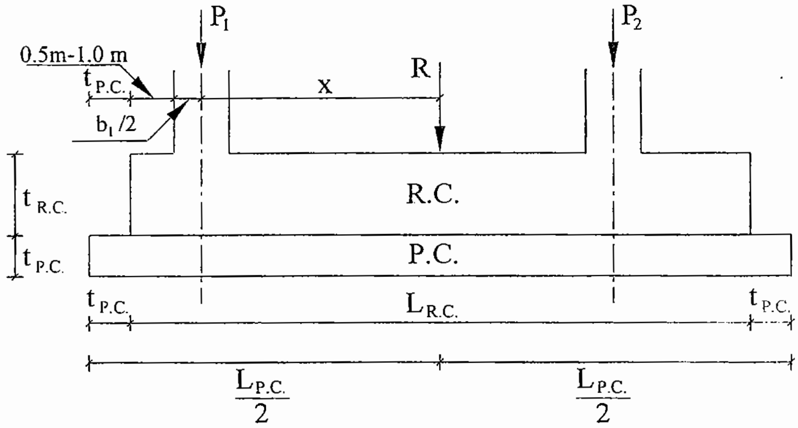
- Column load (P_1, P_2)
- Column dimensions (a_1, b_1 & a_2, b_2)
- Spacing between columns (S)
- q_{all} = allowable bearing capacity
- $t_{P.C.}$ = plain concrete thickness
- f_{cu} & f_y



-Steps of design:-

1- Calculate the dimensions of footing:-





$$R = P_1 + P_2$$

$$\sum M_{@A}$$

$$\Rightarrow R \cdot x = P_2 \cdot S$$

$$\therefore x = \frac{P_2 \cdot S}{R}$$

Where $P_2 > P_1$

$$\frac{L_{P.C.}}{2} = x + \frac{b_1}{2} + (0.5\text{ m} - 1.0\text{ m}) + t_{P.C.}$$

$\therefore L_{P.C.} = \surd$ تقرب لأقرب ٥ سم بالزيادة

$$\therefore L_{R.C.} = L_{P.C.} - 2\, t_{P.C.}$$

i- for $t_{P.C.} < 20$ cm:-

$$A_{R.C.} = \frac{R}{q_{all}} = B_{R.C.} \times L_{R.C.}$$

$\Rightarrow B_{R.C.} = \surd$

تقرب لأقرب ٥ سم بالزيادة

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

ii- for $t_{P.C.} > 20$ cm:-

$$A_{P.C.} = \frac{R}{q_{all}} = B_{P.C.} \times L_{P.C.}$$

$\Rightarrow B_{P.C.} = \surd$

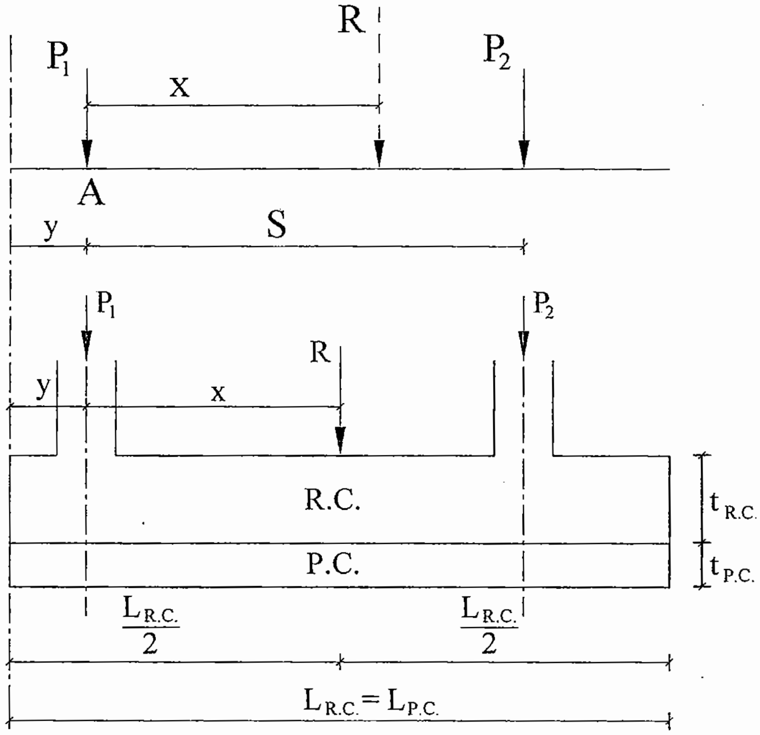
تقرب لأقرب ٥ سم بالزيادة

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

- ملاحظة هامة:-

– فى حالة وجود عمود قريب من حد الجار يكون طرف القاعدة المشتركة ينطبق على حد الجار أى أن المسافة (L/2) محددة مسبقاً ويتم حساب أبعاد القاعدة كما يلى:-

1- Calculate the dimensions of footing:-



$$R = P_1 + P_2$$

$$\sum M_{@A}$$

$$\Rightarrow R \cdot x = P_2 \cdot S$$

$$\therefore x = \frac{P_2 \cdot S}{R}$$

Where $P_2 > P_1$

$$\frac{L_{R.C.}}{2} = x + y$$

$$\therefore L_{R.C.} = \surd$$

(تقرب لأقرب ٥ سم بالزيادة)

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

- لا يتم عمل رفرفة القاعدة العادية فى هذه الحالة حتى ينطبق .c.g العادية على .c.g المسلحة حيث لا نستطيع عمل رفرفة ناحية حد الجار.

i- for $t_{P.C.} < 20$ cm:-

$$A_{R.C.} = \frac{R}{q_{all}} = B_{R.C.} \times L_{R.C.}$$

$$\Rightarrow B_{R.C.} = \surd$$

تقرب لأقرب ٥ سم بالزيادة

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

ii- for $t_{P.C.} > 20$ cm:-

$$A_{P.C.} = \frac{R}{q_{all}} = B_{P.C.} \times L_{P.C.}$$

$$\Rightarrow B_{P.C.} = \surd$$

تقرب لأقرب ٥ سم بالزيادة

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

- Design of R.C. footing:-

١- يتم تحويل جميع الأحمال إلى ultimate loads قبل عمل أى حسابات للعزوم.

$$P_{1u} = P_1 \times 1.5 \quad \& P_{2u} = P_2 \times 1.5 \quad \& R_u = R \times 1.5$$

- $w_u = \dfrac{R_u}{L_{R.C.}}$ = ultimate uniform load under R.C. in long direction

- $q_u = \dfrac{P_u}{B_{R.C.} \times L_{R.C.}}$ = ultimate uniform stress under R.C.

1- Design of footing in longitudinal direction:-

- بمعلومية جميع قيم الأحمال والأبعاد نقوم برسم كل من الـ B.M.D. & S.F.D وذلك عن طريق حساب قيم الـ B.M. & S.F. على وش الأعمدة وكما يجب حساب قيمة $M_{max.}$ وذلك عند الـ Point of zero shear وذلك كما يلى:-

- $Q_1 = w_u \cdot L_1$

- $M_1 = w_u \cdot \dfrac{(L_1)^2}{2}$

- $Q_2 = P_{1u} - w_u \cdot (L_1 + b_1)$

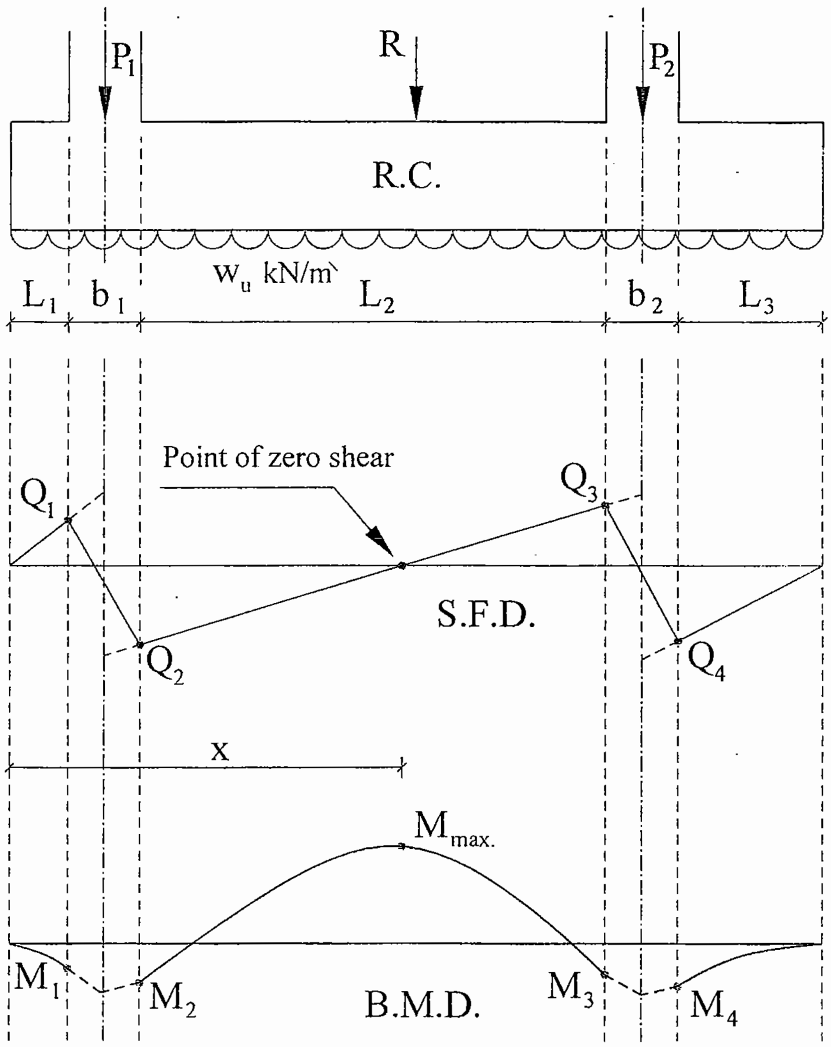
- $M_2 = w_u \cdot \dfrac{(L_1 + b_1)^2}{2} - P_{1u} \cdot (\dfrac{b_1}{2})$

- $Q_3 = P_{2u} - w_u \cdot (L_3 + b_2)$

- $M_3 = w_u \cdot \dfrac{(L_3 + b_2)^2}{2} - P_{2u} \cdot (\dfrac{b_2}{2})$

- $Q_4 = w_u \cdot L_3$

- $M_4 = w_u \cdot \dfrac{(L_3)^2}{2}$



- ملحوظة هامة:-

- قيم الـ .B.M. & S.F السابقة تحسب على الـ calculator بسرعة ونكتبها على الرسم فقط لتوفير الوقت.

- At point of zero shear:-

- $P_{1u} = w_u \cdot x \quad \Rightarrow \quad x = \surd$

$$\therefore M_{max.} = P_{1u}\left(x - \left(L_1 + \frac{b_1}{2}\right)\right) - w_u \cdot \frac{(x)^2}{2}$$

- Design of critical section in B.M.:-

$$- \; d = C_1 \cdot \sqrt{\frac{M_{u_{max}} \times 10^6}{f_{cu} \times B_{R.C.}}}$$

- Where $M_{u\,max}$ is the max. of M_1, M_2, M_3, M_4 & $M_{max.}$
- Assume C_1=3.5-5.0 $\Rightarrow$ d = $\surd$ mm (تقرب لأقرب ٣ سم أو أقرب ٨ سم بالزيادة)

$\Rightarrow \; t_{R.C.} = d + 7$ cm

2- Check shear:-

- القطاع الحرج فى القص يكون على بعد d/2 من وش العمود من الناحية التى عندها قيمة الـ .S.F أكبر ما يمكن.

$$- \; q_{scu} = 0.16\sqrt{\frac{f_{cu}}{1.5}}$$

$$- \; Q_{su_{max.}} = Q_{max.} - w_u \cdot \frac{d}{2}$$

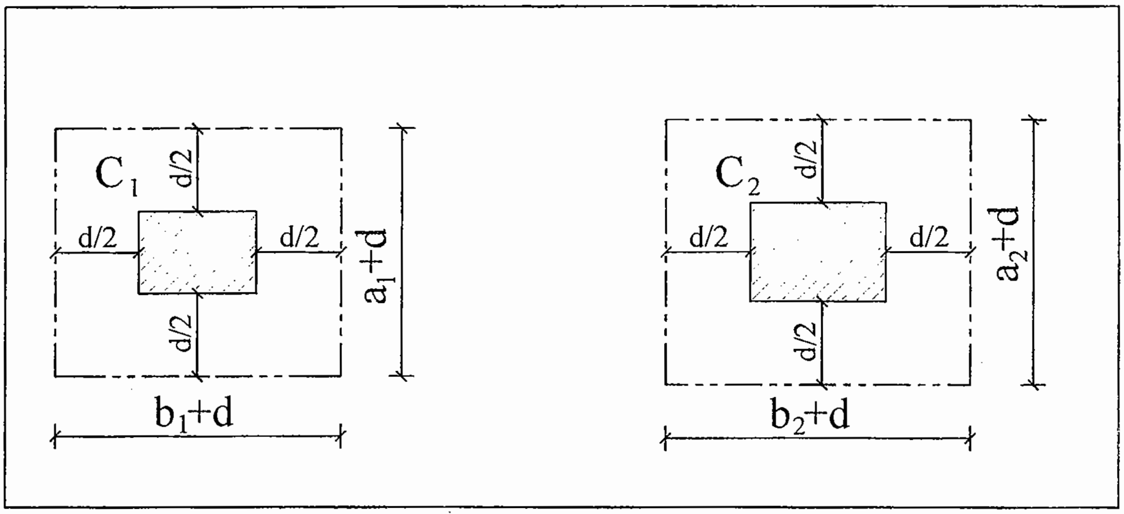
- Where Q_{max} is the max. of Q_1, Q_2, Q_3 & Q_4.

$$- \; q_{su} = \frac{Q_{su_{max}} \times 10^3}{d \times B_{R.C.}} = \surd \qquad (N/mm^2)$$

- if $q_{su} \le q_{scu} \quad \Rightarrow$ safe
- if $q_{su} > q_{scu} \quad \Rightarrow$ unsafe (increase d and recheck)

3- Check punching shear:-

- يتم حساب كل عمود على حده وذلك على بعد (d\2) من وش العمود الخرسانى من كل ناحية.



- For C1

- $q_{pcu_1} = 0.316(0.5 + \frac{a_1}{b_1})\sqrt{\frac{f_{cu}}{1.5}}$ for $\frac{a_1}{b_1} < 0.5$

- $q_{pcu_1} = 0.316\sqrt{\frac{f_{cu}}{1.5}}$ for $\frac{a_1}{b_1} \geq 0.5$

- $Q_{pu_1} = P_{u_1} - q_u\left[(b_1 + d)(a_1 + d)\right]$

- $q_{pu_1} = \frac{Q_{pu_1} \times 10^3}{d\left[(b_1+d)+(a_1+d)\right]\times 2} = \surd$ (N/mm^2)

- if $q_{pu_1} \leq q_{pcu_1}$ $\Rightarrow$ safe
- if $q_{pu_1} > q_{pcu_1}$ $\Rightarrow$ unsafe (increase d and recheck)

- For C2

- $q_{pcu_2} = 0.316(0.5 + \frac{a_2}{b_2})\sqrt{\frac{f_{cu}}{1.5}}$ for $\frac{a_2}{b_2} < 0.5$

- $q_{pcu_2} = 0.316\sqrt{\frac{f_{cu}}{1.5}}$ for $\frac{a_2}{b_2} \geq 0.5$

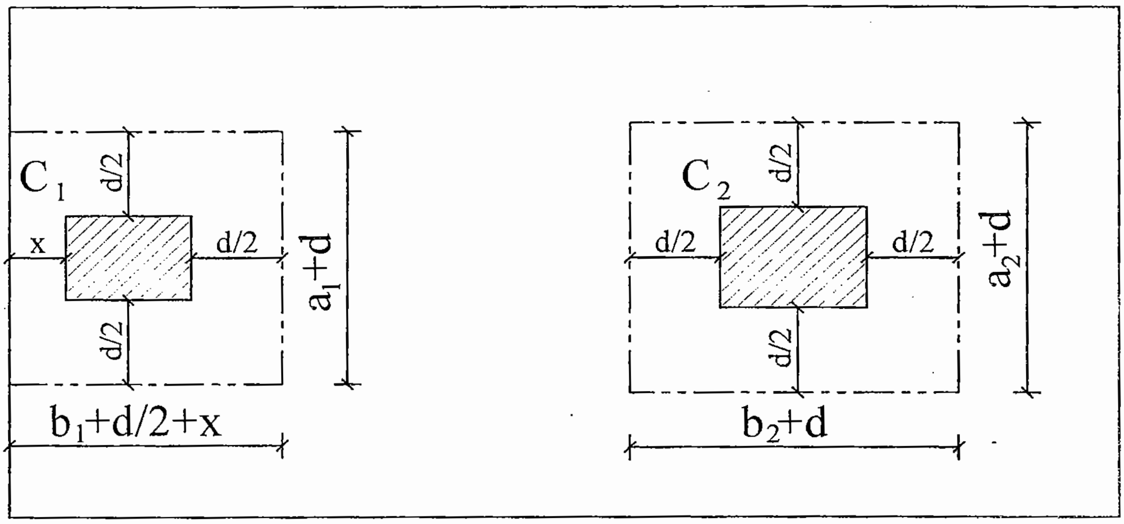
- $Q_{pu_2} = P_{u_2} - q_u\left[(b_2 + d)(a_2 + d)\right]$

- $q_{pu_2} = \dfrac{Q_{pu_2} \times 10^3}{d\left[(b_2+d)+(a_2+d)\right]\times 2} = \surd$ (N/mm^2)

- if $q_{pu_2} \leq q_{pcu_2}$ $\Rightarrow$ safe
- if $q_{pu_2} > q_{pcu_2}$ $\Rightarrow$ unsafe (increase d and recheck)

- ملاحظة هامة جداً:-

- فى حالة وجود عمود قريب من حد الجار قد تكون المسافة من وش العمود الخارجى وطرف القاعدة المشتركة x أقل من d\2 وفى هذه الحالة يكون هناك ثلاثة أضلاع فقط تقاوم حدوث الـ Punching ويتم عمل check punching لهذا العمود كما يلى:-



- For C1

- $q_{pcu_1} = 0.316(0.5 + \frac{a_1}{b_1})\sqrt{\frac{f_{cu}}{1.5}}$ for $\frac{a_1}{b_1} < 0.5$

- $q_{pcu_1} = 0.316\sqrt{\frac{f_{cu}}{1.5}}$ for $\frac{a_1}{b_1} \geq 0.5$

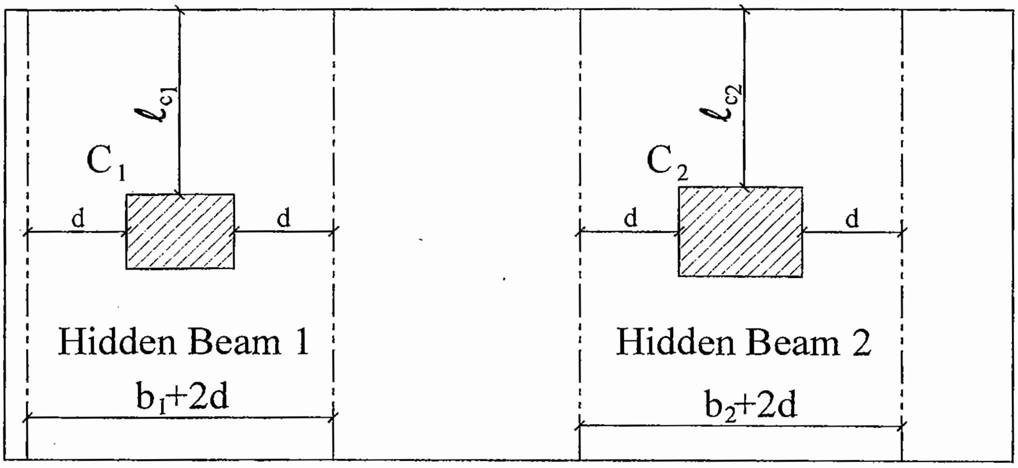
- $Q_{pu_1} = P_{u_1} - q_u\left[(b_1 + d)(a_1 + d)\right]$

- $q_{pu_1} = \dfrac{Q_{pu_1} \times 10^3}{d \cdot \left[2 \times (b_1 + \frac{d}{2} + x) + (a_1 + d)\right]} = \surd$ (N/mm^2)

- if $q_{pu_1} \leq q_{pcu_1}$ $\Rightarrow$ safe
- if $q_{pu_1} > q_{pcu_1}$ $\Rightarrow$ unsafe (increase d and recheck)

4- Design of footing in transverse direction (short direction):-

– يتم تصميم القاعدة فى الإتجاه العرضى (short direction) بإعتبار وجود كمرة مدفونة hidden beam تحت كل عمود حيث:-



- For Hidden Beam 1:-

$$- B = B_{R.C.} \quad \& \quad L_1 = b_1 + 2d$$

$$\Rightarrow q_{u_1} = \frac{P_{u_1}}{B_{R.C.} \times L_1}$$

$$- \ell_{c_1} = \frac{B_{R.C.} - a_1}{2}$$

$$- M_1 = q_{u_1} \times \frac{(\ell_{c_1})^2}{2}$$

- For Hidden Beam 2:-

$$- B = B_{R.C.} \quad \& \quad L_2 = b_2 + 2d$$

$$\Rightarrow q_{u_2} = \frac{P_{u_2}}{B_{R.C.} \times L_2}$$

$$- \ell_{c_2} = \frac{B_{R.C.} - a_2}{2}$$

$$- M_2 = q_{u_2} \times \frac{(\ell_{c_2})^2}{2}$$

- Choose the max. of M_1 & $M_2 \Rightarrow M_{max.}$

- Check the safety of d under $M_{max.}$

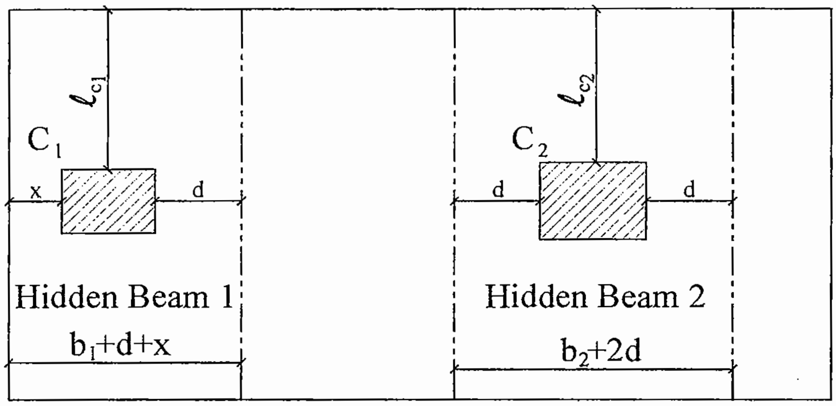
- where:-

$$- d = C_1 \sqrt{\frac{M_{max} \times 10^6}{f_{cu} \times 1000}} \qquad \Rightarrow \quad C_1 = \surd$$

- If $C_1 > 2.8 \qquad \Rightarrow$ safe
- If $C_1 < 2.8 \qquad \Rightarrow$ unsafe $\Rightarrow$ take $C_1 = 2.8$ and find d

- **ملاحظة هامة جداً:-**

– فى حالة وجود عمود قريب من حد الجار قد تكون المسافة من وش العمود الخارجى وطرف القاعدة المشتركة x أقل من d وفى هذه الحالة يكون نهاية الـ Hidden beam 1 عند وش القاعدة وليس على بعد d من وش العمود ويتم تصميم الـ Hidden beam 1 أسفل هذا العمود كما يلى:-



- For Hidden Beam 1:-

$$- B = B_{R.C.} \quad \& \quad L_1 = b_1 + d + x$$

$$\Rightarrow q_{u_1} = \frac{P_{u_1}}{B_{R.C.} \times L_1}$$

$$- \ell_{c_1} = \frac{B_{R.C.} - a_1}{2}$$

$$- M_1 = q_{u_1} \times \frac{(\ell_{c_1})^2}{2}$$

- For Hidden Beam 2:-

$$- B = B_{R.C.} \quad \& \quad L_2 = b_2 + 2d$$

$$\Rightarrow q_{u_2} = \frac{P_{u_2}}{B_{R.C.} \times L_2}$$

$$- \ell_{c_2} = \frac{B_{R.C.} - a_2}{2}$$

$$- M_2 = q_{u_2} \times \frac{(\ell_{c_2})^2}{2}$$

- Choose the max. of M_1 & $M_2 \Rightarrow M_{max.}$

- Check the safety of d under $M_{max.}$

- where:-

$$- d = C_1 \sqrt{\frac{M_{max} \times 10^6}{f_{cu} \times 1000}} \qquad \Rightarrow \quad C_1 = \surd$$

$- \text{If } C_1 > 2.8 \qquad \Rightarrow$ safe

$- \text{If } C_1 < 2.8 \qquad \Rightarrow$ unsafe $\Rightarrow$ take $C_1 = 2.8$ and find d

5- RFT:-

- $A_{s_{min}} = 1.5 \times d$ or $5 \not\!\!\!\not\!\!\phi 12 \backslash m'$ أيهما أكبر

- RFT in long direction:-

$$- A_{s_{top}} = \frac{M_{u_{max\ (top)}} \times 10^6}{f_y \times j \times d} = \surd \ \ mm^2 / B_{R.C.} = \surd \ \ mm^2/m'$$

$$- A_{u_{top}} = \frac{M_{u_{max\ (bottom)}} \times 10^6}{f_y \times j \times d} = \surd \ \ mm^2 / B_{R.C.} = \surd \ \ mm^2/m'$$

- RFT in short direction:-

- For Hidden beam 1:-

$$- A_1 = \frac{M_1 \times 10^6}{f_y \times j \times d} = \surd \ \ mm^2 / m'$$

- For Hidden beam 2:-

$$- A_2 = \frac{M_2 \times 10^6}{f_y \times j \times d} = \surd \ \ mm^2 / m'$$

- check $A_s > A_{smin.}$

- If As<Asmin. ⇒ use Asmin.

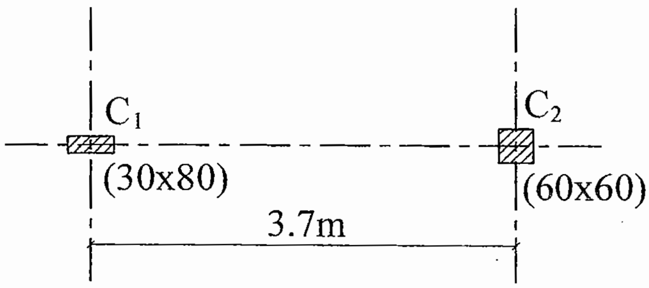
  - use $A_{s_{Top}} = ?\phi ? \backslash m'$
  - use $A_{s_{Bottom}} = ?\phi ? \backslash m'$
  - use $A_{s_1} = ?\phi ? \backslash m'$
  - use $A_{s_2} = ?\phi ? \backslash m'$

6- Details of RFT:-

- See next examples

- Example 1:-

For the two columns shown in the given plan: The load in column C_1 is 1600KN, The load in column C_2 is 2500KN. It is required to:



a) Design the required combined footing, if the thickness of P.C. is 30 cm, and $q_{all} = 175\ KN/m^2$.
($f_{cu} = 25\ N/mm^2$, $f_y = 360\ N/mm^2$)

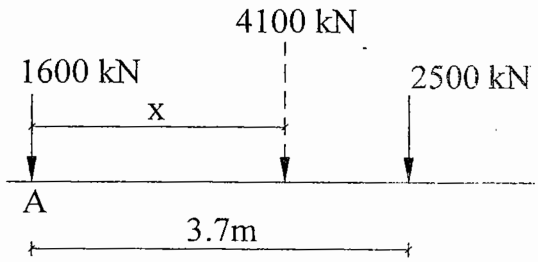
b) Draw a plan and sectional elevation for the footing with scale 1:50, showing on them the reinforcement details.

- Solution:-

1- Dimensions of footing:-

$$- R = P_1 + P_2 = 1600 + 2500 = 4100kN$$

$$- R \cdot x = P_2 \cdot S$$



$$\Rightarrow 4100(x) = 2500 \times 3.7$$

$$\therefore x = 2.26m$$

$$- \frac{L_{P.C.}}{2} = x + \frac{b_1}{2} + (0.5 \rightarrow 1.0) + t_{P.C.}$$

$$\Rightarrow \frac{L_{P.C.}}{2} = 2.26 + 0.4 + 0.5 + 0.3 = 3.46m$$

$$- L_{P.C.} = 2 \times 3.46 = 6.92\ m \quad \Rightarrow \text{use } L_{P.C.} = 6.95\ m$$

$$\Rightarrow L_{R.C.} = L_{P.C.} - 2 \times t_{P.C.} = 6.95 - 2 \times 0.3 = 6.35\ m$$

$$A_{P.C.} = \frac{R}{q_{all}} = B_{P.C.} \times L_{P.C.}$$

$$\Rightarrow A_{P.C.} = \frac{4100}{175} = 23.43m^2 = B_{P.C.} \times 6.95$$

$$\Rightarrow B_{P.C.} = 3.37\ m \qquad \Rightarrow \text{take } B_{P.C.} = 3.40m$$

$$\Rightarrow B_{R.C.} = B_{P.C.} - 2 \cdot t_{P.C.} = 3.40 - 2 \times 0.3 = 2.80\ m$$

2- Design of R.C. footing:-

- $P_{1u} = 1600 \times 1.5 = 2400$ kN
- $P_{2u} = 2500 \times 1.5 = 3750$ kN

$R_u = 4100 \times 1.5 = 6150$ kN

- $w_u = \dfrac{6150}{6.35} = 968.5$ kN/m\`
- $q_u = \dfrac{6150}{6.35 \times 2.8} = 345.9$ kN/m^2

1- Design of footing in longitudinal direction:-

-At point of zero shear:-

- $P_{1u} = w_u \cdot x$

$\Rightarrow 2400 = 968.5\ (x)$

$\Rightarrow x = 2.48$ m

$$\therefore M_{max.} = 2400 \times 1.68 - 968.5 \times \frac{(2.48)^2}{2}$$

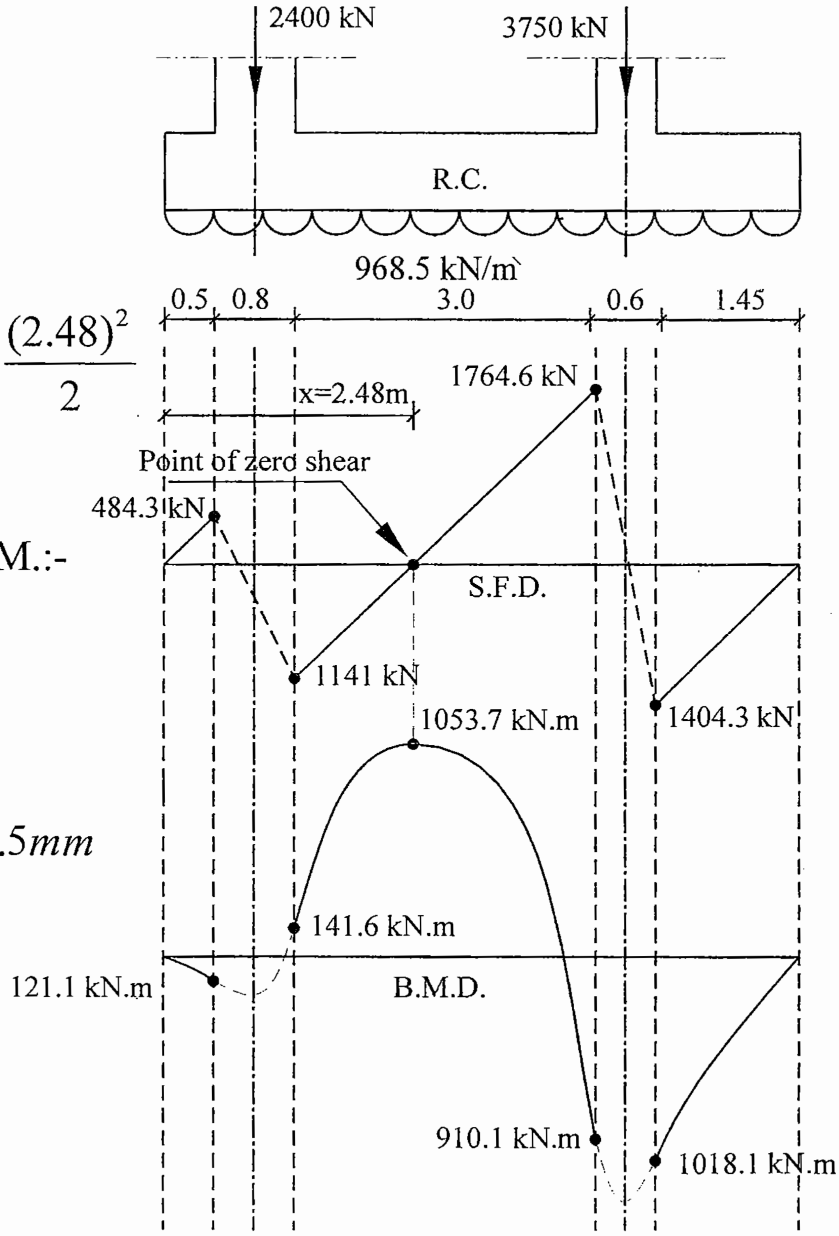
$$\Rightarrow M_{max.} = 1053.7 \text{ kN.m}$$

- Design of critical section in B.M.:-

$$- d = C_1 \sqrt{\frac{M_{u\,max} \times 10^6}{f_{cu} \times B_{R.C.(mm)}}}$$

$$\Rightarrow d = 5 \times \sqrt{\frac{1053.7 \times 10^6}{25 \times 2800}} = 613.5 mm$$

$\Rightarrow$ use d = 630 mm



2- Check shear:-

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

- $Q_{sumax.} = Q_{max.} - w_u \cdot \frac{d}{2} = 1764.6 - 968.5 \times \frac{0.63}{2} = 1459.5\ kN$

- $q_{su} = \frac{Q_{su\,max.} \times 10^3}{d_{(mm)} \times B_{R.C.(mm)}} = \frac{1459.5 \times 10^3}{630 \times 2800} = 0.827 N/mm^2 > q_{scu}$ unsafe

- Try $d = 730$ mm

- $Q_{sumax.} = Q_{max.} - w_u \cdot \frac{d}{2} = 1764.6 - 968.5 \times \frac{0.73}{2} = 1411.1\ kN$

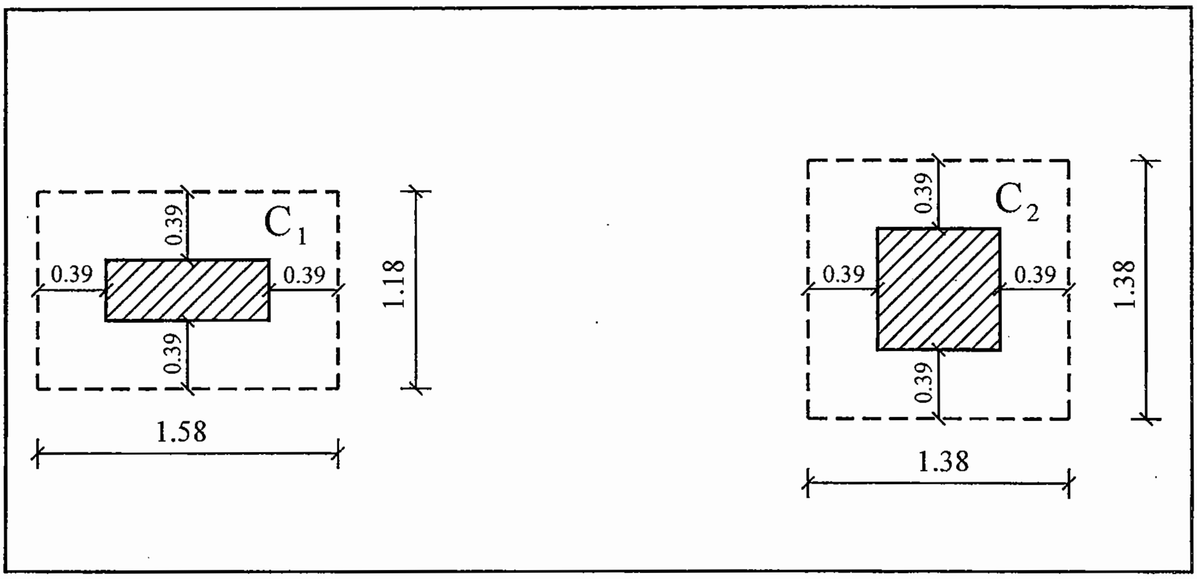
- $q_{su} = \frac{Q_{su\,max.} \times 10^3}{d_{(mm)} \times B_{R.C.(mm)}} = \frac{1411.1 \times 10^3}{730 \times 2800} = 0.69 N/mm^2 > q_{scu}$ unsafe

- Try $d = 780$ mm

- $Q_{sumax.} = Q_{max.} - w_u \cdot \frac{d}{2} = 1764.6 - 968.5 \times \frac{0.78}{2} = 1386.9\ kN$

- $q_{su} = \frac{Q_{su\,max.} \times 10^3}{d_{(mm)} \times B_{R.C.(mm)}} = \frac{1386.9 \times 10^3}{780 \times 2800} = 0.635 N/mm^2 < q_{scu}$ safe

3- Check punching shear:-



- For C1(30x80)

$$- q_{pcu1} = 0.316(0.5 + \frac{a_1}{b_1})\sqrt{\frac{f_{cu}}{1.5}} \quad \text{for } \frac{a_1}{b_1} < 0.5$$

$$- q_{pcu1} = 0.316(0.5 + \frac{300}{800})\sqrt{\frac{25}{1.5}} = 1.129 N/mm^2$$

$$- Q_{pu1} = 2400 - 345.9[1.58 \times 1.18] = 1751 kN$$

$$- q_{pu1} = \frac{1751 \times 10^3}{780[1580+1180] \times 2} = 0.41 N/mm^2 \quad < q_{pcu1} \quad \text{safe}$$

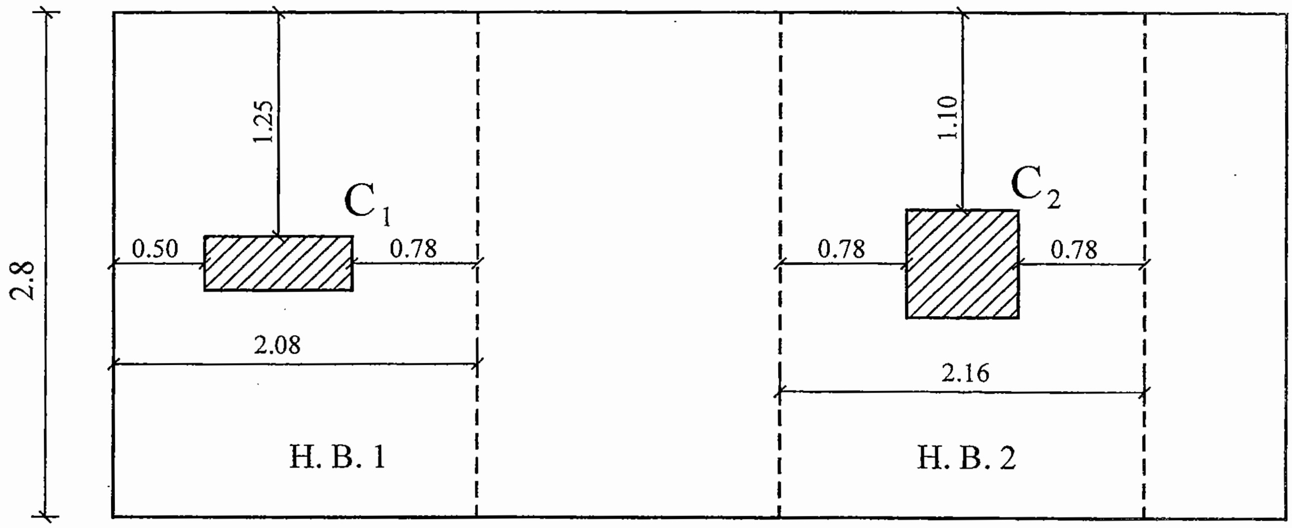
- For C2(60x60)

$$- q_{pcu2} = 0.316\sqrt{\frac{f_{cu}}{1.5}} = 0.316\sqrt{\frac{25}{1.5}} = 1.29 N/mm^2$$

$$- Q_{pu2} = 3750 - 345.9[1.38 \times 1.38] = 3091.3 kN$$

$$- q_{pu1} = \frac{3091.3 \times 10^3}{780 \times 1380 \times 4} = 0.72 \text{ N/mm}^2 < q_{pcu2} \quad \text{safe}$$

4- Design of footing in transverse direction (short direction):-



- For Hidden Beam 1:-

$$- q_{u1} = \frac{2400}{2.8 \times 2.08} = 412.1 \text{ kN/m}^2$$

$$- M_1 = 412.1 \times \frac{(1.25)^2}{2} = 322 \text{ kN.m}$$

- For Hidden Beam 2:-

$$- q_{u2} = \frac{3750}{2.8 \times 2.16} = 620 \text{ kN/m}^2$$

$$- M_2 = 620 \times \frac{(1.1)^2}{2} = 375.1 \text{ kN.m}$$

$$- d = C_1 \sqrt{\frac{M_{max} x 10^6}{f_{cu} \times 1000}} \Rightarrow 780 = C_1 \sqrt{\frac{375.1x10^6}{25x1000}}$$

$$\Rightarrow C_1 = 6.4 < 2.3 \; O.K$$

5- RFT:-

- $A_{s_{min}} = 1.5 \times d_{mm} = 1.5 \times 780 = 1170\,mm^2/m^\backslash$

- $A_{s_{min.}} = 6 \phi 16 \backslash m^\backslash$

- RFT in long direction:-

- $A_{s\ top} = \dfrac{1053.7 \times 10^6}{360 \times 0.826 \times 780} = 4543 \quad mm^2/2.8m = 1622 \quad mm^2/m^\backslash$

- $A_{s\ bottom} = \dfrac{1018.1 \times 10^6}{360 \times 0.826 \times 780} = 4389 \quad mm^2/2.8m = 1568 \quad mm^2/m^\backslash$

- RFT in short direction:-

- $A_{s1} = \dfrac{322 \times 10^6}{360 \times 0.826 \times 780} = 1388 \quad mm^2/m^\backslash$

- $A_{s2} = \dfrac{375.1 \times 10^6}{360 \times 0.826 \times 780} = 1617 \quad mm^2/m^\backslash$

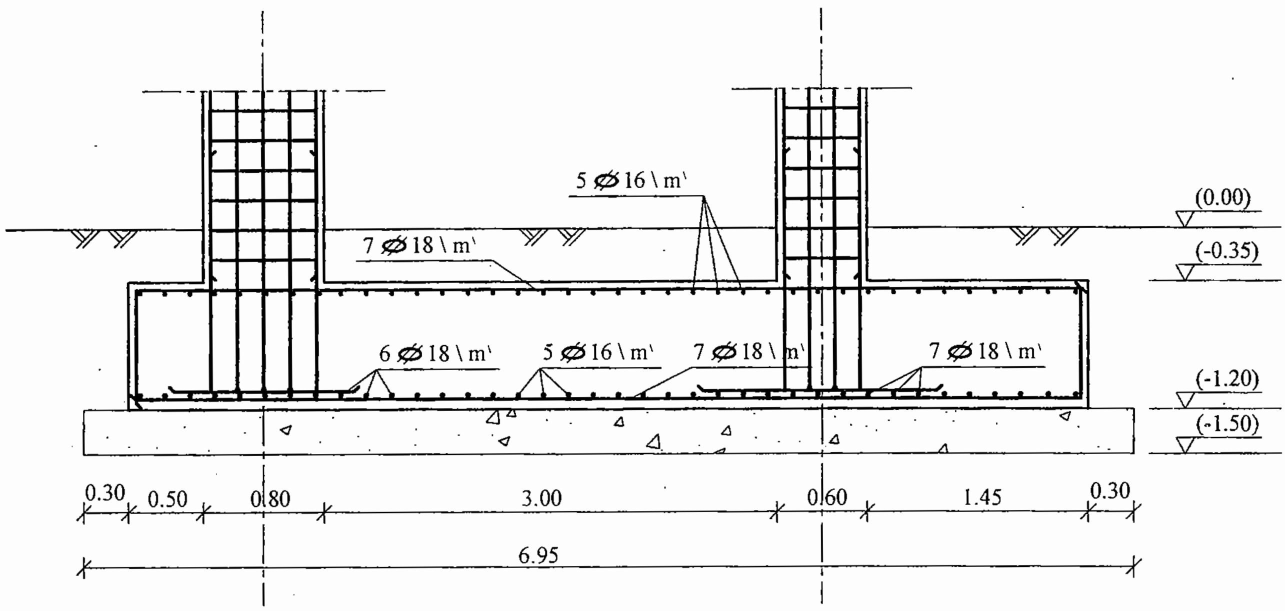
- use $A_{s_{Top}} = 7 \phi 18 \backslash m^\backslash$

- use $A_{s_{Bottom}} = 7 \phi 18 \backslash m^\backslash$

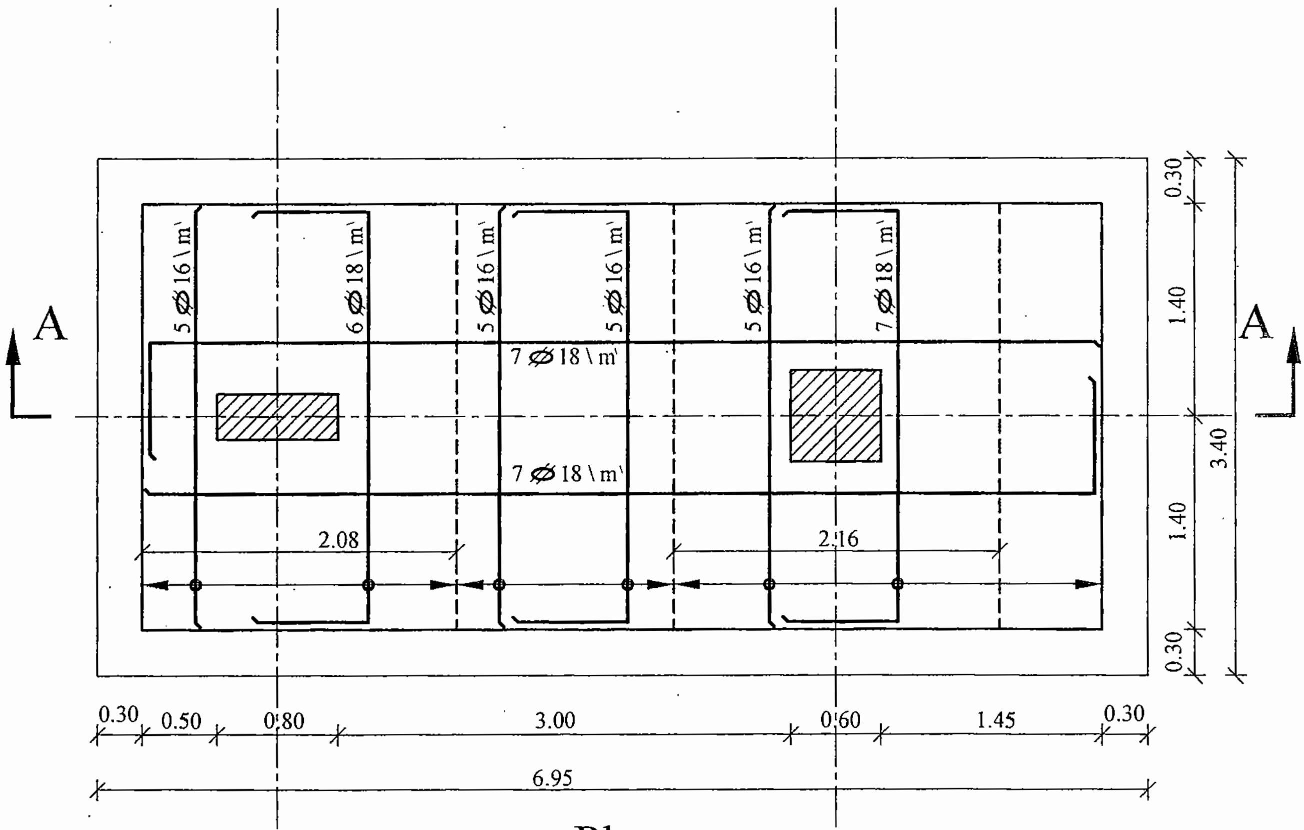
- use $A_{s_1} = 6 \phi 18 \backslash m^\backslash$

- use $A_{s_2} = 7 \phi 18 \backslash m^\backslash$

- Details of RFT:-



Section A-A
scale 1:50



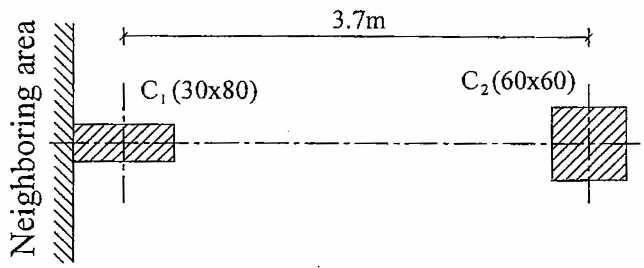
Plan
scale 1:50

- Example 2:-

For the two columns shown in the given plan:

The outer column load is 1600KN,

The inner column load is 2500KN.



- It is required to:
  a) Design the required combined footing, if the thickness of P.C. is 30 cm, and $q_{all} = 175\ KN/m^2$. ($f_{cu} = 25\ N/mm^2$, $f_y = 360\ N/mm^2$)

  b) Draw a plan and sectional elevation for the footing with scale 1:50, showing on them the reinforcement details.

- Solution:-

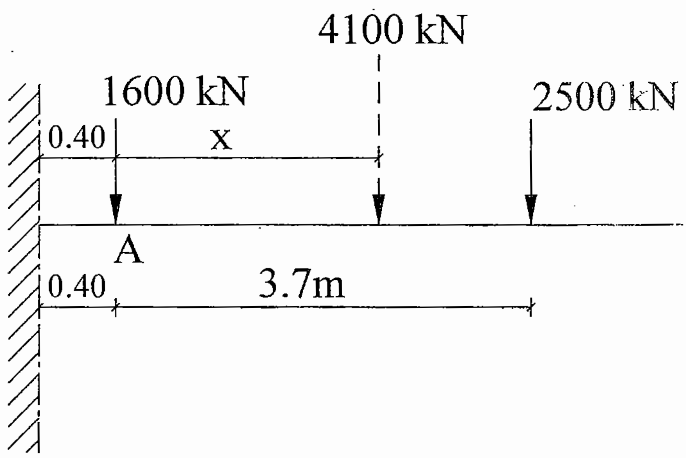
1- Dimensions of footing:-

$$R = P_1 + P_2 = 1600 + 2500 = 4100 kN$$

$$\sum M_{@A} = 0 \Rightarrow R.x = P_2.S$$

$$\Rightarrow 4100(x) = 2500 \times 3.7$$

$$\therefore x = 2.26m$$



$$- \ \frac{L_{P.C.}}{2} = x + \frac{b_1}{2}$$

$$\Rightarrow \frac{L_{P.C.}}{2} = 2.26 + 0.4 = 2.66m$$

$$- \ L_{P.C.} = 2 \times 2.66 = 5.32 \qquad \Rightarrow \text{use } L_{P.C.} = L_{R.C.} = 5.35\ m$$

$$A_{P.C.} = \frac{R}{q_{all}} = B_{P.C.} \times L_{P.C.}$$

$$\Rightarrow A_{P.C.} = \frac{4100}{175} = 23.43\ m^2 = B_{P.C.} \times 5.35$$

$$\Rightarrow B_{P.C.} = 4.38\ m \qquad \Rightarrow \text{use } B_{P.C.} = 4.40\ m$$

$$\Rightarrow B_{R.C.} = B_{P.C.} - 2\ t_{P.C.} = 4.4 - 2 \times 0.3 = 3.80\ m$$

2- Design of R.C. footing:-

- $P_{1u} = 1600 \times 1.5 = 2400$ kN   - $P_{2u} = 2500 \times 1.5 = 3750$ kN

$R_u = 4100 \times 1.5 = 6150$ kN   - $w_u = \dfrac{6150}{5.35} = 1149.5$ kN/m\

- $q_u = \dfrac{6150}{3.8 \times 5.35} = 302.5$ kN/m^2

1- Design of footing in longitudinal direction:-

-At point of zero shear:-

- $P_{1u} = w_u . x$

$\Rightarrow 2400 = 1149.5\ (x) \qquad x = 2.1m$

$\therefore M_{max.} = 2400 \times 1.7 - 1149.5 \times \dfrac{(2.1)^2}{2}$

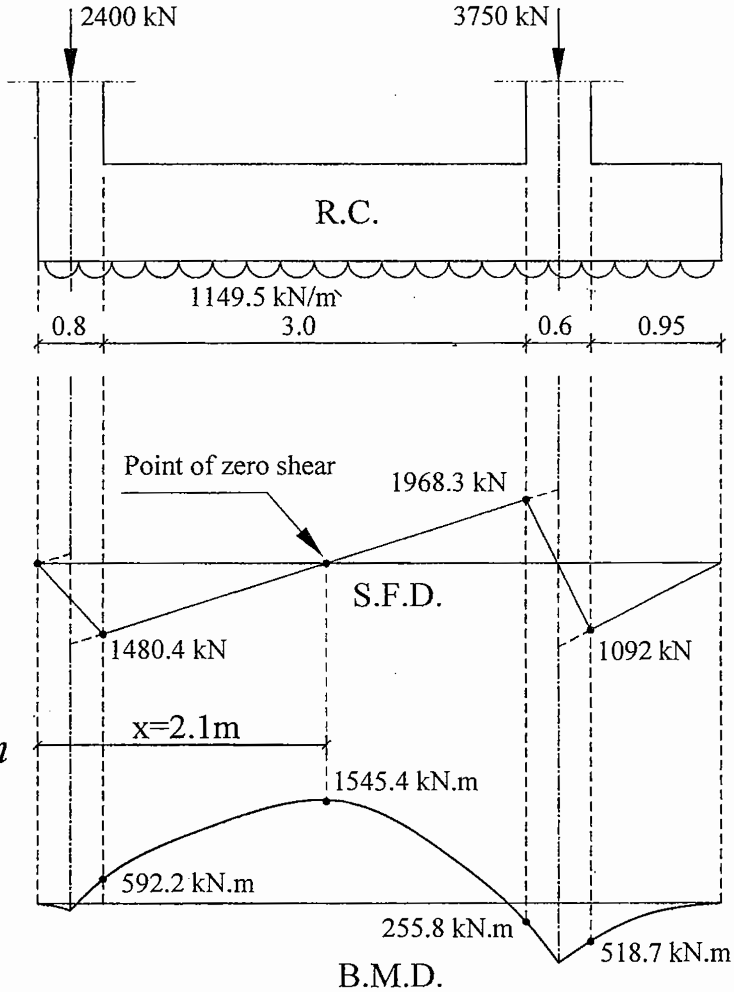
$\Rightarrow M_{max.} = 1545.4$ kN.m

- Design of critical section in B.M.:-

$$- d = C_1 \sqrt{\frac{M_{u\max} \times 10^6}{f_{cu} \times B_{R.C.(mm)}}}$$

$$\Rightarrow d = 5 \times \sqrt{\frac{1545.4 \times 10^6}{25 \times 3800}} = 637.7mm$$

$\Rightarrow$ use $d = 680mm \qquad \Rightarrow t = 750mm$



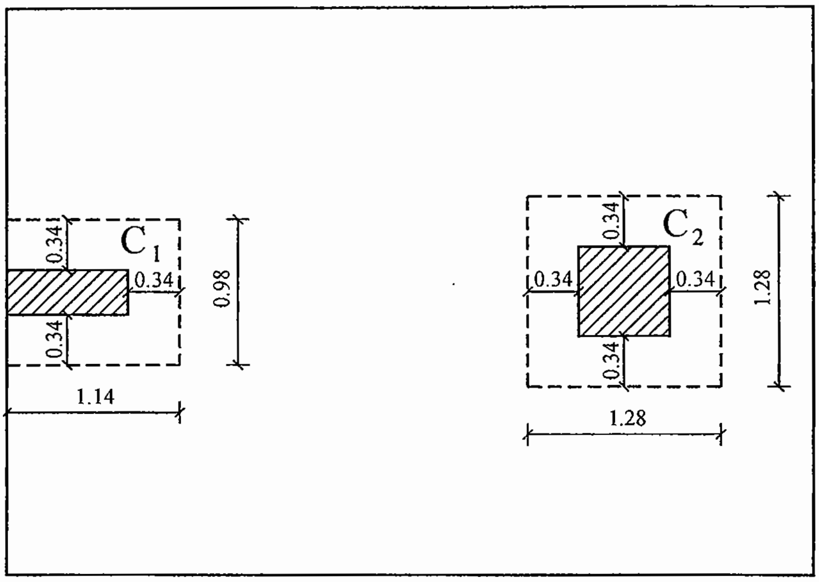
2- Check shear:-

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

$$- Q_{su_{max.}} = Q_{max.} - w_u \cdot \frac{d}{2} = 1968.8 - 1149.5 \times \frac{0.68}{2} = 1577.97\ kN$$

$$- q_{su} = \frac{Q_{su_{max.}} \times 10^3}{d_{(mm)} \times B_{R.C.(mm)}} = \frac{1577.97 \times 10^3}{680 \times 3800} = 0.611 N/mm^2 < q_{scu} \quad \text{safe}$$

3- Check punching shear:-



- For C1(30x80)

$$- q_{pcu1} = 0.316(0.5 + \frac{a_1}{b_1})\sqrt{\frac{f_{cu}}{1.5}} \quad \text{for } \frac{a_1}{b_1} < 0.5$$

$$- q_{pcu1} = 0.316(0.5 + \frac{300}{800})\sqrt{\frac{25}{1.5}} = 1.129 \; N/mm^2$$

$$- Q_{pu1} = 2400 - 302.5[1.14 \times 0.98] = 2062 \; kN$$

$$- q_{pu1} = \frac{2062 \times 10^3}{680[2 \times 1140 + 980]} = 0.93 \; N/mm^2 < q_{pcu1} \qquad \text{safe}$$

- For C2(60x60)

$$- q_{pcu2} = 0.316\sqrt{\frac{f_{cu}}{1.5}} = 0.316\sqrt{\frac{25}{1.5}} = 1.29 N/mm^2$$

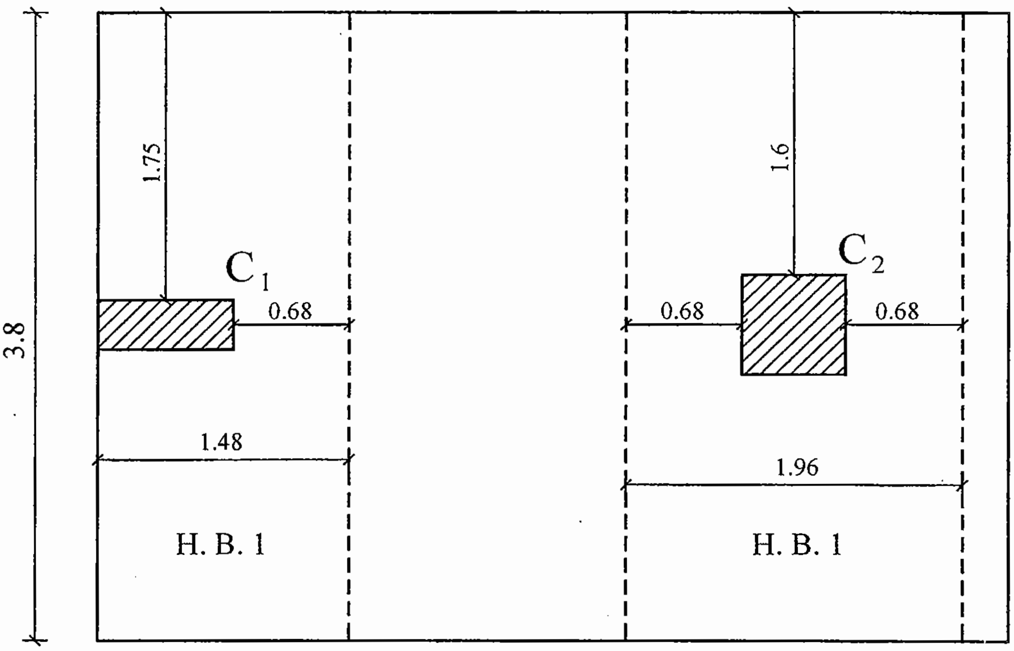
$$- Q_{pu2} = P_{u2} - q_u[(b_2 + d)(a_2 + d)]$$

$$= 3750 - 302.5[1.28 \times 1.28] = 3254.4 kN$$

$$- q_{pu1} = \frac{Q_{Pu2} \times 10^3}{d_{(mm)}[(b_{2(mm)} + d_{(mm)}) + (a_{2(mm)} + d_{(mm)})] \times 2}$$

$$= \frac{3254.4 \times 10^3}{680[1280 + 1280]x2} = 0.93 \; N/mm^2 < q_{pcu2} \qquad \text{safe}$$

4- Design of footing in transverse direction (short direction):-



- For Hidden Beam 1:-

$$- q_{u1} = \frac{2400}{3.8 \times 1.48} = 426.7 \ N/mm^2$$

$$- M_1 = 426.7 \times \frac{(1.75)^2}{2}$$

$$= 653.4 \ kN \cdot m$$

$$- d = C_1 \sqrt{\frac{M_u \times 10^6}{f_{cu} \times 1000}}$$

$$\Rightarrow 680 = C_1 \sqrt{\frac{653.4 \times 10^6}{25 \times 1000}}$$

$$\Rightarrow \ C_1 = 4.2 > 2.8 \ \Rightarrow \text{ safe}$$

$$\Rightarrow \ J = 0.81$$

- For Hidden Beam 2:-

$$- q_{u2} = \frac{3750}{3.8 \times 1.96} = 503.5 \ N/mm^2$$

$$- M_2 = 503.5 \times \frac{(1.6)^2}{2}$$

$$= 644.5 \ kN \cdot m$$

$$- d = C_1 \sqrt{\frac{M_u \times 10^6}{f_{cu} \times 1000}}$$

$$\Rightarrow 680 = C_1 \sqrt{\frac{644.5 \text{x} 10^6}{25 \text{x} 1000}}$$

$$\Rightarrow \ C_1 = 4.24 > 2.8 \ \Rightarrow \text{ safe}$$

$$\Rightarrow \ J = 0.81$$

5- RFT:-

- $A_{Smin} = 1.5 \times d_{mm} = 1.5 \times 680 = 1020 \ \ mm^2/m^\backslash$

- $A_{s_{min}} = 5 \not\phi \ 16 \backslash m^\backslash$

- RFT in long direction:-

- $A_{s\ top} = \dfrac{1545.4 \times 10^6}{360 \times 0.826 \times 680} = 7643 \quad mm^2 / 3.8m = 2011 \quad mm^2 / m^\backslash$

- $A_{s\ bottom} = \dfrac{518.7 \times 10^6}{360 \times 0.826 \times 680} = 2565 \quad mm^2 / 3.8m = 675 \quad mm^2 / m^\backslash$

- RFT in short direction:-

- $A_{s1} = \dfrac{653.4 \times 10^6}{360 \times 0.81 \times 680} = 3295 \quad mm^2 / m^\backslash$

- $A_{s2} = \dfrac{644.5x \ 10^6}{360 \times 0.81 \times 680} = 3250 \quad mm^2 / m^\backslash$

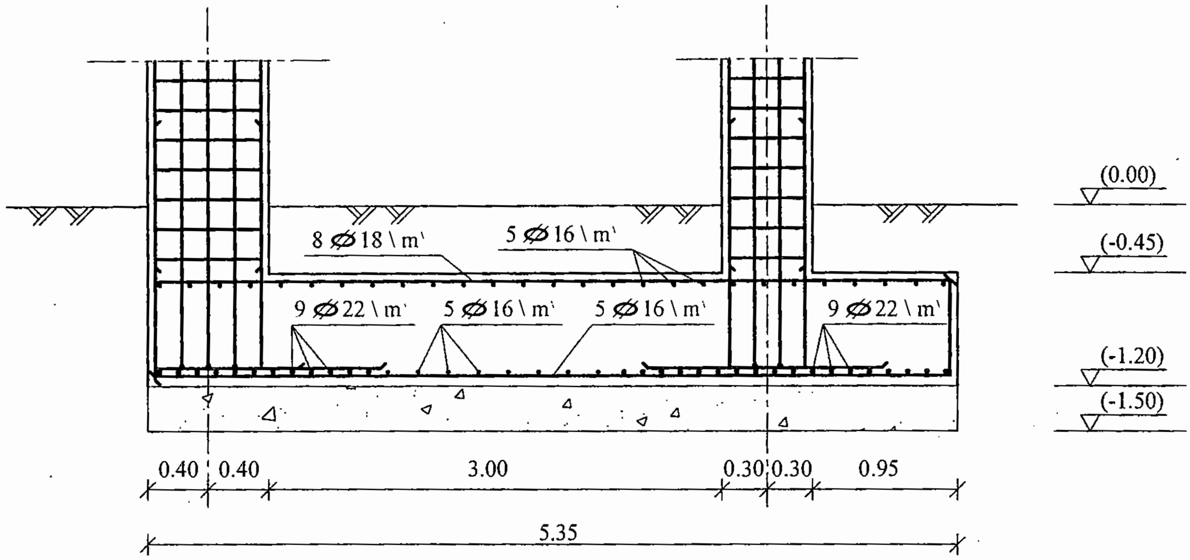
- use $A_{s_{Top}} = 8 \not\phi \ 18 \backslash m^\backslash$

- use $A_{s_{Bottom}} = A_{s_{min.}} = 5 \not\phi 16 \backslash m^\backslash$

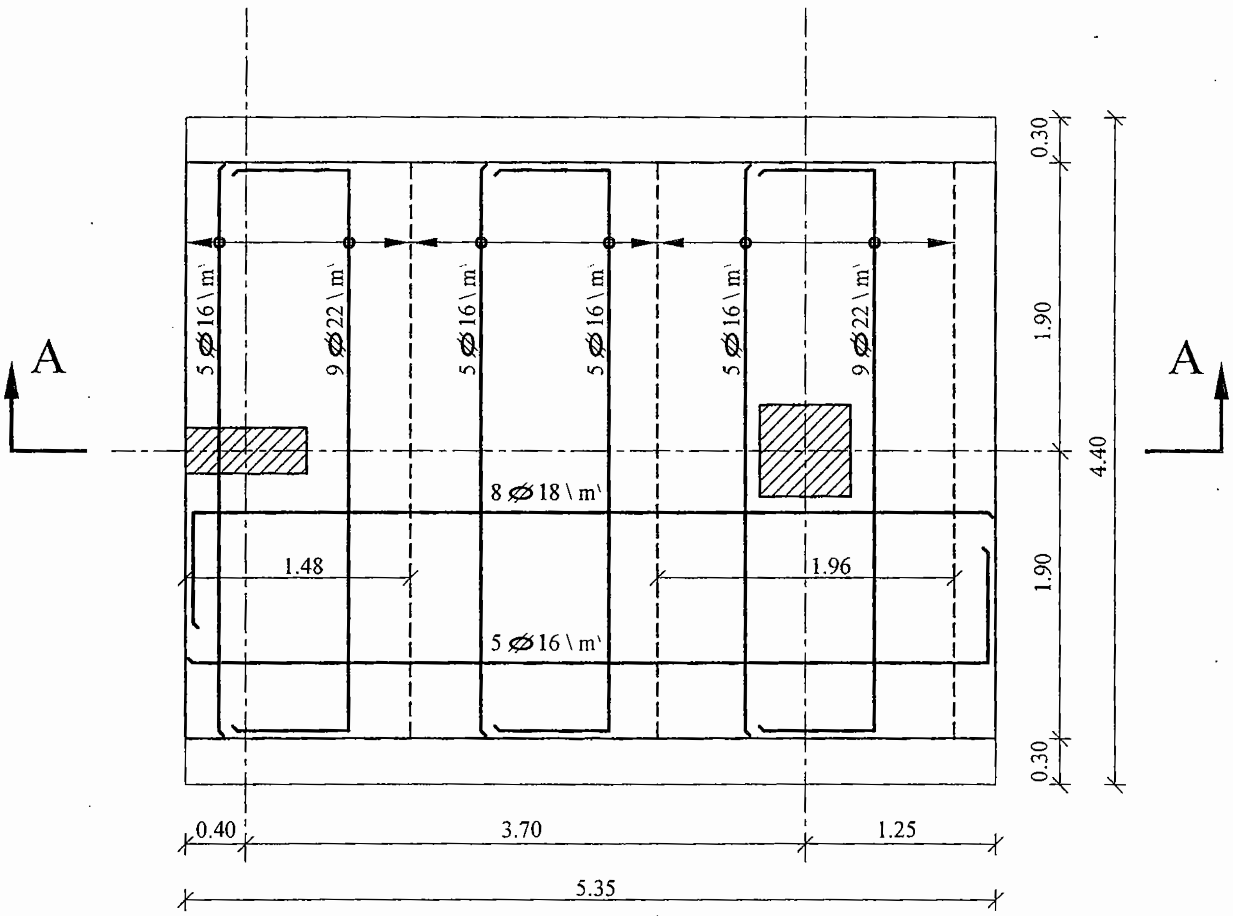
- use $A_{s_1} = 9 \not\phi \ 22 \backslash m^\backslash$

- use $A_{s_1} = 9 \not\phi \ 22 \backslash m^\backslash$

- Details of RFT:-



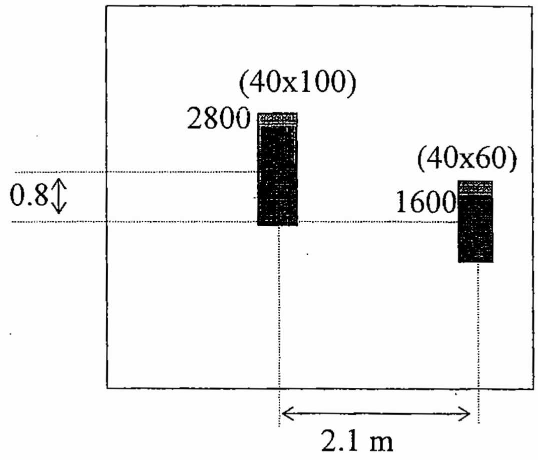
Section A-A
scale 1:50



Plan
scale 1:50

- Example 3:-

For the shown combined footing, if the thickness of P.C. is 40cm, and q_{all} = 200 KN/m^2 it is required to:
Determine the suitable P.C. and R.C. horizontal dimensions, and draw a plan with scale 1:50.



N.B.: No complete design is required. Loads are in KN.

- Solution:-

-Area of footing:-

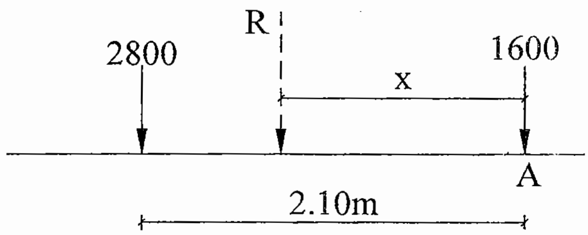
1- In long direction:-

$$R = 2800 + 1600 = 4400 kN$$

$$\sum M_{@A} = 0$$

$$\Rightarrow 4400(x) = 2800 \times 2.1$$

$$\therefore x = \frac{2800 \times 2.1}{4400} = 1.34 m$$



$$- \frac{L_{P.C.}}{2} = 1.34 + \frac{0.40}{2} + 0.5m + 0.40 = 2.44m$$

$$\Rightarrow L_{P.C._{min}} = 2 \times 2.44 = 4.88$$

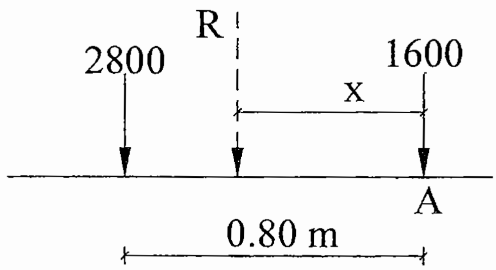
2- In short direction:-

$$R = 2800 + 1600 = 4400 kN$$

$$\sum M_{@A} = 0$$

$$\Rightarrow 4400(x) = 2800 \times 0.80$$

$$\therefore x = \frac{2800 \times 0.80}{4400} = 0.51 m$$



- $\frac{B_{P.C.}}{2} = 0.51 + \frac{0.40}{2} + 0.5 + 0.40 = 1.61m$

$\Rightarrow B_{P.C._{min}} = 2 \times 1.61 = 3.22m$

- $A_{P.C.} = \frac{R}{q_{all}} = \frac{4400}{200} = 22\ m^2 = B_{P.C.} \times L_{P.C.}$

$\Rightarrow (4.88 + x)(3.22 + x) = 22$

$\Rightarrow x^2 + 8.1x - 6.29 = 0 \quad \Rightarrow x = 0.71$ m

$\Rightarrow B_{P.C.} = 3.22 + 0.71 = 3.93$

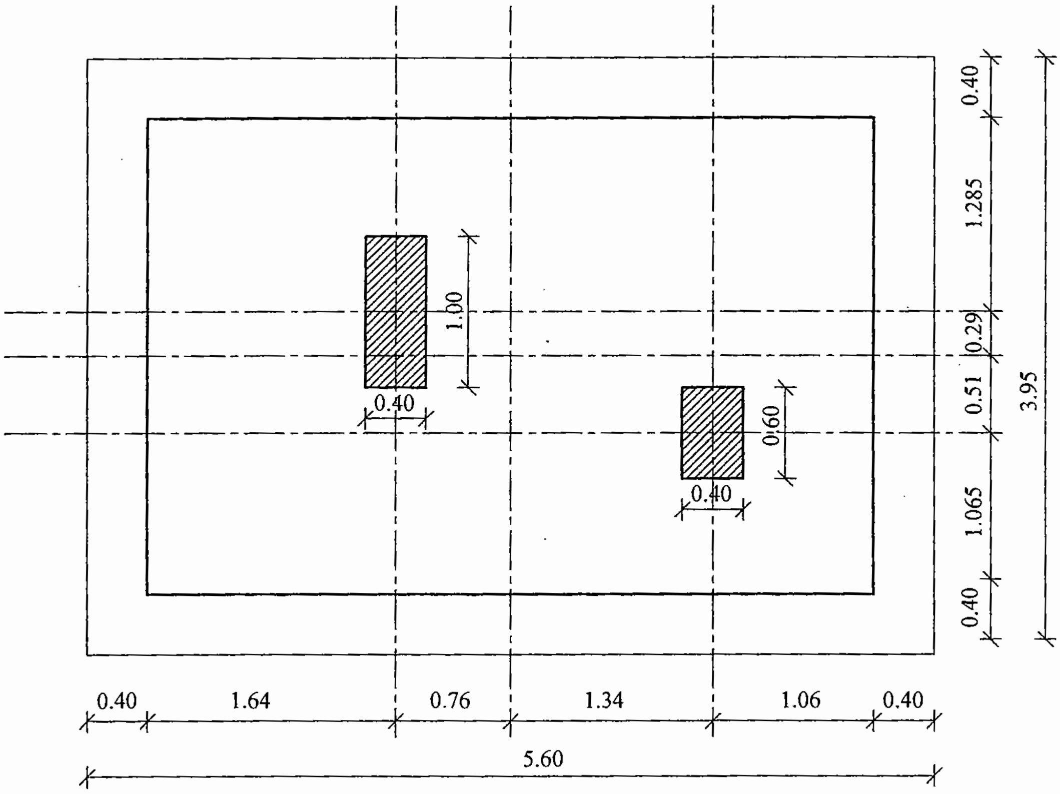
$\Rightarrow take\ B_{P.C.} = 3.95$ m

$\Rightarrow L_{P.C.} = 4.88 + 0.71 = 5.59$

$\Rightarrow take\ L_{P.C.} = 5.60$ m

$\Rightarrow B_{R.C.} = 3.95 - 2\ (0.4) = 3.15\ m$

& $L_{R.C.} = 5.6 - 2\ (0.4) = 4.8\ m$



Plan

scale 1:50