فونديشن رابعه

انشاءات

mid-Term

9

4th Year Civil - Structures

Foundation Design

(9)

Mid-term revision
Part (1)

- Example 1:-

Design an isolated footing to carry a column load of 2500 KN. The column dimensions are 0.90 x 0.40 m. Draw a sectional elevation and a plan with scale 1: 50. Thickness of P.C. is 40 cm, and q_{all} = 150 KN/m^2. (f_{cu} = 25 N/mm^2, f_y = 360 N/mm^2).

- Solution:-

1- Area of footing:-

$$- A_{P.C.} = \frac{P_{col}}{q_{all}} = \frac{2500}{150} = 16.67\ m^2 = B_{P.C.} \times L_{P.C.}$$

$$- L_{P.C.} - B_{P.C.} = b - a = 0.9 - 0.4 = 0.5\ m$$

$$\Rightarrow L_{P.C.} = B_{P.C.} + 0.5 \quad \text{But } B_{P.C.} \times L_{P.C.} = 16.67\ m^2$$

$$\Rightarrow B_{P.C.}\,(B_{P.C.} + 0.5) = 16.67\ m^2$$

$$\Rightarrow (B_{P.C.})^2 + 0.5\,(B_{P.C.}) - 16.67 = 0$$

$$\Rightarrow B_{P.C.} = 3.84\ m \Rightarrow \text{use } B_{P.C.} = 3.85\ m$$

$$\Rightarrow L_{P.C.} = 3.85 + 0.5 = 4.35\ m$$

$$\Rightarrow B_{R.C.} = B_{P.C.} - 2\ t_{P.C.} = 3.85 - 2 \times 0.4 = 3.05\ m$$

$$\Rightarrow L_{R.C.} = L_{P.C.} - 2\ t_{P.C.} = 4.35 - 2 \times 0.4 = 3.55\ m$$

2- Design of critical section for Bending Moment:-

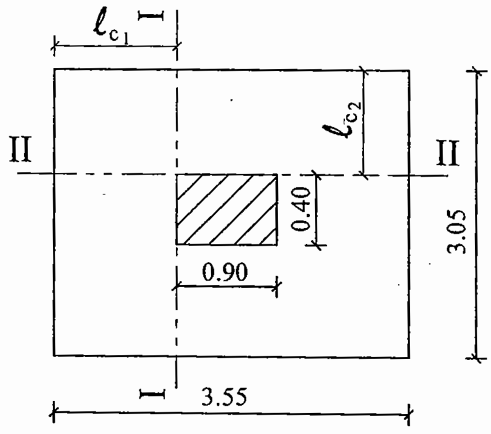
$$- P_u = 2500 \times 1.5 = 3750\ kN$$

$$- q_u = \frac{3750}{3.05 \times 3.55} = 346.3\ kN/m^2$$

$$- \ell_{c_1} = \ell_{c_2} = \frac{3.55 - 0.90}{2} = 1.325\ m$$

$$- M_{u_I} = M_{u_{II}} = q_u \times \frac{(\ell_{c_1})^2}{2} \times B$$

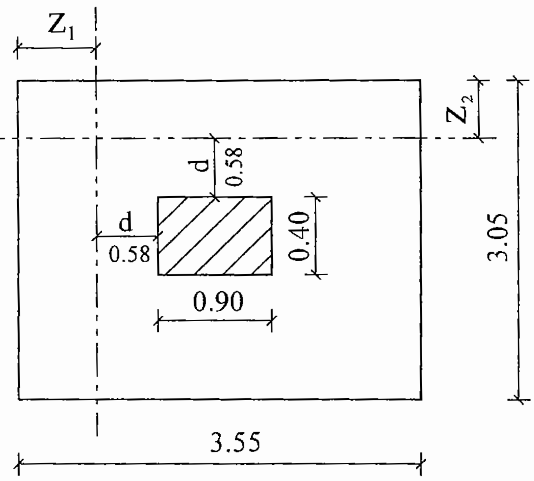
$$= 346.3 \times \frac{(1.325)^2}{2} \times 3.05 = 927.2\ kN.m$$



$$- d_I = d_{II} = C_1 \cdot \sqrt{\frac{M_{u_I} \times 10^6}{f_{cu} \times (B/2)}} = 3.5 \times \sqrt{\frac{927.2 \times 10^6}{25 \times (3050/2)}} = 545.8\ mm$$

$$\Rightarrow \quad \text{take } d = 580\ mm \qquad \Rightarrow t = 650\ mm$$

3- Check shear:-

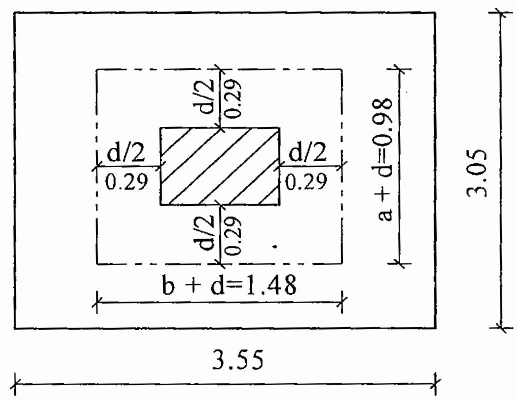


- $q_{scu} = 0.16 \times \sqrt{\frac{25}{1.5}} = 0.653 \text{ N/mm}^2$
- $z_1 = z_2 = \ell_{c_1} - d$

  $= 1.325 - 0.58 = 0.745 \text{ m}$
- $Q_{su_1} = Q_{su_2} = q_u \times z_1$

  $= 346.3 \times 0.745 = 258 \text{ kN}$
- $q_u = \frac{Q_{su_{max}} \times 10^3}{d \times 1000} = \frac{258 \times 10^3}{580 \times 1000} = 0.445 \quad \text{N/mm}^2 < q_{scu} \Rightarrow \text{safe}$

4- Check punching shear:-



- $\frac{a}{b} = \frac{0.4}{0.9} = 0.44 < 0.5$

$\Rightarrow q_{pcu} = 0.316 \times (0.5 + \frac{0.4}{0.9})\sqrt{\frac{25}{1.5}}$

$= 1.218 \text{ N/mm}^2$

- $Q_{pu} = P_u - q_u\left[(b+d)(a+d)\right]$

  $= 3750 - 346.3 \times \left[(1.48)(0.98)\right] = 3247.7 \text{ kN}$
- $q_{pu} = \frac{Q_{pu} \times 10^3}{d\left[(b+d)+(a+d)\right] \times 2}$
- $q_{pu} = \frac{3247.7 \times 10^3}{580\left[1480+980\right] \times 2} = 1.138 \quad \text{N/mm}^2 < q_{pcu} \Rightarrow \text{safe}$

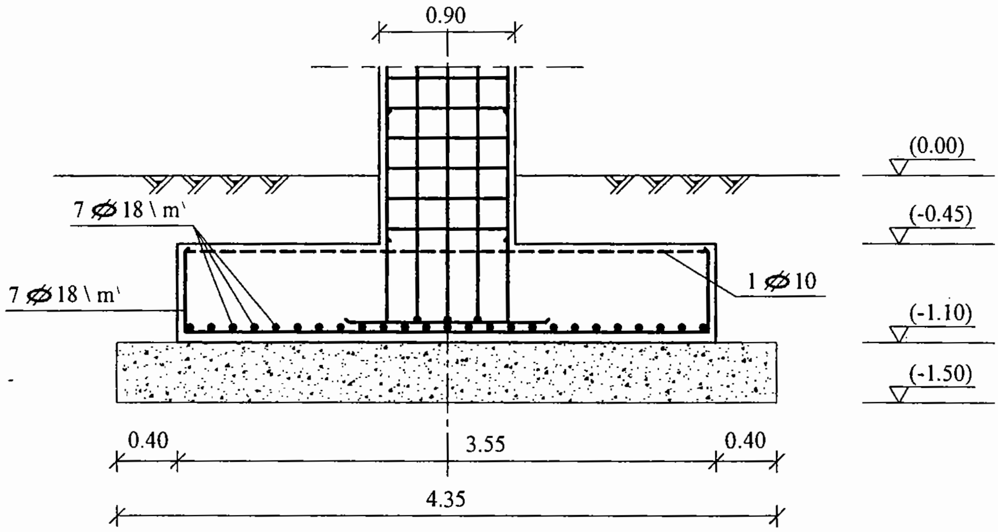
5- RFT:-

- $A_{s_{min}} = 1.5 \times d = 1.5 \times 580 = 870 \text{ mm}^2 / \text{m}'$
- $A_{s_I} = A_{s_{II}} = \frac{M_{u_I} \times 10^6}{f_y \times J \times d} = \frac{927.2 \times 10^6}{360 \times 0.826 \times 580}$

  $= 5376 \text{ mm}^2 / 3.05\text{m} = 1763 \text{ mm}^2 / \text{m}' > A_{s_{min}}$

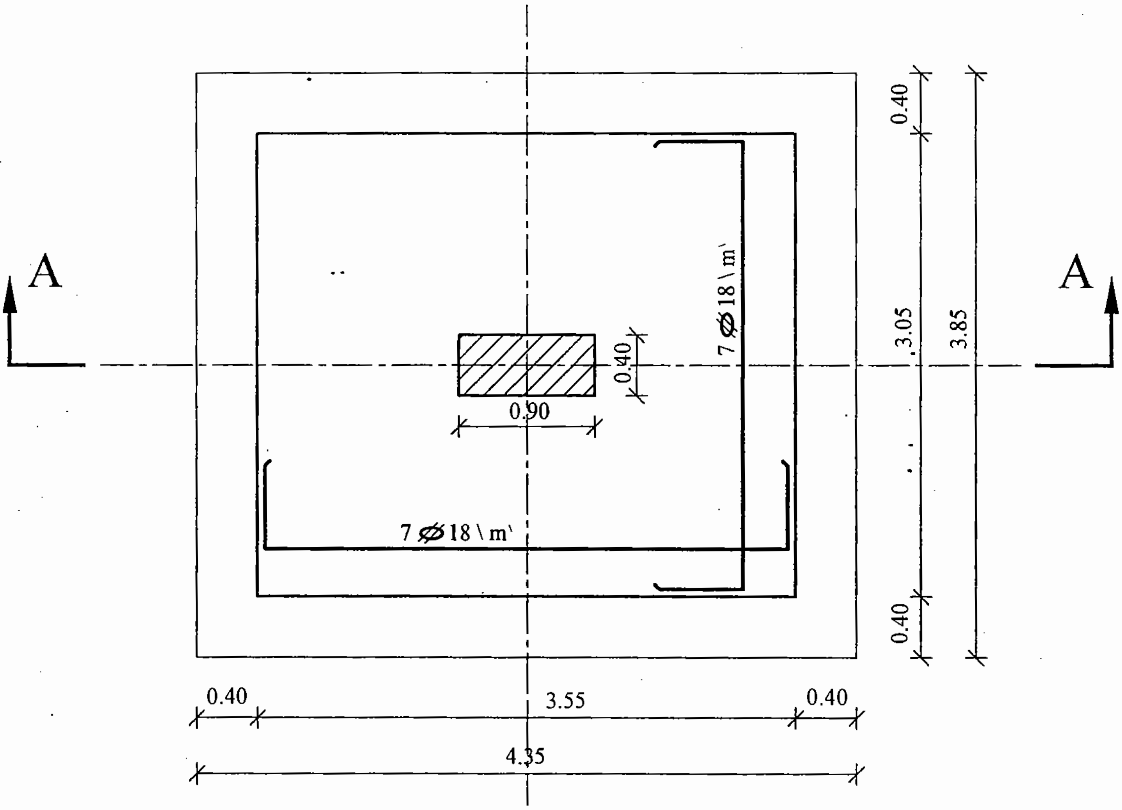
- use $A_{s_I} = A_{s_{II}} = 7 \, \phi \, 18 \setminus \text{m}'$

- Details of RFT:-



Section A-A

scale 1:50



Plan

scale 1:50

- Example 2:-

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.

- Solution:-

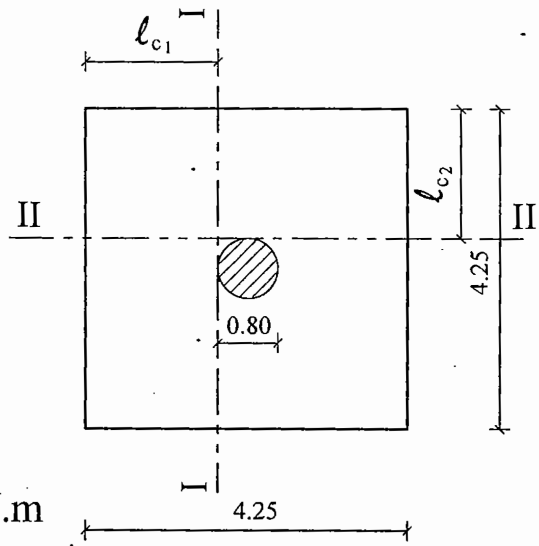
1- Area of footing:-

$$- A_{P.C.} = \frac{P_{col}}{q_{all}} = \frac{3500}{150} = 23.33 \ m^2 = (B_{P.C.})^2$$

$$\Rightarrow B_{P.C.} = 4.83 \ m \Rightarrow \text{use } B_{P.C.} = 4.85 \ m$$

$$\Rightarrow B_{R.C.} = B_{P.C.} - 2 \ t_{P.C.} = 4.85 - 2 \times 0.3 = 4.25 \ m$$

2- Design of critical section for Bending Moment:-



$$- P_u = 3500 \times 1.5 = 5250 \ kN$$

$$- q_u = \frac{5250}{4.25 \times 4.25} = 290.7 \ kN/m^2$$

$$- \ell_{c_1} = \ell_{c_2} = \frac{4.25 - 0.8}{2} = 1.725 \ m$$

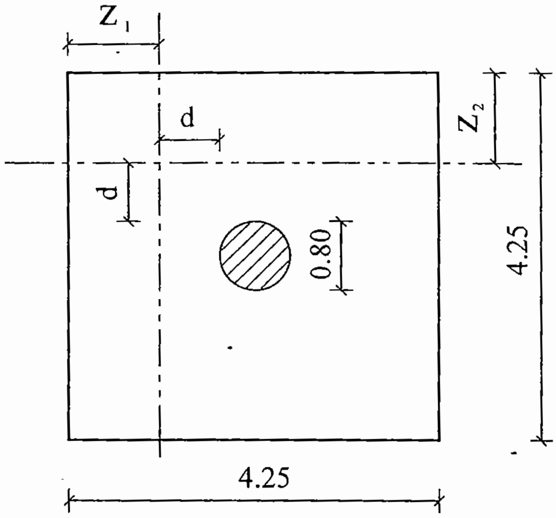
$$- M_{u_I} = M_{u_{II}} = q_u \times \frac{(\ell_{c_1})^2}{2} \times B$$

$$= 290.7 \times \frac{(1.725)^2}{2} \times 4.25 = 1838.2 \ kN.m$$

$$- d_I = d_{II} = C_1 \cdot \sqrt{\frac{M_I \times 10^6}{f_{cu} \times (B/2)}} = 3.5 \times \sqrt{\frac{1838.2 \times 10^6}{25 \times (4250/2)}} = 651 \ mm$$

$$\Rightarrow \quad \text{use } \ d = 680 \ mm \qquad \Rightarrow t = 750 \ mm$$

3- Check shear:-



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

$$- z_1 = z_2 = \ell_{c_1} - d$$

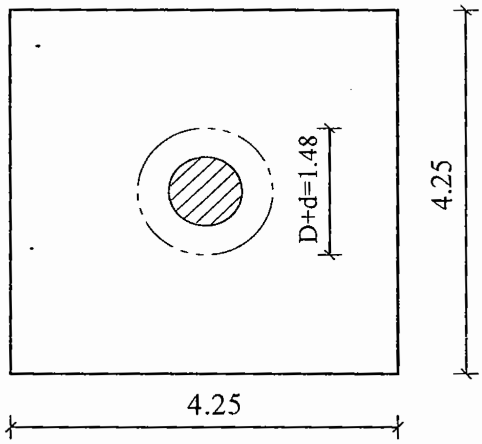
$$= 1.725 - 0.68 = 1.045 \text{ m}$$

$$- Q_{su_1} = Q_{su_2} = q_u \times z_1$$

$$= 290.7 \times 1.045 = 303.8 \text{ kN}$$

$$- q_u = \frac{Q_{su_{max}} \times 10^3}{d \times 1000} = \frac{303.8 \times 10^3}{680 \times 1000} = 0.447 \quad \text{N/mm}^2 < q_{scu} \Rightarrow \text{safe}$$

4- Check punching shear:-



$$- \frac{a}{b} = 1 < 0.5$$

$$\Rightarrow q_{pcu} = 0.316 \times \sqrt{\frac{25}{1.5}}$$

$$= 1.29 \text{ N/mm}^2$$

$$- Q_{pu} = P_u - q_u \left[\pi \times \frac{(D+d)^2}{4} \right]$$

$$= 5250 - 290.7 \times \left[\pi \times \frac{(1.48)^2}{4} \right] = 4749.9 \text{ kN}$$

$$- q_{pu} = \frac{Q_{pu} \times 10^3}{d[\pi \times (D+d)]}$$

$$- q_{pu} = \frac{4749.9 \times 10^3}{680(\pi \times 1480)} = 1.5 \quad \text{N/mm}^2 > q_{pcu} \Rightarrow \text{unsafe}$$

- Try d = 730 mm

$$- Q_{pu} = 5250 - 290.7 \times \left[\pi \times \frac{(1.53)^2}{4} \right] = 4715.5 \text{ kN}$$

$$- q_{pu} = \frac{4715.5 \times 10^3}{730(\pi \times 1530)} = 1.34 \quad \text{N/mm}^2 > q_{pcu} \Rightarrow \text{unsafe}$$

- Try d = 780 mm

$$- Q_{pu} = 5250 - 290.7 \times \left[\pi \times \frac{(1.58)^2}{4}\right] = 4680 \text{ kN}$$

$$- q_{pu} = \frac{4680 \times 10^3}{780(\pi \times 1580)} = 1.209 \quad \text{N/mm}^2 < q_{pcu} \Rightarrow \text{safe}$$

$\Rightarrow$ use d = 780 mm & t = 850 mm

5- RFT:-

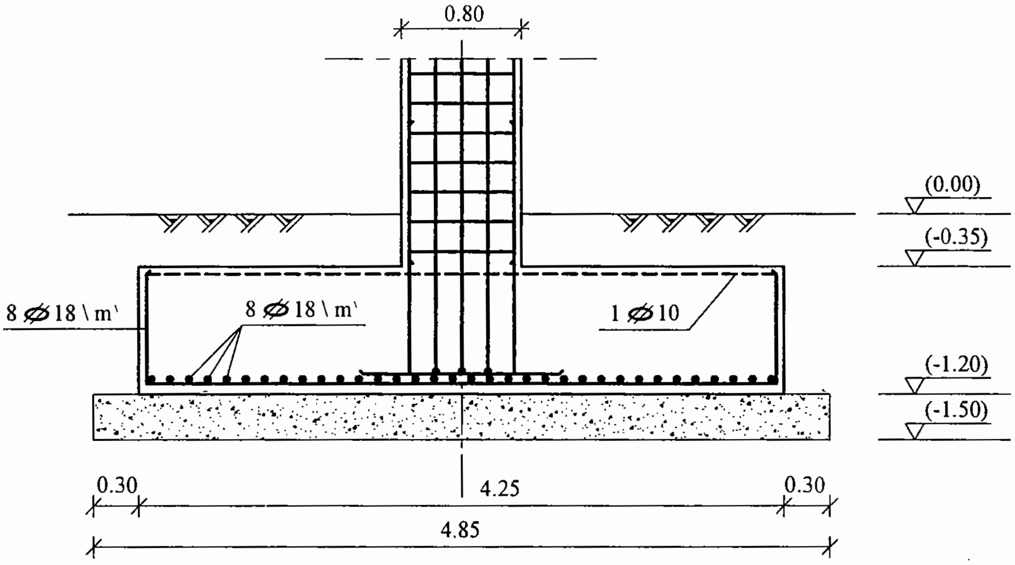
$$- A_{s_{min}} = 1.5 \times d = 1.5 \times 780 = 1170 \text{ mm}^2 / \text{m}^{\backslash}$$

$$- A_{s_I} = A_{s_{II}} = \frac{M_{u_I} \times 10^6}{f_y \times J \times d} = \frac{1838.2 \times 10^6}{360 \times 0.826 \times 780}$$

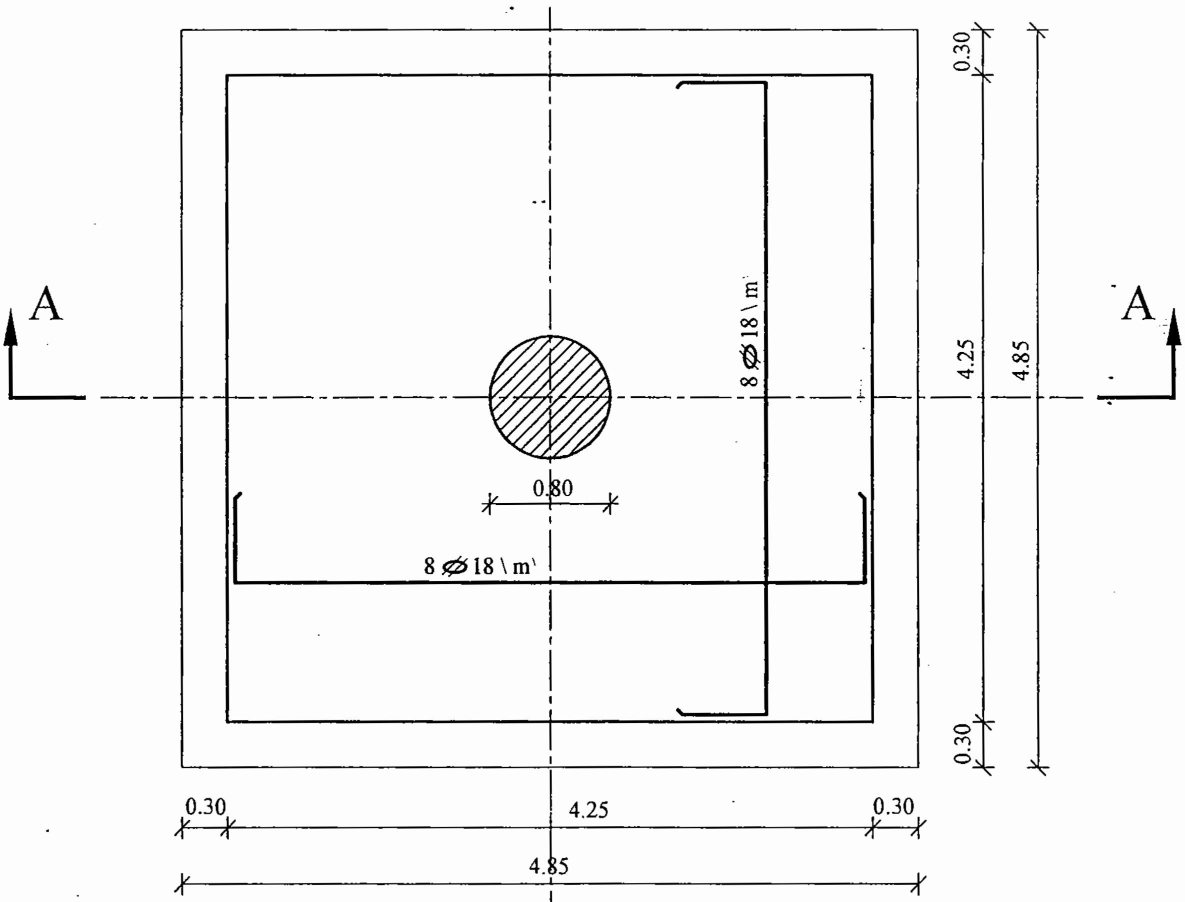
$$= 7925.3 \text{ mm}^2 / 4.25 \text{ m} = 1865 \text{ mm}^2 / \text{m}^{\backslash} > A_{s_{min}}$$

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

- Details of RFT:-



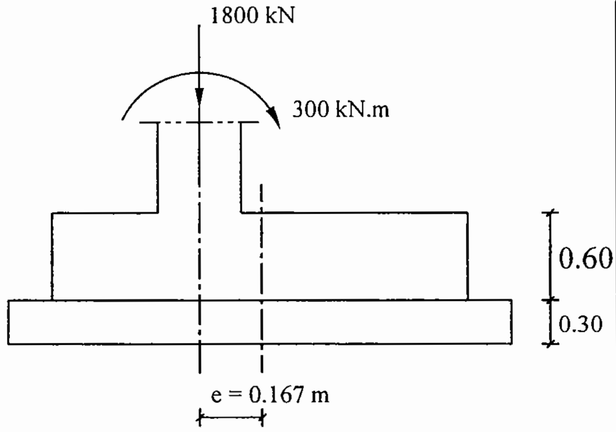
Section A-A
scale 1:50



Plan
scale 1:50

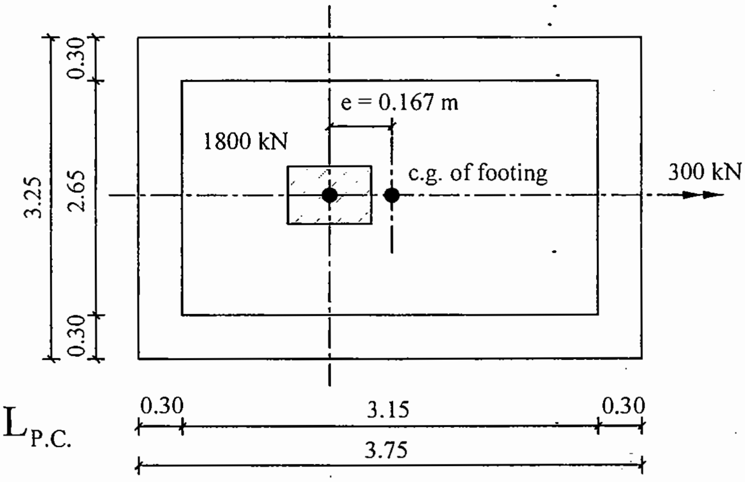
- Example 3:-

Design an isolated footing to carry a column subjected to 1800 KN vertical load and 300 KN.m permanent bending moment. The column dimensions are 0.90 x 0.40 m, draw a plan and sectional elevation with scale 1:50.
(f_{cu}=25 N/mm^2, f_y=360 N/mm^2). Thickness of P.C. is 30 cm, and q_{all} = 150 KN/m^2.



Given:-

- N = 1800 kN
- M = 300 kN.m
- q_{all} = 150 kN/m^2
- Column dimensions = 40 x 90 cm^2
- $t_{P.C.}$ = 30 cm



- Solution:-

1- Area of footing:-

$$- e = \frac{M}{N} = \frac{300}{1800} = 0.167 \text{ m}$$

$$- A_{P.C.} = \frac{P_{col}}{q_{all}} = \frac{1800}{150} = 12 \text{ m}^2 = B_{P.C.} \times L_{P.C.}$$

$$- L_{P.C.} - B_{P.C.} = b - a$$

$$\Rightarrow L_{P.C.} - B_{P.C.} = 0.9 - 0.4 \Rightarrow \; L_{P.C.} = B_{P.C.} + 0.5$$

But $B_{P.C.} \times L_{P.C.} = 12 \text{ m}^2$

$$\Rightarrow B_{P.C.}\,(B_{P.C.} + 0.5) = 12 \text{ m}^2$$

$$\Rightarrow (B_{P.C.})^2 + 0.5\,(B_{P.C.}) - 12 = 0$$

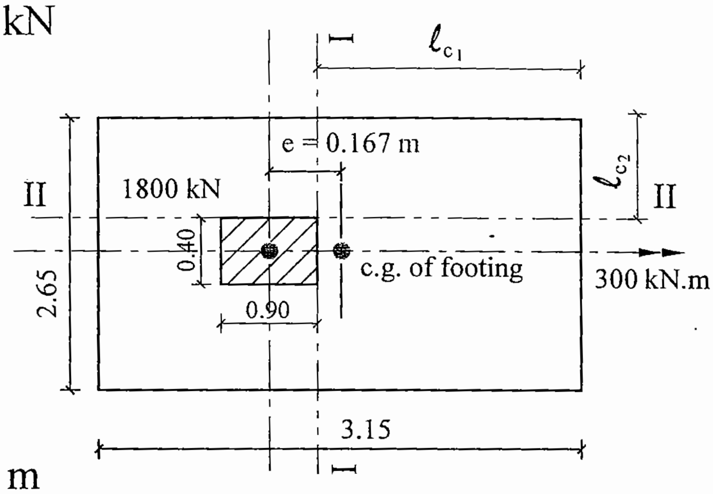
$$\Rightarrow B_{P.C.} = 3.22 \text{ m} \Rightarrow \; \text{take } B_{P.C.} = 3.25 \text{ m}$$

$$- L_{P.C.} = 3.25 + 0.5 = 3.75 \text{ m}$$

$$- B_{R.C.} = B_{P.C.} - 2\, t_{P.C.} = 3.25 - 2 \times 0.3 = 2.65 \text{ m}$$

$$- L_{R.C.} = L_{P.C.} - 2\, t_{P.C.} = 3.75 - 2 \times 0.3 = 3.15 \text{ m}$$

2- Design of critical section for Bending Moment:-



- $P_u = P_{col} \times 1.5 = 1800 \times 1.5 = 2700$ kN

- $q_u = \dfrac{P_u}{B_{R.C.} \times L_{R.C.}}$

$$= \frac{2700}{2.65 \times 3.15} = 323.5 \quad \text{kN/m}^2$$

- $\ell_{c_1} = \dfrac{L_{R.C.} - b}{2} + e$

$$= \frac{3.15 - 0.90}{2} + 0.167 = 1.292 \text{ m}$$

- $M_{u_I} = q_u \times \dfrac{(\ell_{c_1})^2}{2} \times B = 323.5 \times \dfrac{(1.292)^2}{2} \times 2.65 = 715.5$ kN.m

- $\ell_{c_2} = \dfrac{B_{R.C.} - a}{2} = \dfrac{2.65 - 0.40}{2} = 1.125$ m

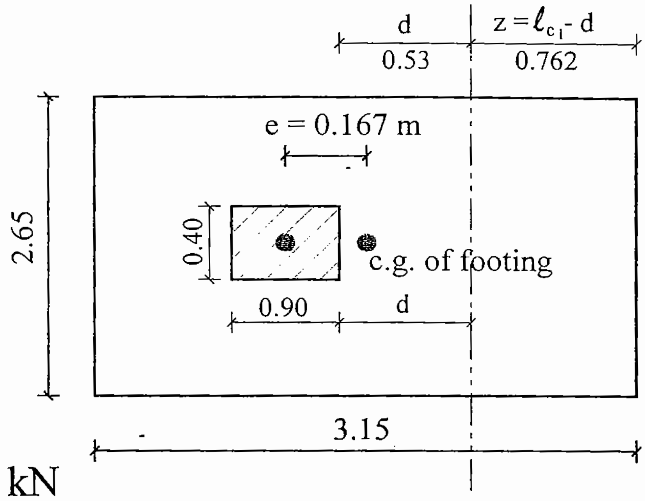
- $M_{u_{II}} = q_u \times \dfrac{(\ell_{c_2})^2}{2} \times L = 323.5 \times \dfrac{(1.125)^2}{2} \times 3.15 = 644.9$ kN.m

- $d_I = C_1 \cdot \sqrt{\dfrac{M_{u_I} \times 10^6}{f_{cu} \times (B/2)}} = 3.5 \sqrt{\dfrac{715.5 \times 10^6}{25 \times (2650/2)}} = 514.4 \quad \text{mm}$

- $d_{II} = C_1 \cdot \sqrt{\dfrac{M_{u_{II}} \times 10^6}{f_{cu} \times (L/2)}} = 3.5 \sqrt{\dfrac{644.9 \times 10^6}{25 \times (3150/2)}} = 447.9 \quad \text{mm}$

$\Rightarrow$ take $d = 530$ mm $\quad \Rightarrow t = 600$ mm

3- Check shear:-



- $z_1 = \ell_{c_1} - d$

$$= 1.292 - 0.53 = 0.762 \text{ m}$$

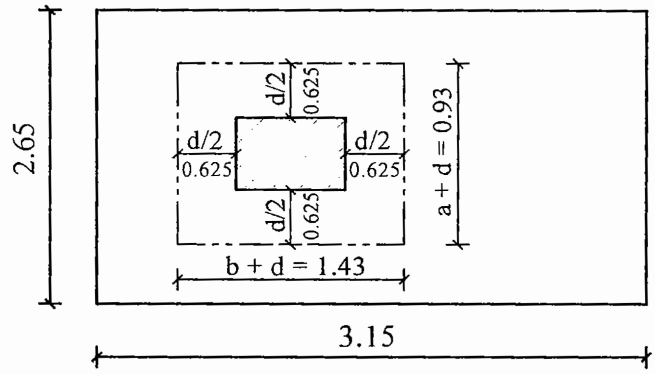
- $q_{scu} = 0.16\sqrt{\dfrac{f_{cu}}{1.5}}$

$$= 0.16 \times \sqrt{\frac{25}{1.5}} = 0.653 \text{ N/mm}^2$$

- $Q_{su_1} = q_u \times z_1 = 323.5 \times 0.762 = 246.5 \text{ kN}$

- $q_{su} = \dfrac{Q_{su_1} \times 10^3}{d \times 1000} = \dfrac{246.5 \times 10^3}{530 \times 1000} = 0.465 \quad \text{N/mm}^2 < q_{scu} \Rightarrow \text{safe}$

4- Check punching shear:-



- $\dfrac{a}{b} = \dfrac{0.4}{0.9} = 0.44 < 0.5$

$$\Rightarrow q_{pcu} = 0.316(0.5 + \frac{a}{b})\sqrt{\frac{f_{cu}}{1.5}}$$

$$= 0.316(0.5 + \frac{0.4}{0.9})\sqrt{\frac{25}{1.5}} = 1.218 \text{ N/mm}^2$$

- $Q_{pu} = P_u - q_u\left[(b+d)(a+d)\right]$

$$= 2700 - 323.5 \times \left[(1.43)(0.93)\right] = 2269.8 \text{ kN}$$

- - $q_{pu} = \dfrac{Q_{pu} \times 10^3}{d\left[(b+d) + (a+d)\right] \times 2}$

$$= \frac{2269.8\text{x } 10^3}{530\left[(1430)+(930)\right] \times 2} = 0.907 \quad \text{N/mm}^2 < q_{pcu} \Rightarrow \text{safe}$$

5- RFT:-

- $A_{s_{min}} = 1.5 \times d = 1.5 \times 530 = 795\ mm^2/m^\backprime$

- $A_{s_I} = \dfrac{M_{u_I} \times 10^6}{f_y \times J \times d_{mm}}$

$$= \frac{715.5 \times 10^6}{360 \times 0.786 \times 530} = 4771\ mm^2 / 2.65\ m = 1800\ \ mm^2/m^\backprime > A_{Smin}$$

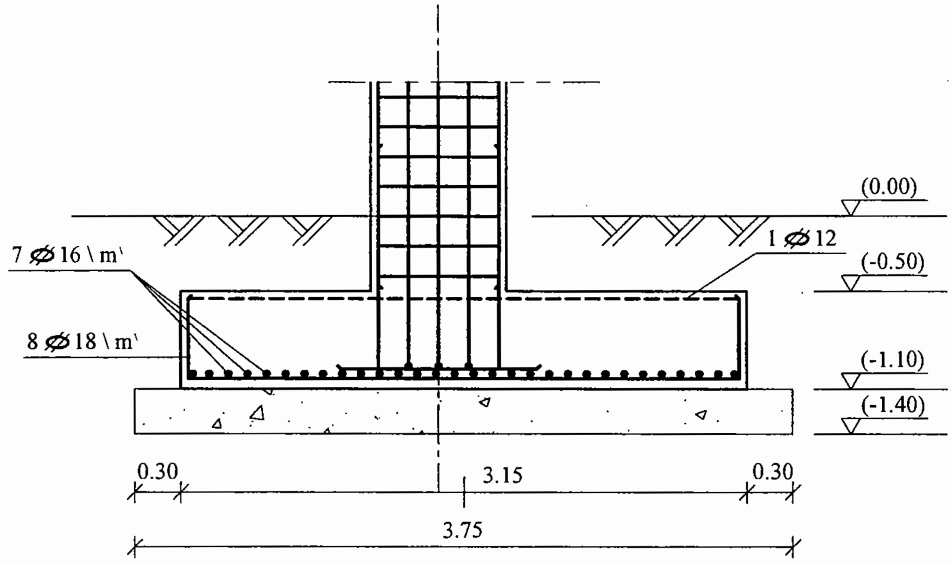
- $A_{s_{II}} = \dfrac{M_{u_{II}} \times 10^6}{f_y \times J \times d_{mm}}$

$$= \frac{644.9 \times 10^6}{360 \times 0.808 \times 530} = 4183\ mm^2 / 3.15\ m = 1328\ \ mm^2/m^\backprime > A_{Smin}$$

- use $A_{s_I} = 8 \not\phi 18 \backslash m^\backprime$

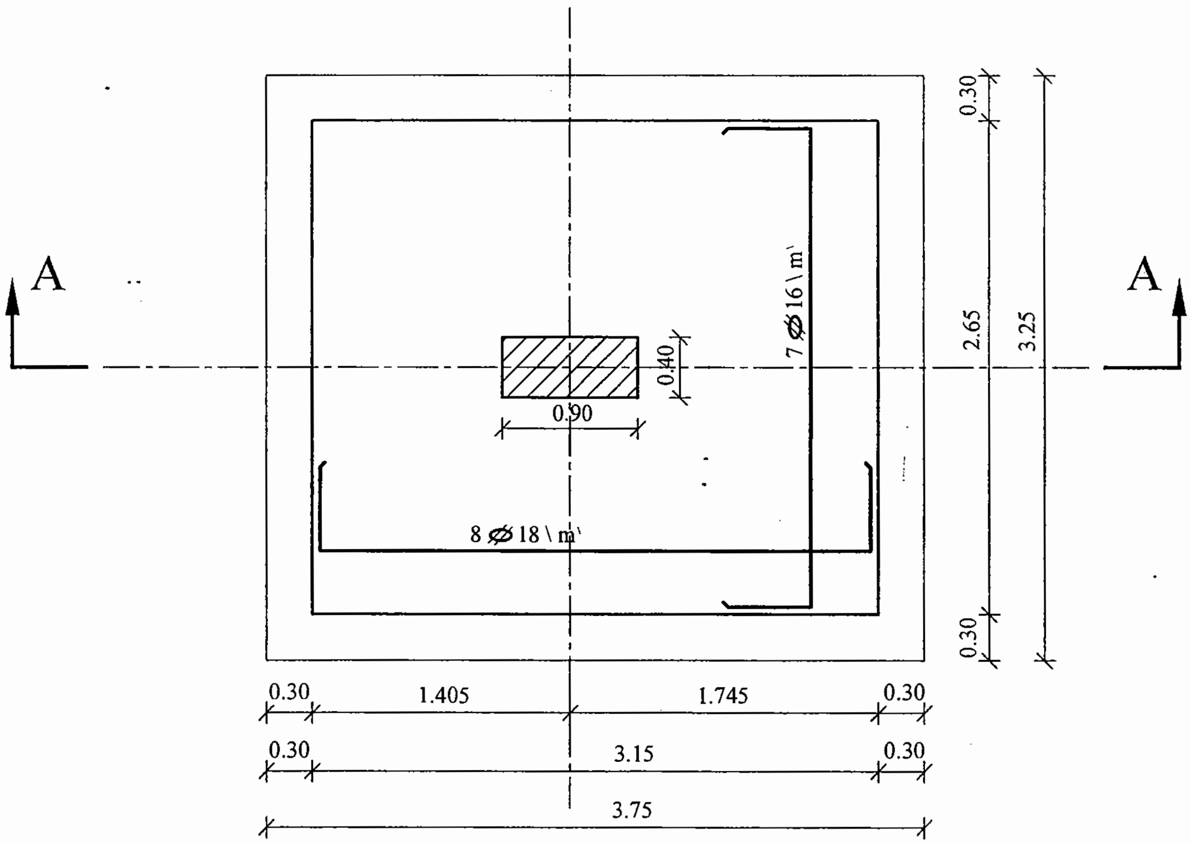
- use $A_{s_{II}} = 7 \not\phi 16 \backslash m^\backprime$

- Details of RFT:-



Section A-A

scale 1:50



Plan

scale 1:50

- Example 4:-

Design an isolated footing to carry a column subjected to 1800 KN vertical load and 300 KN.m temporary bending moment. The column dimensions are 0.90 x 0.40 m, draw a plan and sectional elevation with scale 1:50.
(f_{cu}=25 N/mm^2, f_y=360 N/mm^2). Thickness of P.C. is 30 cm, and q_{all} = 150 KN/m^2.

- Solution:-

I- Area of footing:-

$$- A_{R.C.} = \frac{N}{q_{all}} + \frac{6M}{\sqrt{N \times q_{all}}}$$

$$= \frac{1800}{150} + \frac{6(300)}{\sqrt{1800 \times 150}} = B_{R.C.} \times L_{R.C.} = 15.5 \text{ m}^2$$

$$- L_{R.C.} - B_{R.C.} = b - a \Rightarrow L_{R.C.} - B_{R.C.} = 0.9 - 0.4 = 0.5$$

$$\Rightarrow L_{R.C.} = B_{R.C.} + 0.5$$

$$- B_{R.C.}(B_{R.C.} + 0.5) = 15.5$$

$$\Rightarrow (B_{R.C.})^2 + 0.5\, B_{R.C.} - 15.5 = 0 \qquad \Rightarrow B_{R.C.} = 3.69 \text{ m}$$

$$\text{- take } B_{R.C.} = 3.7 \text{ m} \qquad \Rightarrow L_{R.C.} = 3.7 + 0.5 = 4.2 \text{ m}$$

- Check:-

$$- e = \frac{300}{1800} = 0.167$$

$$- f_1 = \frac{1800}{3.7 \times 4.2}\left(1 + \frac{6 \times 0.167}{4.2}\right) = 143.4 \text{kN/m}^2 \le q_{all} \qquad \text{safe}$$

$$- f_2 = \frac{1800}{3.7 \times 4.2}\left(1 - \frac{6 \times 0.167}{4.2}\right) = 88.3 \text{kN/m}^2 > \text{zero} \qquad \text{safe}$$

$$\Rightarrow B_{P.C.} = B_{R.C.} + 2\,t_{P.C.} = 3.7 + 2(0.15) = 4.0 \text{ m}$$

$$\& \quad L_{P.C.} = L_{R.C.} + 2\,t_{P.C.} = 4.2 + 2(0.15) = 4.5 \text{ m}$$

II- Design of R.C. footing:-

1- Calculate the ultimate stresses under R.C. footing :-

- $N_u = 1.5 \times N = 1.5 \times 1800 = 2700$ kN
- $M_u = 1.5 \times M = 1.5 \times 300 = 450$ kN.m
- $A = 3.7 \times 4.2 = 15.54$ m^2
- $I = \dfrac{3.7 \times (4.2)^3}{12} = 22.84$ m^4
- $\ell_{c_1} = \dfrac{L_{R.C.} - b}{2} = \dfrac{4.2 - 0.9}{2} = 1.65$ m
- $f_1 = \dfrac{N_u}{A} + \dfrac{M_u}{I} \cdot (L_{R.C.}/2)$

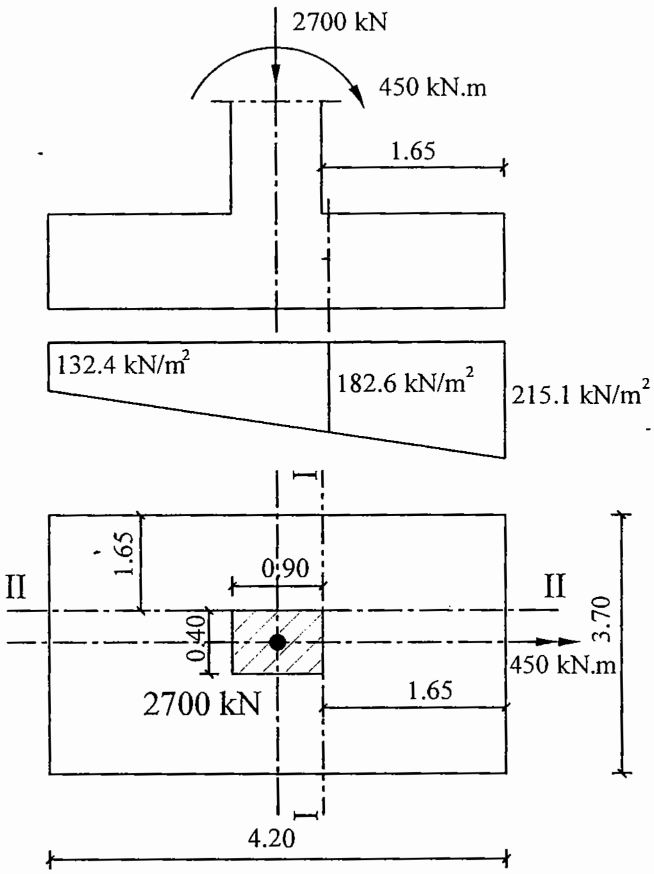
$$= \frac{2700}{15.54} + \frac{450}{22.84} \cdot (2.1) = 215.1 \text{ kN/m}^2$$

- $f_2 = \dfrac{N_u}{A} - \dfrac{M_u}{I} \cdot (L_{R.C.}/2)$

$$= \frac{2700}{15.54} - \frac{450}{22.84} \cdot (2.1) = 132.4 \text{ kN/m}^2$$

- $f_3 = \dfrac{N_u}{A} + \dfrac{M_u}{I} \cdot (b/2)$

$$= \frac{2700}{15.54} + \frac{450}{22.84} \cdot (0.45) = 182.6 \text{ kN/m}^2$$



2- Design of critical section for Bending Moment:-

- $M_{u_I} = \left(\dfrac{f_1 + f_3}{2}\right) \times \dfrac{(\ell_{c_1})^2}{2} \times B$

$$= \left(\frac{215.1 + 182.6}{2}\right) \times \frac{1.65^2}{2} \times 3.7 = 1001.5 \text{ kN.m}$$

- $d = C_1 \sqrt{\dfrac{M_{u_I} \times 10^6}{f_{cu} \times (B_{R.C.}/2)}} = 3.5 \times \sqrt{\dfrac{1001.5 \times 10^6}{25 \times (3700/2)}} = 515$ mm

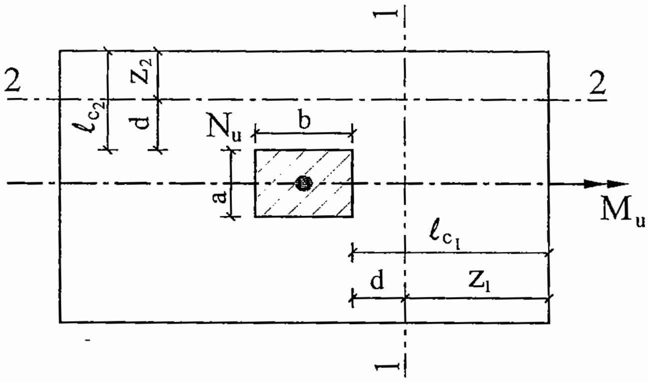
– take $d = 530$ mm

$\Rightarrow t_{R.C.} = 600$ mm

$$- M_{u_{II}} = \left(\frac{f_1 + f_2}{2}\right) \times \frac{(\ell_{c_2})^2}{2} \times L$$

$$= \left(\frac{215.1 + 132.4}{2}\right) \times \frac{1.65^2}{2} \times 4.2 = 993.4 \text{ kN.m}$$

3- Check shear:-

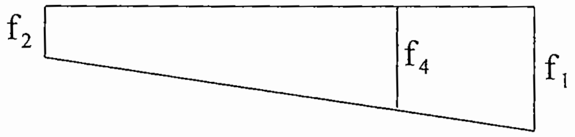


$$- q_{scu} = 0.16\sqrt{\frac{f_{cu}}{1.5}}$$

$$= 0.16\sqrt{\frac{25}{1.5}} = 0.653 \text{ N/mm}^2$$

$$- z_1 = \ell_{c_1} - d$$

$$= 1.35 - 0.53 = 0.82 \text{ m}$$



$$- f_4 = \frac{N_u}{A} + \frac{M_u}{I} \cdot (b/2 + d)$$

$$= \frac{2700}{11.16} + \frac{450}{12.1} \cdot (0.45 + 0.53) = 278.4 \text{ kN/m}^2$$

$$- Q_{su} = \frac{(f_1 + f_4)}{2} \times z_1$$

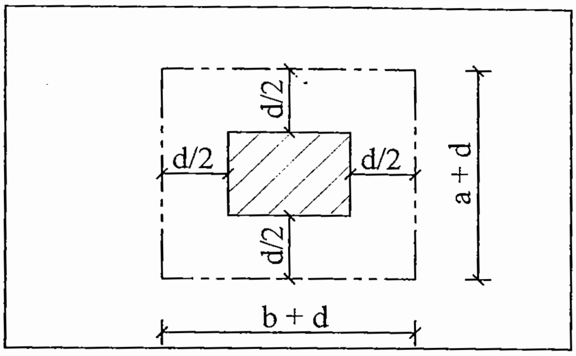
$$= \frac{(308.9 + 278.4)}{2} \times 0.82 = 240.8 \text{ kN}$$

$$- q_{su} = \frac{Q_{su} \times 10^3}{d \times 1000}$$

$$= \frac{240.8 \times 10^3}{530 \text{x} 1000} = 0.454 \quad \text{N/mm}^2 \quad \leq q_{scu} \quad \Rightarrow \text{ safe}$$

4- Check punching shear:-

- $\frac{a}{b} = \frac{0.4}{0.9} = 0.44$



- $q_{pcu} = 0.316(0.5 + \frac{a}{b})\sqrt{\frac{f_{cu}}{1.5}}$

$= 0.316(0.5 + \frac{0.4}{0.9})\sqrt{\frac{25}{1.5}}$

$= 1.218 \text{ N/mm}^2$

- $Q_{pcu} = N_u - \frac{(f_1 + f_2)}{2} \cdot [(b+d)(a+d)]$

$= 2700 - \frac{(308.9 + 175)}{2} \cdot [(0.9 + 0.53)(0.4 + 0.53)] = 2378.2 \text{ kN}$

- $q_{pu} = \frac{Q_{pu} \times 10^3}{d[(b+d) + (a+d)] \times 2}$

$= \frac{2378.2 \times 10^3}{530[(900 + 530) + (400 + 530)] \times 2}$

$= 0.951 \text{ N/mm}^2 \leq q_{pcu} \Rightarrow$ safe

5- RFT:-

- $A_{s_{min}} = 1.5 \times d = 1.5 \times 530 = 795 \text{ mm}^2/\text{m}'$

- $A_{s_I} = \frac{M_{u_I} \times 10^6}{f_y \times J \times d} = \frac{1001.5 \times 10^6}{360 \times 0.786 \times 530} = 6678 \text{ mm}^2/3.7 \text{ m}$

$= 1804 \text{ mm}^2/\text{m}'$

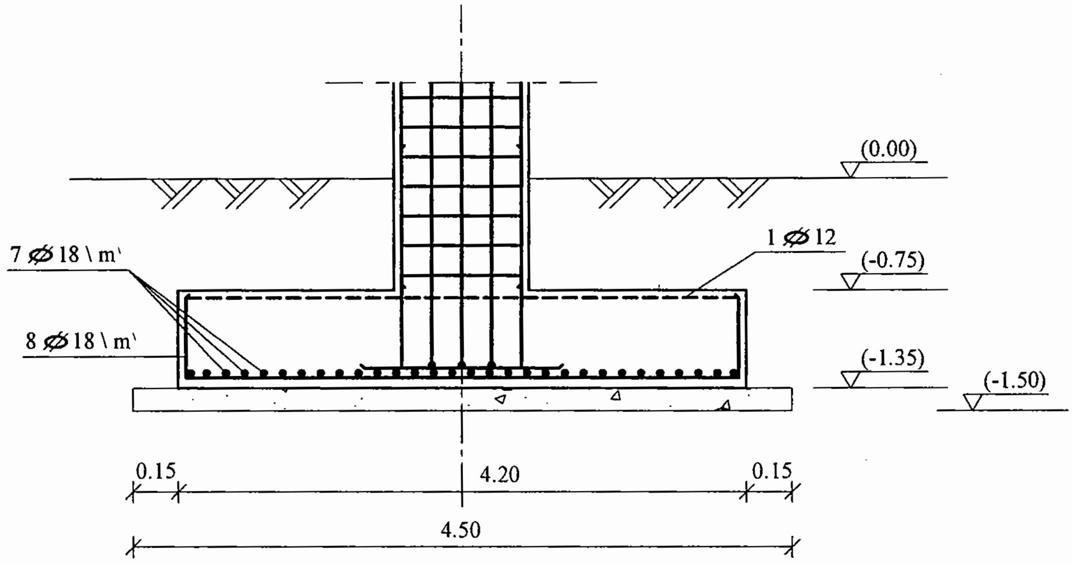
- $A_{s_{II}} = \frac{M_{u_{II}} \times 10^6}{f_y \times J \times d} = \frac{993.4 \times 10^6}{360 \times 0.78 \times 530} = 6675 \text{ mm}^2/4.2 \text{ m}$

$= 1589 \text{ mm}^2/\text{m}'$

- use $A_{s_I} = 8 \phi 18 \backslash m'$

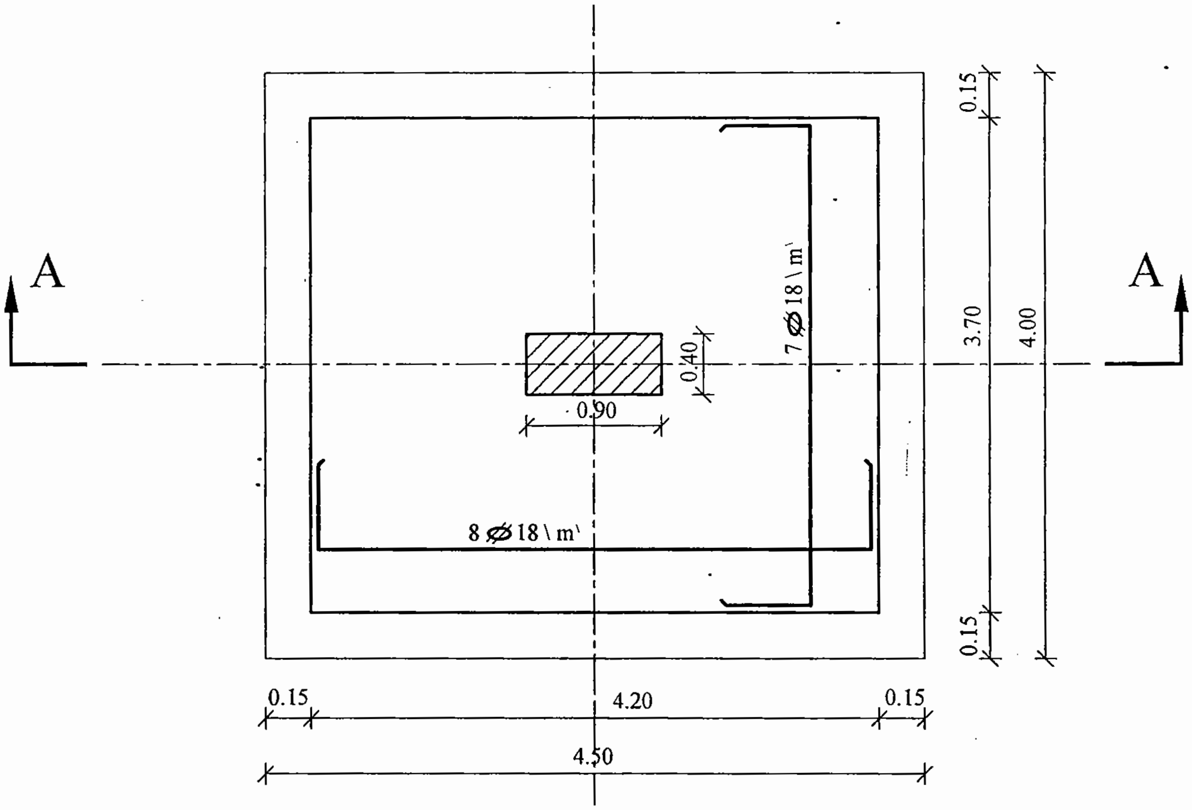
- use $A_{s_{II}} = 7 \phi 18 \backslash m'$

- Details of RFT:-



Section A-A

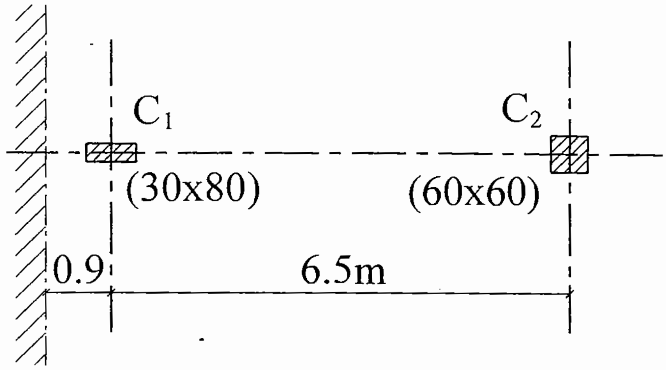
scale 1:50



Plan

scale 1:50

- Example 5:-



For the two columns shown in the given plan:
The outer column load is 1600 kN,
The inner column load is 2500 kN.

It is required to:-

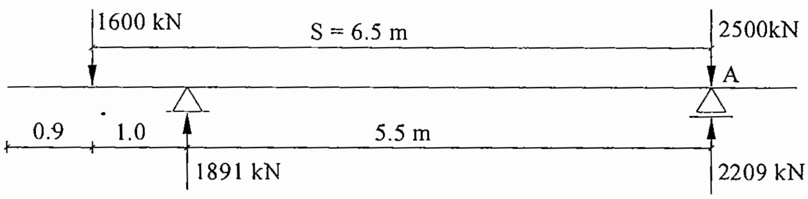
a) Design the required strap beam footing system, if the thickness of P.C. is 30 cm, and qall = 175 KN/m^2. (f_{cu} = 25 N/mm^2, f_y = 360 N/mm^2)

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

-Solution:-

1- Dimensions of footings:-

- Assume $e = 0.15\ S$



$\Rightarrow e = 0.15(6.5) = 0.975$

- take $e = 1.0$ m

$\sum M_{@A} = 0$

$\Rightarrow 1600 \times 6.5 = R_1 \times 5.5 \qquad \Rightarrow R_1 = 1891 kN$

- $R_2 = P_1 + P_2 - R_1$

- $R_2 = 1600 + 2500 - 1891 \quad \Rightarrow R_2 = 2209$ kN

- Dimensions of F1:-

- $L_{P.C.} = L_{R.C.} = 2(1 + 0.9) = 3.8$ m

- $A_{P.C.} = \dfrac{1891}{175} = 10.81\ m^2 = B_{P.C.} \times 3.8$

- $B_{P.C.} = \dfrac{10.81}{3.8} = 2.84\ m \quad \Rightarrow$ take $B_{P.C.} = 2.85$ m

- $B_{R.C.} = 2.85 - 2(0.3) = 2.25\ m < 1.5 \times L_{R.C.} = 4.2$ m O.K.

- Dimensions of F2:-

$$- A_{P.C.} = \frac{2209}{175} = 12.62\ m^2 = (B_{P.C.})^2$$

$$\Rightarrow B_{P.C.} = 3.55\ m$$

$$- B_{R.C.} = 3.55 - 2(0.3) = 2.95\ m$$

$$y = S - e - \frac{L_{P.C._1}}{2} - \frac{L_{P.C._2}}{2}$$

$$= 6.5 - 1 - \frac{3.8}{2} - \frac{3.55}{2} = 1.825\ m > \frac{3.55}{2} = 1.775\ m \quad O.K$$

2- Design of Strap beam:-

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

$$- R_{1u} = 1891 \times 1.5 = 2836.5\ kN \qquad - R_{2u} = 2209 \times 1.5 = 3313.5\ kN$$

$$- w_{1u} = \frac{2836.5}{3.8} = 746.4\ kN/m^{\backslash} \qquad - w_{2u} = \frac{3313.5}{2.95} = 1123.2\ kN/m^{\backslash}$$

- At point of zero shear:-

$$- 2400 = 746.4(x)$$

$$\Rightarrow x = 3.22\ m$$

$$\therefore M_{max.} = 2400(3.22 - 0.9) - 746.4 \times \frac{(3.22)^2}{2}$$

$$\Rightarrow M_{max.} = 1698.5\ kN.m$$

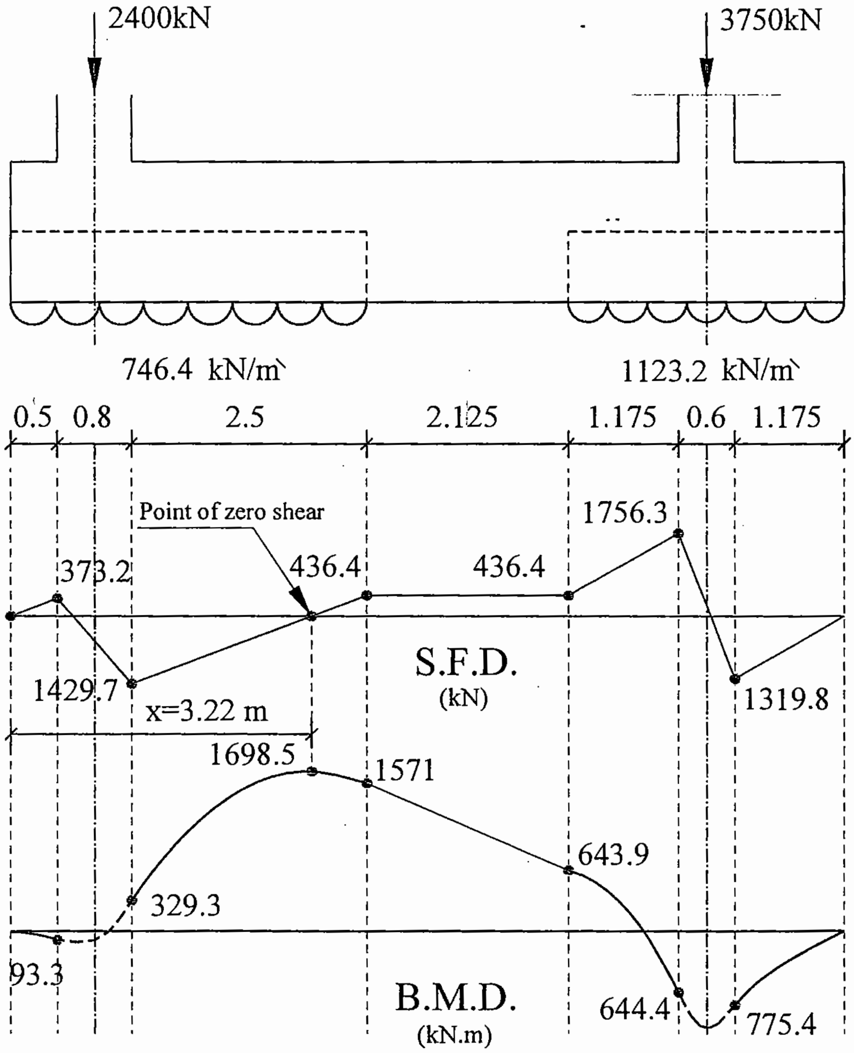
$$- d = C_1 \times \sqrt{\frac{M_{umax} \times 10^6}{f_{cu} \times b_{(mm)}}}$$

$$\Rightarrow d = 3.5 \times \sqrt{\frac{1698.5 \times 10^6}{25 \times 600}}$$

$$= 1178\ mm$$

- take d = 1180 mm

$$\Rightarrow t = 1250\ mm$$



2- Check shear for strap beam:-

$$- q_{scu} = 0.24 \times \sqrt{\frac{25}{1.5}} = 0.98 \ N/mm^2$$

$$- q_{scu_{max.}} = 0.7 \times \sqrt{\frac{25}{1.5}} = 2.86 \ N/mm^2$$

$$- Q_{su_{max.}} = Q_{max.} - w_u \cdot (\frac{d}{2}) = 1756.7 - 1123.2 \times (\frac{1.08}{2}) = 1150.2 \text{ kN}$$

$$- q_{su} = \frac{1050.2 \times 10^3}{1180 \times 600} = 1.48 \ N/mm^2$$

- $q_{scu} < q_{su} < q_{scu_{max.}}$ $\Rightarrow$ use shear RFT (stirupps)

$$- q_{su} - \frac{q_{scu}}{2} = \frac{n \times A_\varphi \times f_y/\gamma_s}{b \times S}$$

- Try Stirrups ϕ 8 4 branches

$$- 1.48 - \frac{0.98}{2} = \frac{4 \times 50.3 \times 360/1.15}{600 \times S}$$

$\Rightarrow S = 106$ mm

- use Stirrups 10 ϕ 10 \ m' 4 branches

3- RFT of strap beam:-

$$- A_{s_{Top}} = \frac{M_{umax.top} \times 10^6}{f_y \times j \times d} = \frac{1698.5 \times 10^6}{360 \times 0.781 \times 1180} = 5120 \text{ mm}^2$$

$$- A_{s_{Bottom}} = \frac{M_{umax.bottom} \times 10^6}{f_y \times j \times d} = \frac{775.2 \times 10^6}{360 \times 0.826 \times 1180} = 2209 \text{ mm}^2$$

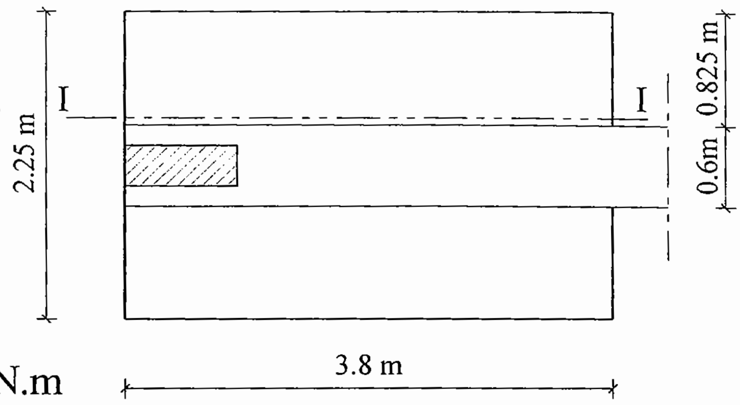
$$- As_{min} = \frac{0.15}{100} b\, d = \frac{0.15}{100} \times 600 \times 1180 = 1062 \text{ mm}^2$$

- use $A_{s_{Top}}$ = 11 ϕ 25

- use $A_{s_{Bottom}}$ = 5 ϕ 25

4- Design of footings:-

- Design of F_1:-



$$- q_{u_1} = \frac{2836.5}{2.25 \times 3.8} = 331.8 \quad kN/m^2$$

$$- \ell_{c_1} = \frac{2.25 - 0.6}{2} = 0.825 \ m$$

$$- M_{u_1} = 331.8 \times \frac{(0.825)^2}{2} = 112.9 \ kN.m$$

$$- d_1 = 5 \times \sqrt{\frac{112.9 \times 10^6}{25 \times 1000}} = 336 \ mm$$

$$\Rightarrow \text{take } d_1 = 380 \ mm \ \ \& \ t_1 = 450 \ mm$$

2- Check shear:-

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

$$- z_1 = 0.825 - 0.38 = 0.445 \ m$$

$$- Q_{su_1} = q_{u_1} \times z_1 = 360.2 \times 0.445 = 160.3 \ kN$$

$$- q_{su_1} = \frac{160.3 \times 10^3}{380 \times 1000} = 0.422 \quad N/mm^2 \quad < q_{scu} \qquad \text{safe}$$

3- RFT:-

$$- A_{s_{min}} = 1.5 \times 380 = 570 \ mm^2/m'$$

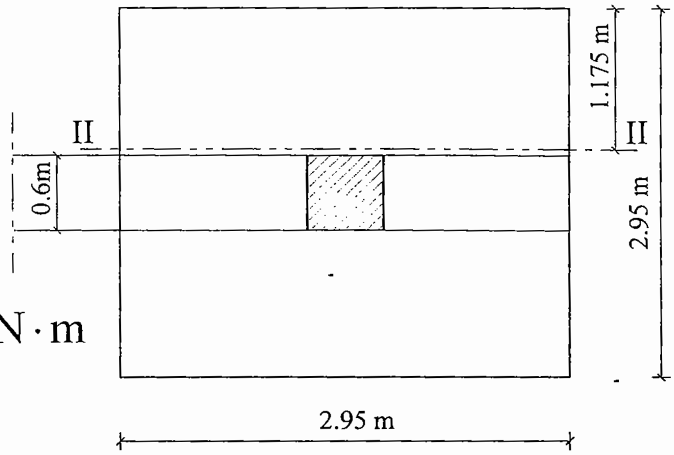
$$- A_{s_1} = \frac{112.9 \times 10^6}{360 \times 0.826 \times 380} = 999 \ mm^2/m'$$

- use $A_{s_1} = 5 \not\phi 16 \setminus m'$

- Design of F_2:-

$$- q_{u_2} = \frac{3313.5}{2.95 \times 2.95} = 380.8 \ kN/m^2$$

$$- \ell_{c_2} = \frac{2.95 - 0.6}{2} = 1.175 \ m$$



$$- M_{u_2} = 380.8 \times \frac{(1.175)^2}{2} = 262.9 \ kN \cdot m$$

$$- d_2 = 5 \times \sqrt{\frac{262.9 \times 10^6}{25 \times 1000}} = 512.7 \ mm$$

$\Rightarrow$ take $d_2 = 530$ mm & $t_2 = 600$ mm

2- Check shear:-

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

$$- z_2 = 1.175 - 0.53 = 0.645 \ m$$

$$- Q_{su_2} = q_{u_2} \times z_2 = 380.8 \times 0.645 = 245.6 \ kN$$

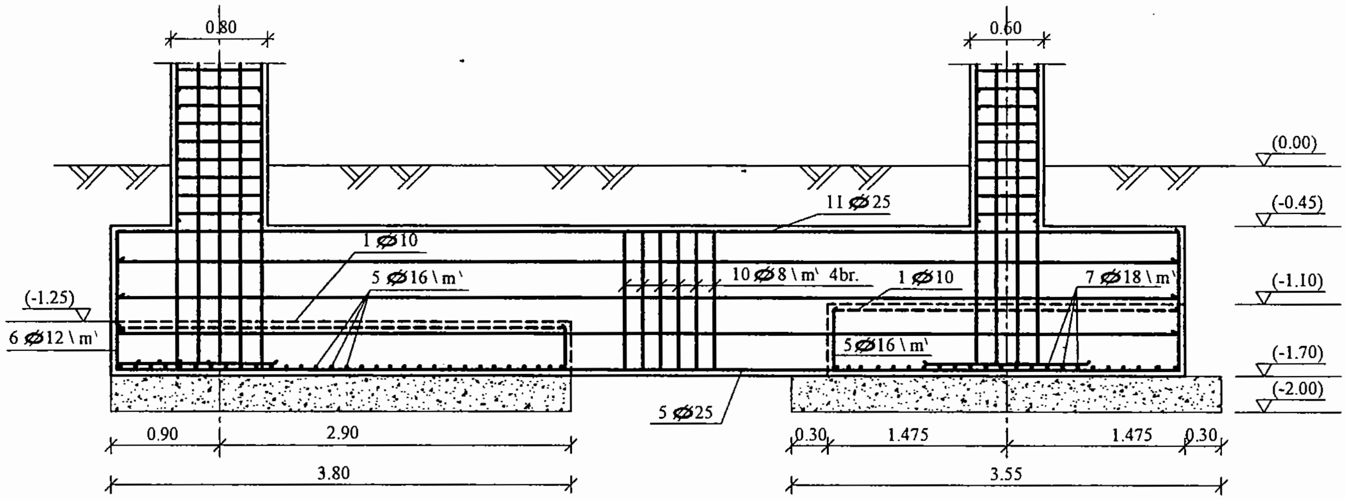
$$- q_{su_2} = \frac{245.6 \times 10^3}{530 \times 1000} = 0.463 \ N/mm^2 \quad < q_{scu}$$ safe

3- RFT:-

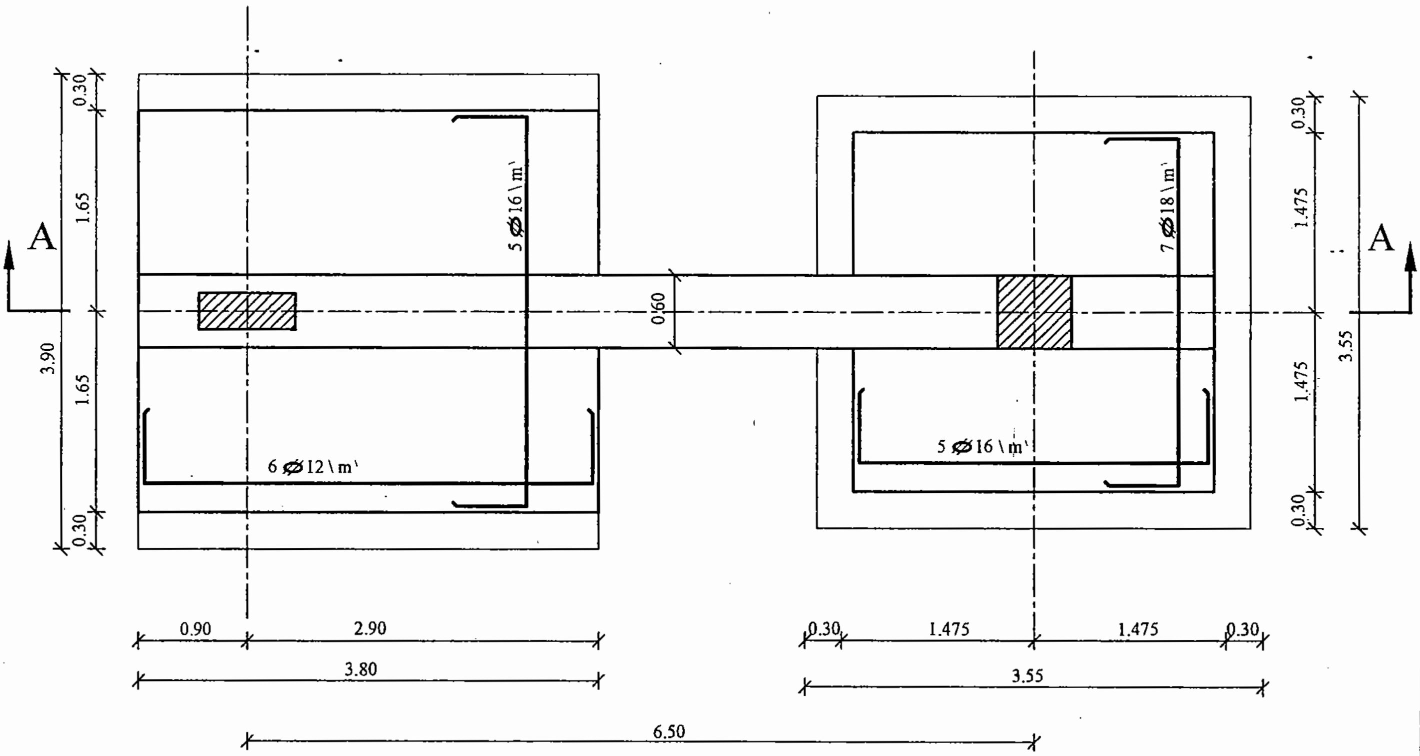
$$- A_{s_{min}} = 1.5 \times 530 = 795 \ mm^2/m'$$

$$- A_{s_2} = \frac{262.9 \times 10^6}{360 \times 0.826 \times 530} = 1668 \ mm^2/m'$$

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



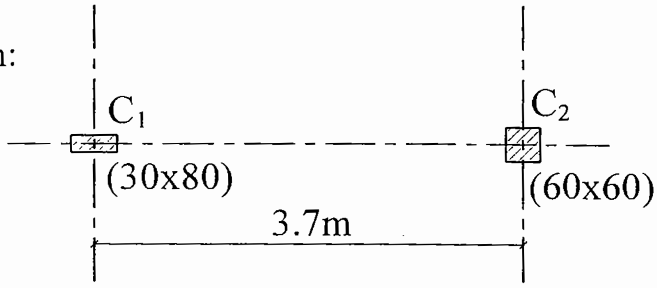
Section A-A
scale 1:50



Plan
scale 1:50

- Example 6:-

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:

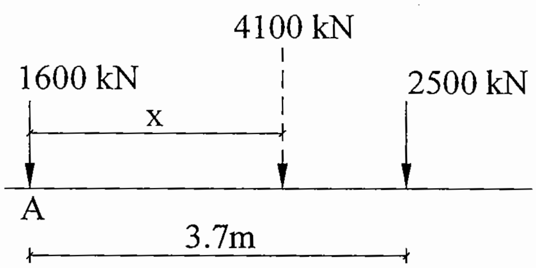


a) Design the required combined footing, if the thickness of P.C. is 30 cm, and $q_{all} = 175\ KN/m^2$.
($f_{cu} = 25\ N/mm^2$, $f_y = 360\ N/mm^2$)

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:-



- $R = P_1 + P_2 = 1600 + 2500 = 4100\ kN$
- $R \cdot x = P_2 \cdot S$

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

$\therefore x = 2.26\ m$

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

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

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

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

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

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

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

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

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

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

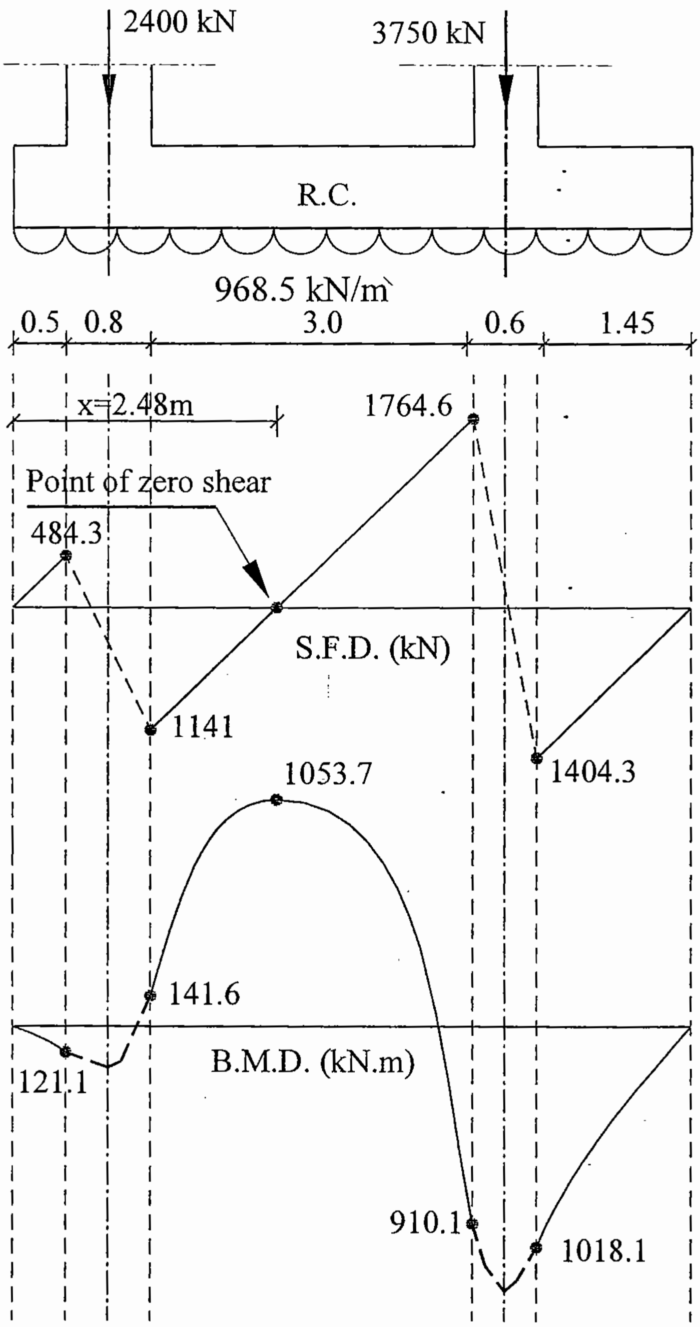
$\Rightarrow M_{max.} = 1053.7$ kN.m

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

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

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

$\Rightarrow$ use d = 630 mm



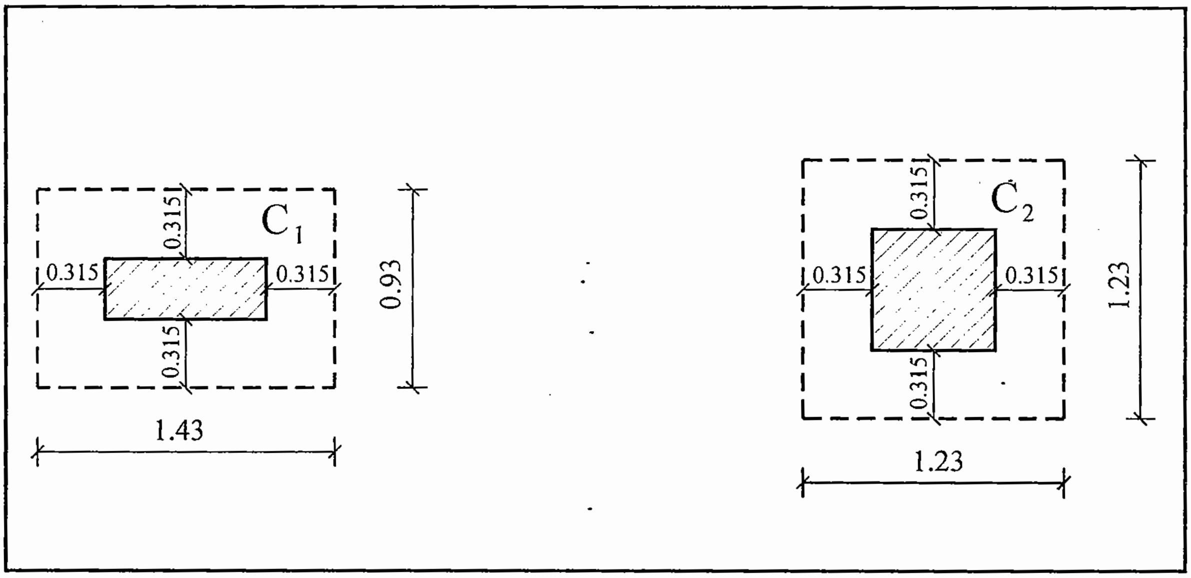
2- Check shear:-

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

$$- Q_{su_{max.}} = Q_{max.} - w_u \cdot d = 1764.6 - 968.5 \times 0.63 = 1154.4 \ kN$$

$$- q_{su} = \frac{Q_{su\,max.} \times 10^3}{d \times B_{R.C.}} = \frac{1154.4 \times 10^3}{630 \times 2800} = 0.654 \text{ N/mm}^2 \cong q_{scu} \text{ safe}$$

3- Check punching shear:-



- For C1(30x80)

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

$$- q_{pcu_1} = 0.316(0.5 + \frac{300}{800})\sqrt{\frac{25}{1.5}} = 1.129 \text{ N/mm}^2$$

$$- Q_{pu_1} = 2400 - 345.9[0.93 \times 1.43] = 1940 \text{ kN}$$

$$- q_{pu_1} = \frac{1940 \times 10^3}{630[930+1430] \times 2} = 0.652 \text{ N/mm}^2 \quad < q_{pcu1} \quad \text{safe}$$

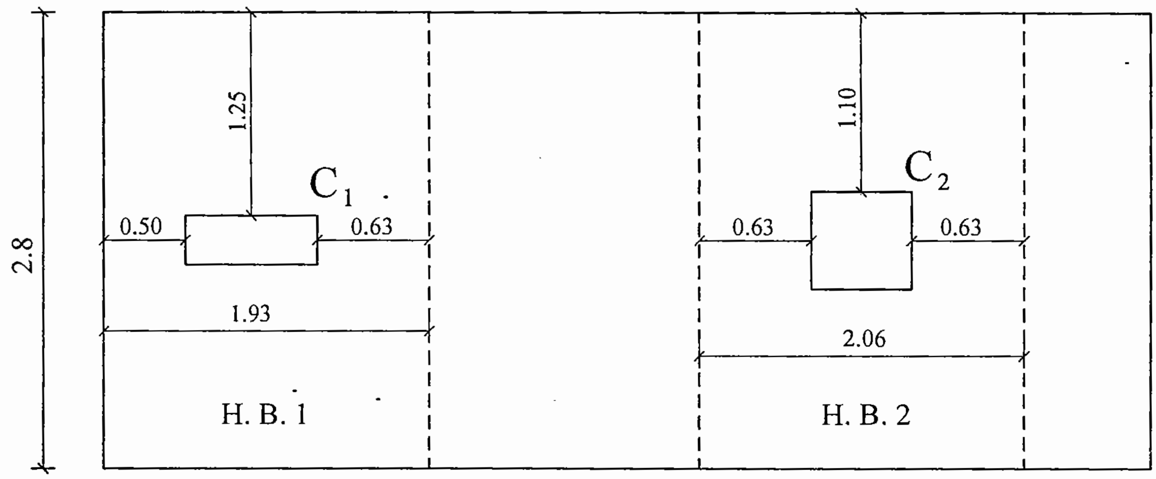
- For C2(60x60)

$$- q_{pcu_2} = 0.316 \times \sqrt{\frac{f_{cu}}{1.5}} = 0.316 \times \sqrt{\frac{25}{1.5}} = 1.29 \text{ N/mm}^2$$

$$- Q_{pu_2} = 3750 - 345.9[1.23 \times 1.23] = 3226.7 \text{ kN}$$

$$- q_{pu_2} = \frac{3226.7 \times 10^3}{630 \times 1230 \times 4} = 1.041 \text{ N/mm}^2 < q_{pcu2} \qquad \text{safe}$$

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



- For Hidden Beam 1:-

$$- q_{u_1} = \frac{2400}{2.8 \times 1.93} = 444.1 \text{ kN/m}^2$$

$$- M_1 = 444.1 \times \frac{(1.25)^2}{2} = 347 \text{ kN.m}$$

- For Hidden Beam 2:-

$$- q_{u_2} = \frac{3750}{2.8 \times 2.06} = 650.1 \text{ kN/m}^2$$

$$- M_2 = 650.1 \times \frac{(1.1)^2}{2} = 393.3 \text{ kN.m}$$

$$- d = C_1 \cdot \sqrt{\frac{M_{max} \times 10^6}{f_{cu} \times 1000}} \Rightarrow 780 = C_1 \cdot \sqrt{\frac{393.3 \times 10^6}{25 \times 1000}}$$

$$\Rightarrow C_1 = 6.2 < 2.3 \text{ O.K}$$

5- RFT:-

- $A_{s_{min}} = 1.5 \times d_{mm} = 1.5 \times 630 = 945\ mm^2/m'$
- $A_{s_{min}} = 6 \not\phi 16 \backslash m'$

- RFT in long direction:-

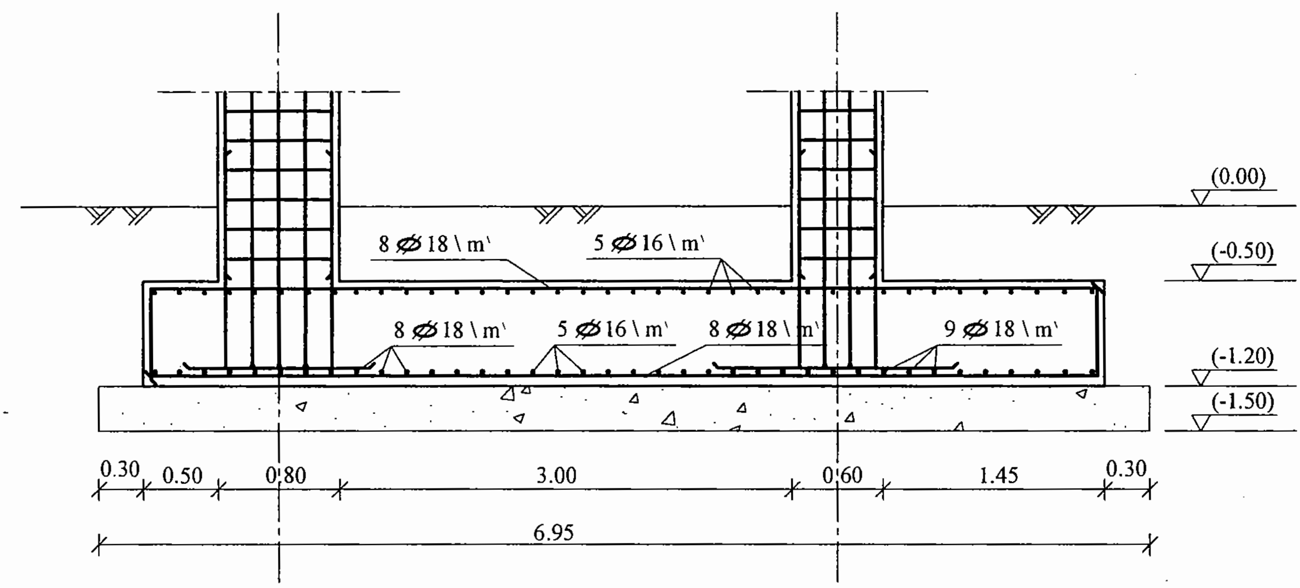
- $A_{s_{top}} = \dfrac{1053.7 \times 10^6}{360 \times 0.826 \times 630} = 5625\ \ mm^2/2.8\ m = 2009\ \ mm^2/m'$
- $A_{s_{bottom}} = \dfrac{1018.1 \times 10^6}{360 \times 0.826 \times 630} = 5435\ \ mm^2/2.8\ m = 1941\ \ mm^2/m'$

- RFT in short direction:-

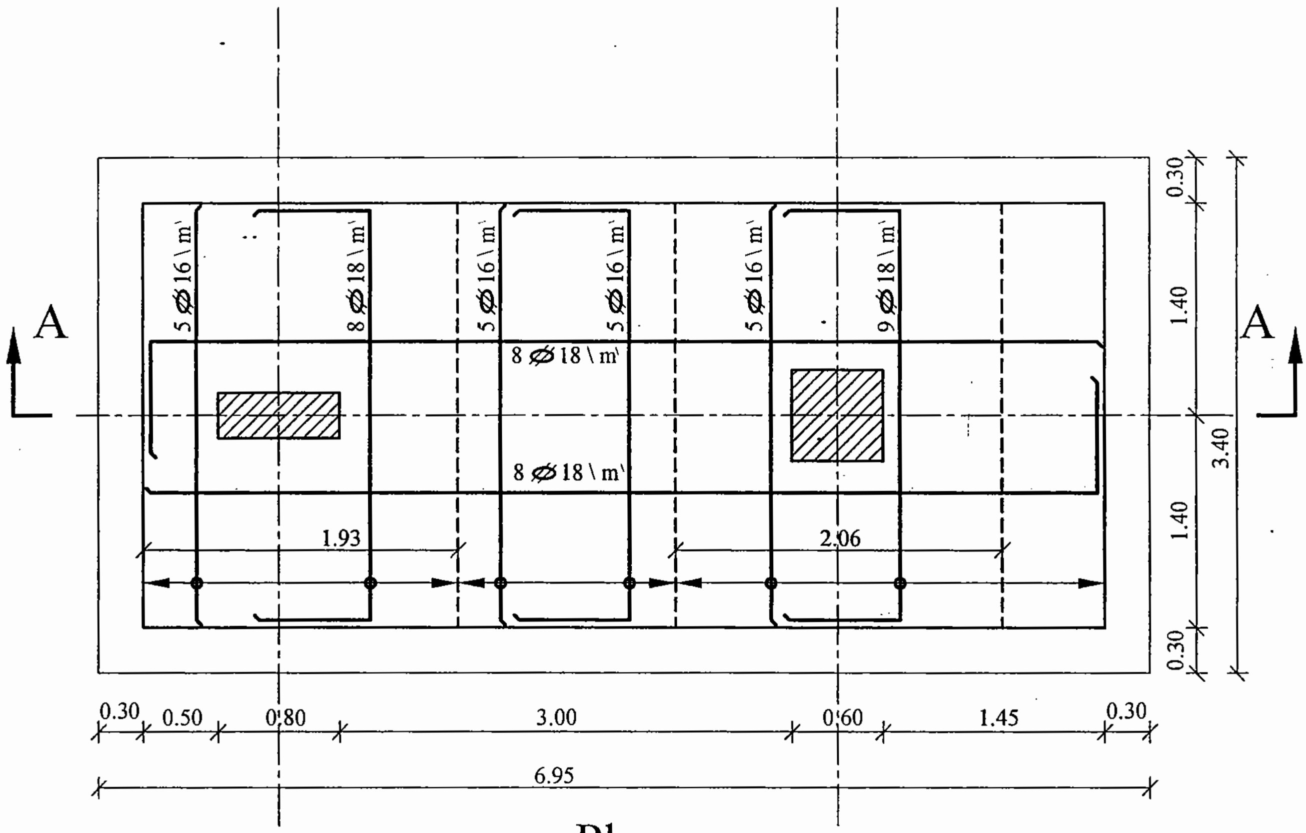
- $A_{s_1} = \dfrac{347 \times 10^6}{360 \times 0.826 \times 630} = 1852\ \ mm^2/m'$
- $A_{s_2} = \dfrac{393.3 \times 10^6}{360 \times 0.826 \times 630} = 2099\ \ mm^2/m'$

- use $A_{s_{Top}} = 8 \not\phi 18 \backslash m'$
- use $A_{s_{Bottom}} = 8 \not\phi 18 \backslash m'$
- use $A_{s_1} = 8 \not\phi 18 \backslash m'$
- use $A_{s_2} = 9 \not\phi 18 \backslash m'$

- Details of RFT:-



Section A-A
scale 1:50



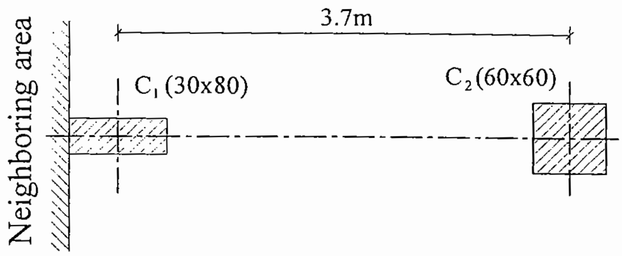
Plan
scale 1:50

- Example 7:-

For the two columns shown in the given plan:

The outer column load is 1600KN,

The inner column load is 2500KN.



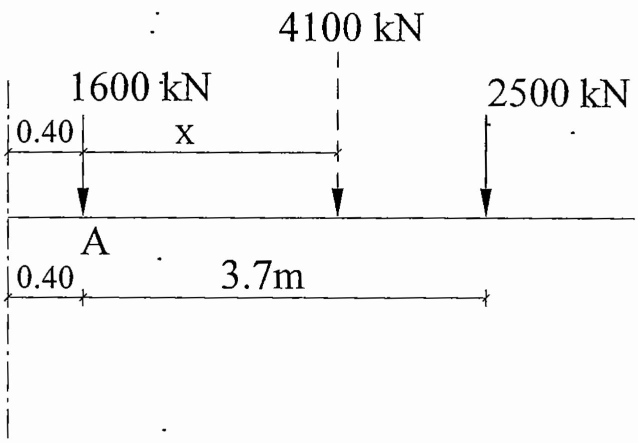
- It is required to:

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:-



$$- R = 1600 + 2500 = 4100 \text{ kN}$$

$$- \sum M_{@A} = 0 \quad \Rightarrow R \cdot x = P_2 \cdot S$$

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

$$\therefore x = 2.26 \text{ m}$$

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

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

$$- L_{P.C.} = 2 \times 2.66 = 5.32$$

$$\Rightarrow \text{ use } L_{P.C.} = L_{R.C.} = 5.35 \text{ m}$$

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

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

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

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

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:-

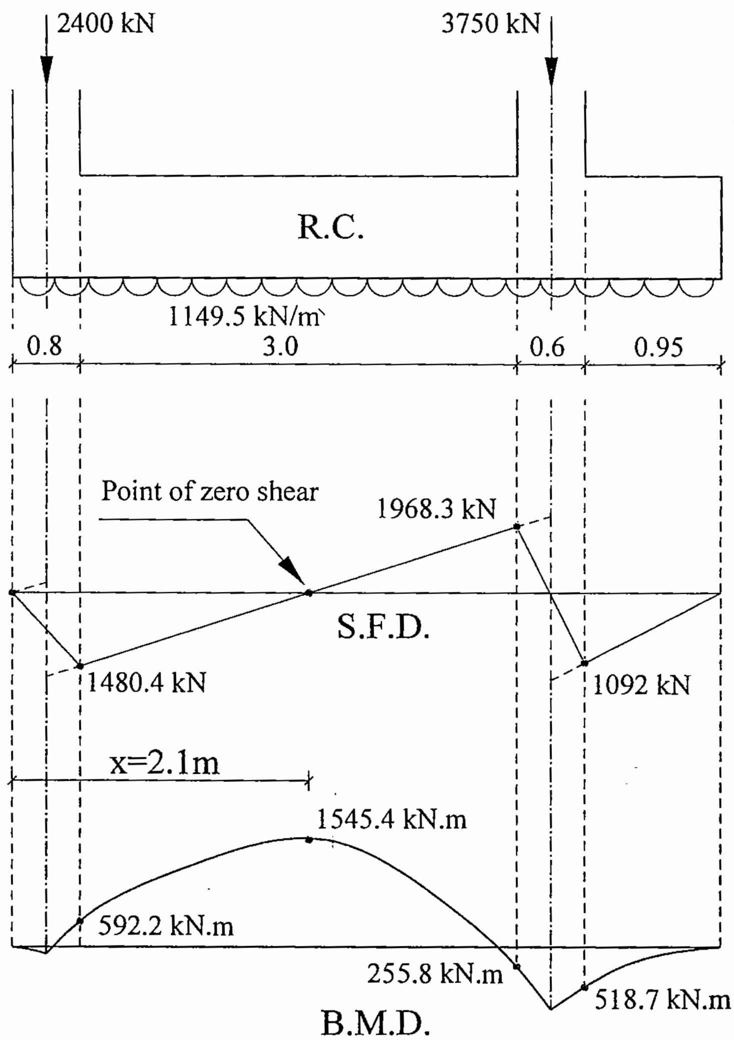
-At point of zero shear:-

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

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

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

$= 1545.4$ kN.m



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

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

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

$\Rightarrow$ use $d = 680$ mm

$\Rightarrow t = 750$ mm

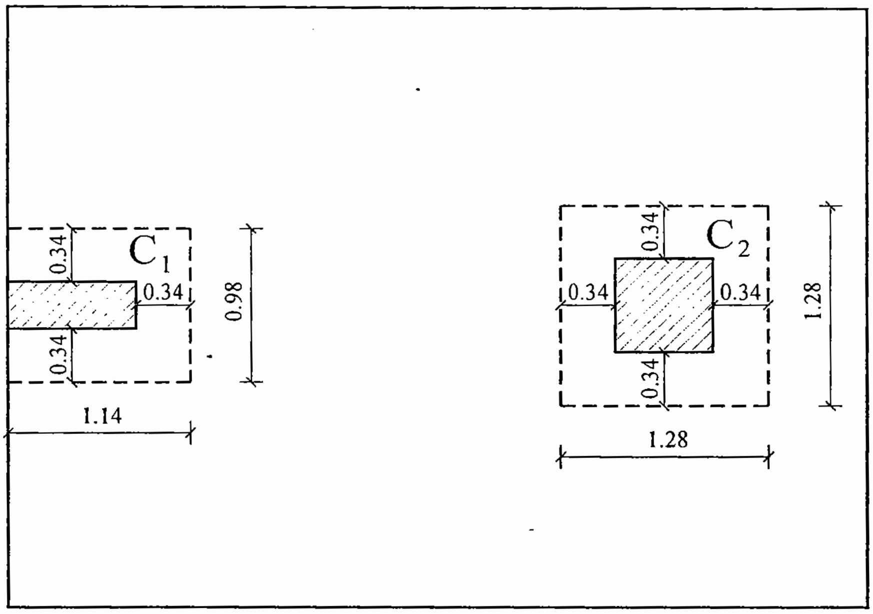
2- Check shear:-

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

- $Q_{su_{max.}} = Q_{max.} - w_u \cdot d = 1968.8 - 1149.5 \times 0.68 = 1187.14$ kN

- $q_{su} = \dfrac{Q_{su_{max.}} \times 10^3}{d \times B_{R.C.}} = \dfrac{1187.14 \times 10^3}{680 \times 3800} = 0.459\,\text{N/mm}^2 < q_{scu}$ safe

3- Check punching shear:-



- For C1(30x80)

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

- $q_{pcu_1} = 0.316(0.5 + \frac{300}{800})\sqrt{\frac{25}{1.5}} = 1.129\ N/mm^2$

- $Q_{pu_1} = 2400 - 302.5[1.14 \times 0.98] = 2062\ kN$

- $q_{pu_1} = \frac{2062 \times 10^3}{680[2 \times 1140 + 980]} = 0.93\ N/mm^2 < q_{pcu_1}$ safe

- For C2(60x60)

- $q_{pcu_2} = 0.316\sqrt{\frac{f_{cu}}{1.5}} = 0.316\sqrt{\frac{25}{1.5}} = 1.29\ N/mm^2$

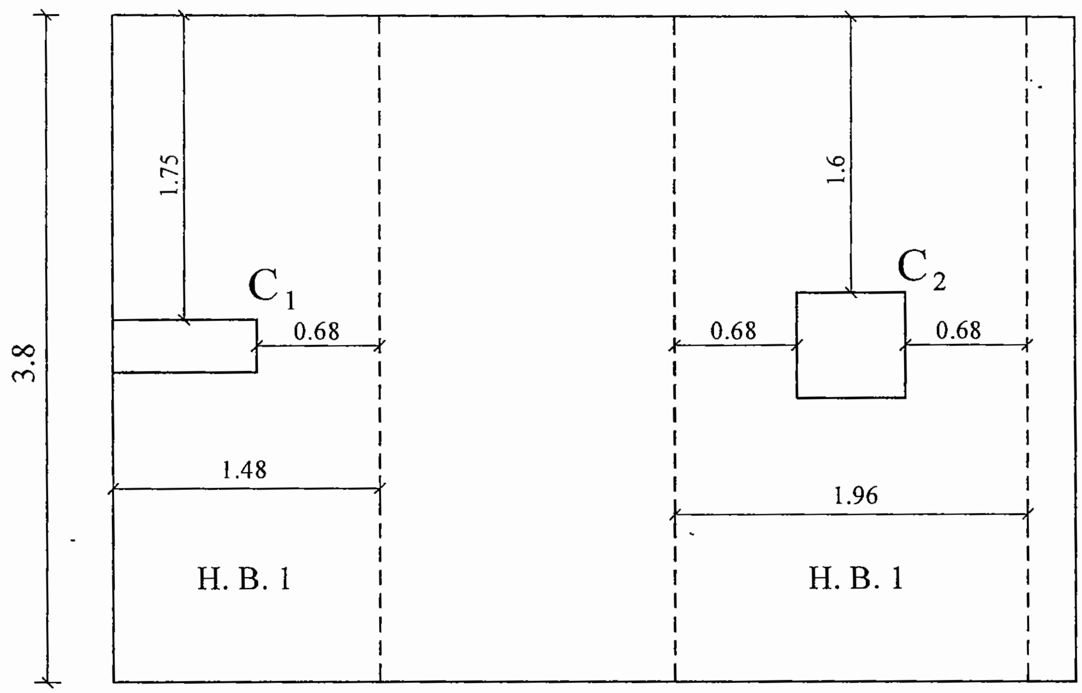
- $Q_{pu_2} = P_{u_2} - q_u[(b_2 + d)(a_2 + d)]$

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

- $q_{pu_2} = \frac{Q_{pu_2} \times 10^3}{d[(b_2 + d) + (a_2 + d)] \times 2}$

$= \frac{3254.4 \times 10^3}{680[1280 + 1280] \times 2} = 0.93\ N/mm^2 < q_{pu_2}$ safe

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



- For Hidden Beam 1:-

- $q_{u_1} = \dfrac{2400}{3.8 \times 1.48} = 426.7 \ N/mm^2$

- $M_u = 426.7 \times \dfrac{(1.75)^2}{2}$

$= 653.4 \ kN \cdot m$

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

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

$\Rightarrow \ C_1 = 4.2 > 2.8 \ \Rightarrow$ safe

$\Rightarrow \ J = 0.81$

- For Hidden Beam 2:-

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

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

$= 644.5 \ kN \cdot m$

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

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

$\Rightarrow \ C_1 = 4.24 > 2.8 \ \Rightarrow$ safe

$\Rightarrow \ J = 0.81$

5- RFT:-

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

- $A_{s_{min}} = 5 \ \phi 16 \ \backslash \ m'$

- RFT in long direction:-

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

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

- RFT in short direction:-

$$- A_{s_1} = \frac{653.4 \times 10^6}{360 \times 0.81 \times 680} = 3295 \quad mm^2 / m^{\backslash}$$

$$- A_{s_2} = \frac{644.5x\ 10^6}{360 \times 0.81 \times 680} = 3250 \quad mm^2 / m^{\backslash}$$

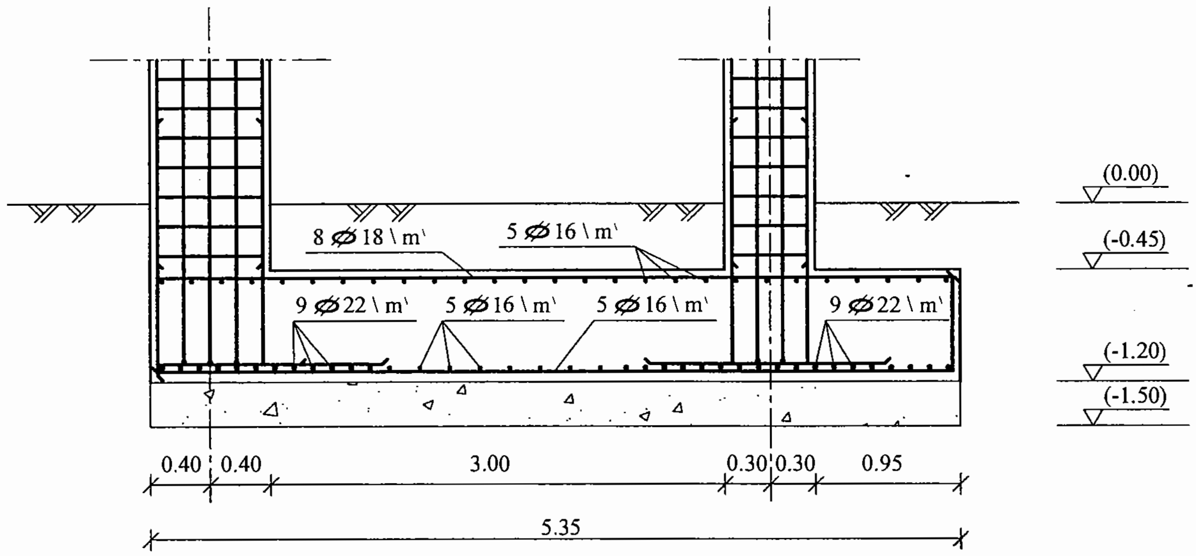
- use $A_{s_{Top}} = 8 \not\phi 18 \backslash m^{\backslash}$

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

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

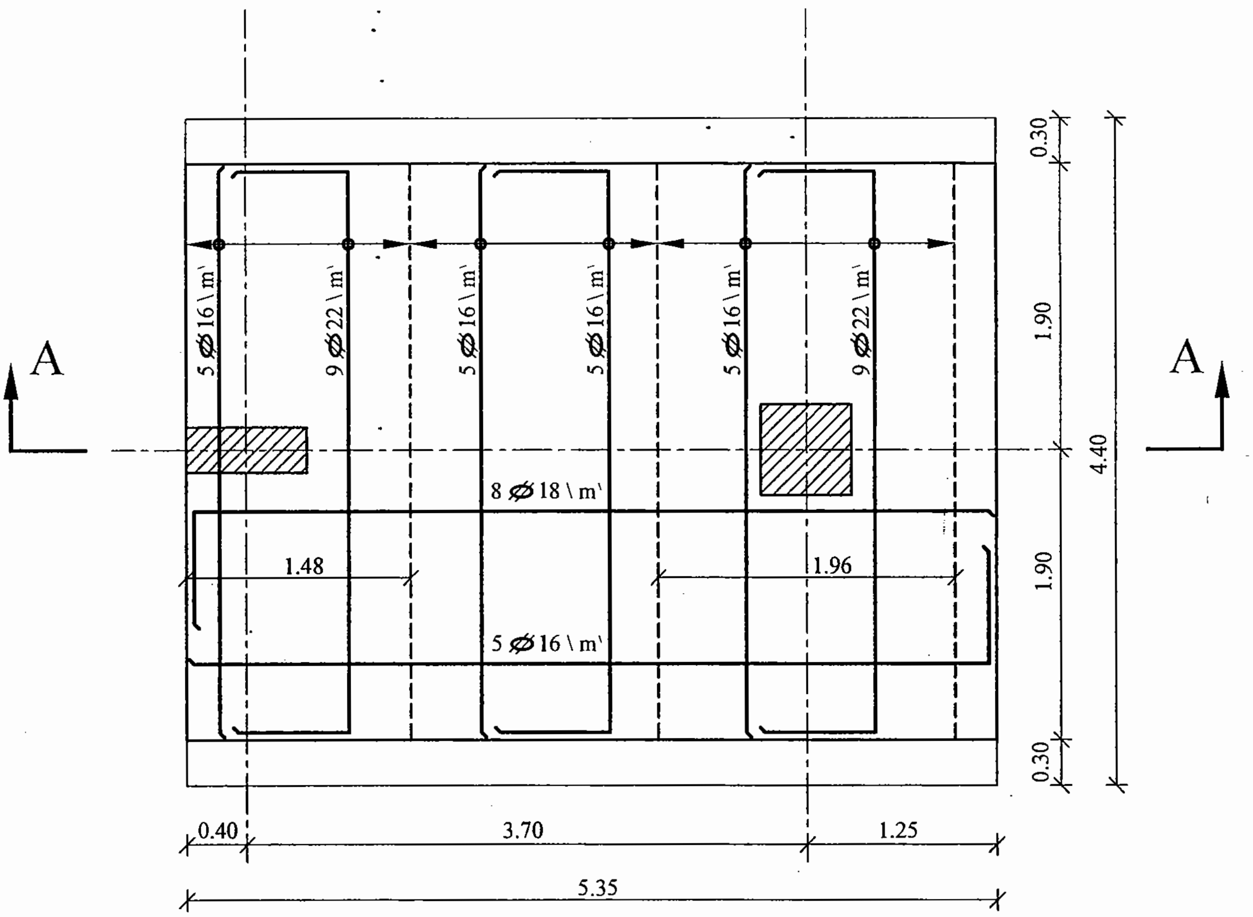
- use $A_{s_2} = 9 \not\phi 22 \backslash m^{\backslash}$

- Details of RFT:-



Section A-A

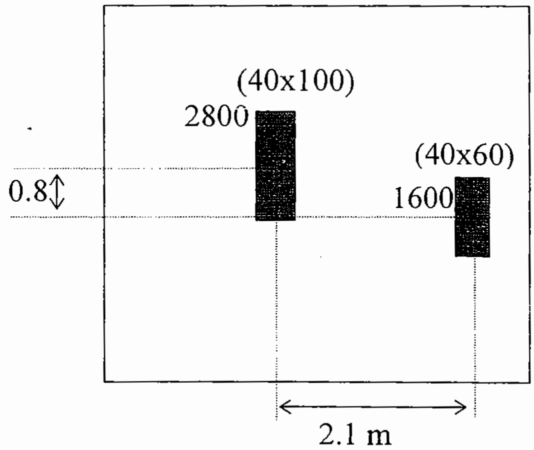
scale 1:50



Plan

scale 1:50

- Example 8:-



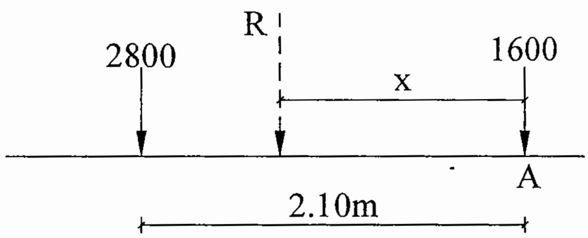
For the shown combined footing, if the thickness of P.C. is 40cm, and q_{all} = 200 KN/m^2 it is required to:
Determine the suitable P.C. and R.C. horizontal dimensions, and draw a plan with scale 1:50.

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

- Solution:-

-Area of footing:-

1- In long direction:-



- $R = 2800 + 1600 = 4400$ kN
- $\sum M_{@A} = 0$

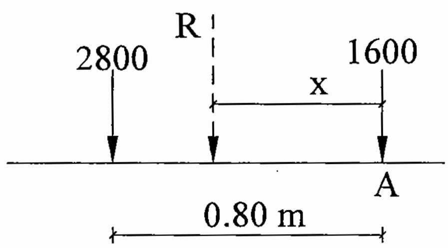
$\Rightarrow 4400(x) = 2800 \times 2.1$

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

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

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

2- In short direction:-



- $R = 2800 + 1600 = 4400$ kN
- $\sum M_{@A} = 0$

$\Rightarrow 4400(x) = 2800 \times 0.8$

$$\therefore x = \frac{2800 \times 0.8}{4400} = 0.51 \text{ m}$$

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

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

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

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

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

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

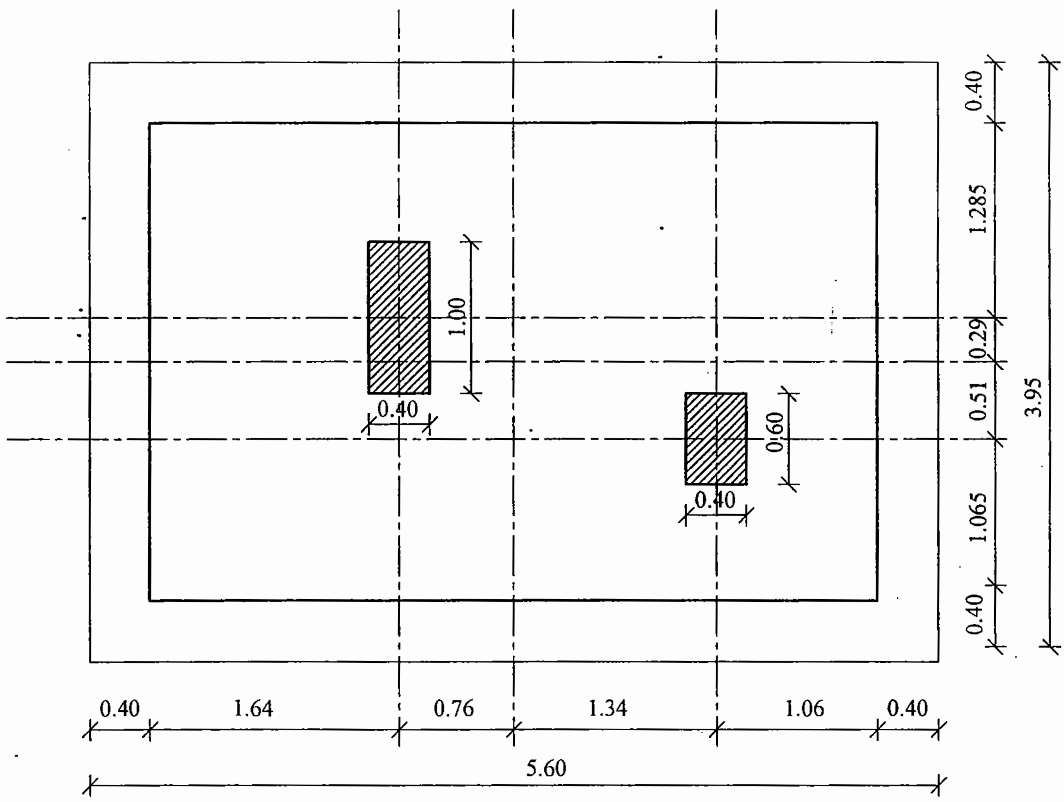
$$\Rightarrow \text{take } B_{P.C.} = 3.95\ m$$

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

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

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

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



Plan
scale 1:50