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Step 1 :- Axial force = ~~255/1.5 = 170~~

$\Rightarrow$ $P = 1260 / 1.5 = 840$ kN

$M_x = 7.5$ kNm, $M_y = 9.375$ kNm.

Step 3 :- Calculate the size of footing.

Assume self-wt of the footing = 10% of P

Total axial load (P_{tot}) = $P + 0.1P$

$= 840 + 84$

$= 924$ kN

Req. area of footing (A_{req}) = $\dfrac{P_{tot}}{SBC}$

$= \dfrac{924}{225}$

$= 4.11 \text{ m}^2$

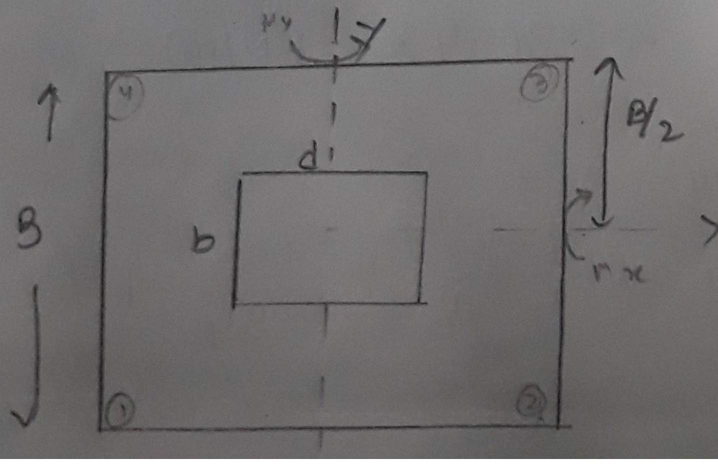
Provided size of footing,

$L \times B = 4.11$

$\therefore$ $L = B = 2.1$ m

$A_{prov.} = 2.1 \times 2.1$

$= 4.41 \text{ m}^2$



Step 4 : Calculate net upward pressure at 4 corners.

$$P_0 = \frac{P_{net}}{A_{prov}} + \frac{M_x}{Z_x} + \frac{M_y}{Z_y}$$

$$I_x = I_y = \frac{LB^3}{12} = \frac{(2.1)(2.1)^3}{12} = 1.62$$

$$Z_y = \frac{I_x}{d_x} = \frac{1.62}{2.1/2} = 1.54$$

$M_x = 7.5$ kNm, $M_y = 9.375$ kNm

For corner (1),

$$P_1 = \frac{924}{4.41} + \frac{7.5}{1.54} + \left(-\frac{9.375}{1.54}\right)$$

$$= 208.306 \text{ kN/m}^2$$

For corner (2),

$$P_2 = \frac{924}{4.41} + \left(-\frac{7.5}{1.54}\right) + \frac{9.375}{1.54}$$

$$= 210.74 \text{ kN/m}^2$$

For corner (3),

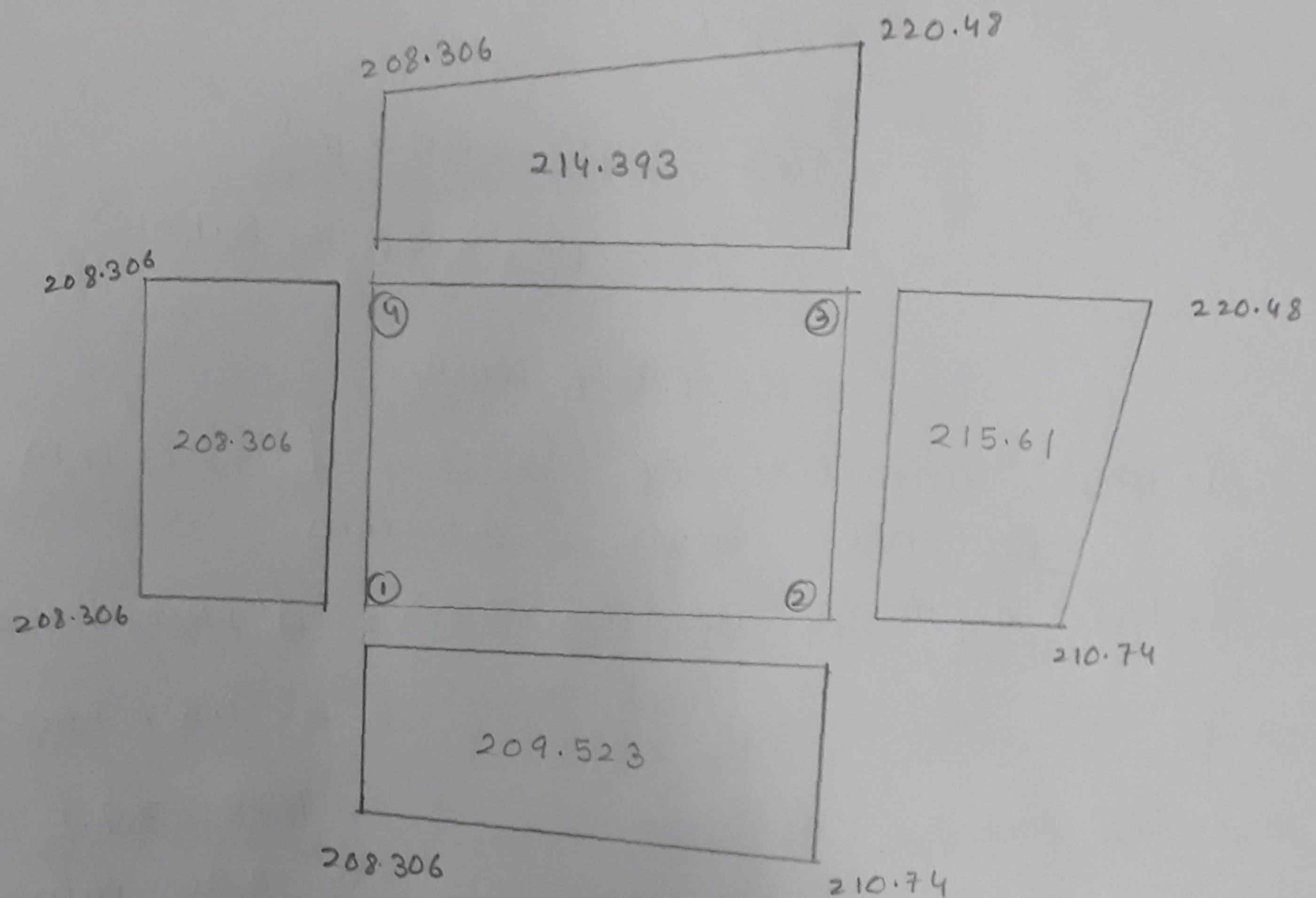
$$P_3 = \frac{924}{4.41} + \frac{7.5}{1.54} + \frac{9.375}{1.54}$$

$$= 220.48 \text{ kN/m}^2$$

For corner (4),

$$P_4 = \frac{924}{4.41} + \frac{7.5}{1.54} + \left(-\frac{9.375}{1.54}\right)$$

$$= 208.306 \text{ kN/m}^2$$



Net upward pressure = max (209.523, 215.61, 214.393, 208.306)

P_o = 215.61 kN/m²

Step 5 : Depth of footing calculation on the basis of BM.

The maximum BM acts at the face of the column, given by

$$M = P_o \frac{B}{8}(B-b)^2$$

$$= 215.61 \times \frac{2.1}{8}(2.1-0.4)^2$$

[column dimension = 400×400]

$$= 163.57 \text{ kNm}$$

Factored moment = 1.5 M

= 245.355 kNm

... minimum at 4 corners.

$$d'_{req} = \sqrt{\frac{M_u}{Q f_{ck} B}} \quad [Q = 0.133 \text{ for } Fe500]$$

$$= \sqrt{\frac{245.355 \times 10^6}{0.133 \times 20 \times 2.1 \times 10^3}}$$

$$= 209.57 \text{ mm}$$

Assume diameter of bars $= \phi = 20$ mm

Nominal cover $= 60$ mm

Total depth of footing $(D) = d' + \text{Nominal cover} + \frac{\phi}{2}$

$$= 209.57 + 60 + \frac{20}{2}$$

$$= 279.57 \text{ mm}$$

$$\simeq 280 \text{ mm}.$$

Step 6 :-

$$A_{st} = 0.5 \frac{f_{ck}}{f_y}\left[1 - \sqrt{1 - \frac{4.6 M_u}{f_{ck} B d'^2}}\right] B d'$$

$$= 0.5 \times \frac{20}{500}\left[1 - \sqrt{1 - \frac{4.6 \times 245.355 \times 10^6}{20 \times 2.1 \times 10^3 \times (210)^2}}\right] \times 2.1 \times 10^3 \times 210$$

$$= 0.5 \times \frac{20}{500} \times 0.375 \times 2.1 \times 10^3 \times 210$$

$$= 3307.5 \text{ mm}^2$$

Minimum A_{st} $= 0.12\%$ of total area

$$= \frac{0.12}{100} \times 4.41 \text{ m}^2$$

~~$= 3.969$ mm² $\simeq 4$ mm²~~

$$= 5292 \text{ mm}^2$$

~~Step 7: Checks for one way shear.~~

Provided $A_{st} = 5300 \text{ mm}^2$

$$n \times \frac{\pi}{4} \times (20)^2 = 5300$$

$$\Rightarrow n \simeq 17$$

$\therefore$ 17 bars are provided.

$$\text{Spacing} = \min \begin{cases} 3d' = 3 \times 210 = 630 \text{ mm} \\ 450 \text{ mm} \\ \frac{L}{N-1} = \frac{2100}{17-1} = 131.25 \text{ mm} \end{cases}$$

Provided spacing = ~~[illegible] mm~~ 131.25 mm

Step 7 : Check for one way shear. (Cl 34.2.4.1)

The critical section lies 'd' distance from the face of the column :

$$\text{Shear force, } (V) = P_o B \{0.5(B-b) - d'\}$$

$$= 215.61 \times 2.1 \{0.5(2.1-0.4) - 0.21\}$$

$$= 289.78 \text{ KN.}$$

$$\text{Factored SF } (V_u) = 1.5 \times 289.78$$

$$= 434.67 \text{ KN}$$

Design shear strength of concrete $(\tau_c') = K \tau_c$

$$K = 1.06 \quad (D = 280 \text{ mm})$$

$$A_{st}\% = 100 \frac{A_s}{bd} = 100 \times \frac{5300}{4.41 \times 10^6} = 0.12\%$$

$$\tau_c = 0.28 \quad (\text{M20 grade})$$

$$\tau_c' = K \tau_c = 1.06 \times 0.28 = 0.2968 \text{ N/mm}^2$$

$$d_1 = \frac{V_u}{B \tau_c'} = \frac{434.67 \times 10^3}{2.1 \times 10^3 \times 0.2968}$$

$$= 697.39 \text{ mm} > d' \quad (209.57 \text{ mm})$$

Hence we need to increase d'.

$d'_{provided} = 700$ mm.

<u>Step 8</u> :- Check for two way shear.

The critical section lies '$d'/2$' distance from the face of the column.

The net shear force acting on the perimeter,

$$F = p_0 \left[B^2 - (b + d')^2 \right] \quad \text{(For square footing)}$$

$$= 215.61 \left[2.1^2 - (0.4 + 0.7)^2 \right]$$

$$= 689.952 \text{ kN}.$$

Factored SF (F_u) $= 1.5$ F

$= 1034.928$ kN.

Nominal shear stress $\tau_v = \dfrac{F_u}{4(b+d')d'}$

$$= \frac{1034.928}{4(0.4+0.7) \times 0.7}$$

$= 336$ kN/m²

$= 0.336$ N/mm²

Permissible shear stress $= k_s \tau_c$

$$k_s = (0.5 + \beta_c) = (0.5 + 1) = 1.5 \text{ (we take 1)}$$

$$\tau_c = 0.25 \sqrt{f_{ck}} = 0.25 \sqrt{20} = 1.11 \text{ N/mm}^2$$

$$k_s \tau_c = 1 \times 1.11 = 1.11$$

$\tau_v < k_s \tau_c$ ok.

Step 9 : Check for development length in tension and compression.

$$L_d = \frac{\phi \sigma_s}{4(\tau_{bd}\, 1.6)} = \frac{20 \times (0.87 \times 500)}{4(1.2 \times 1.6)}$$

$$= 1132.81 \text{ mm}$$

Step 10 :