Fayoum University

Faculty of Engineering
Department of Civil Engineering

CE 402: Part A

Shallow Foundation Design

Lecture No. (4): Combined Footing

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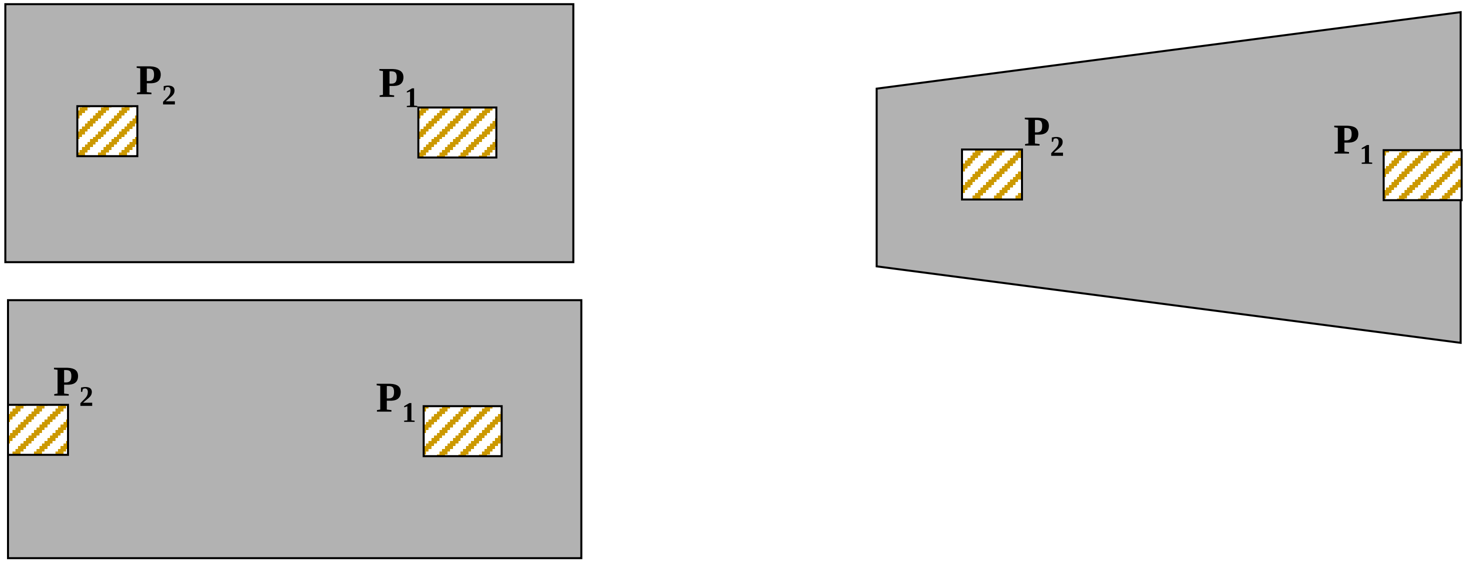
“The most important thing is to keep the most important thing the most important thing”

Combined Footing

- A combined footing is a long footing supporting two or more columns in (typically two) one row.

- A combined footing is a rectangular or trapezoidal shaped footing.



Using of Combined Footing

- Construction practice may dictate using only one footing for two or more columns due to:

a) Closeness of column (for example around elevator shafts and escalators); and

b) Due to property line constraint, which may limit the size of footings at boundary. The eccentricity of a column placed on an edge of a footing may be compensated by tieing the footing to the interior column.

(CONVENTIONAL METHOD)

- **DESIGN OF COMBINED FOOTINGS BY RIGID METHOD:**

The rigid method of design of combined footings assumes that:

1. The footing or mat is infinitely rigid, and therefore, the deflection of the footing or mat does not influence the pressure distribution,

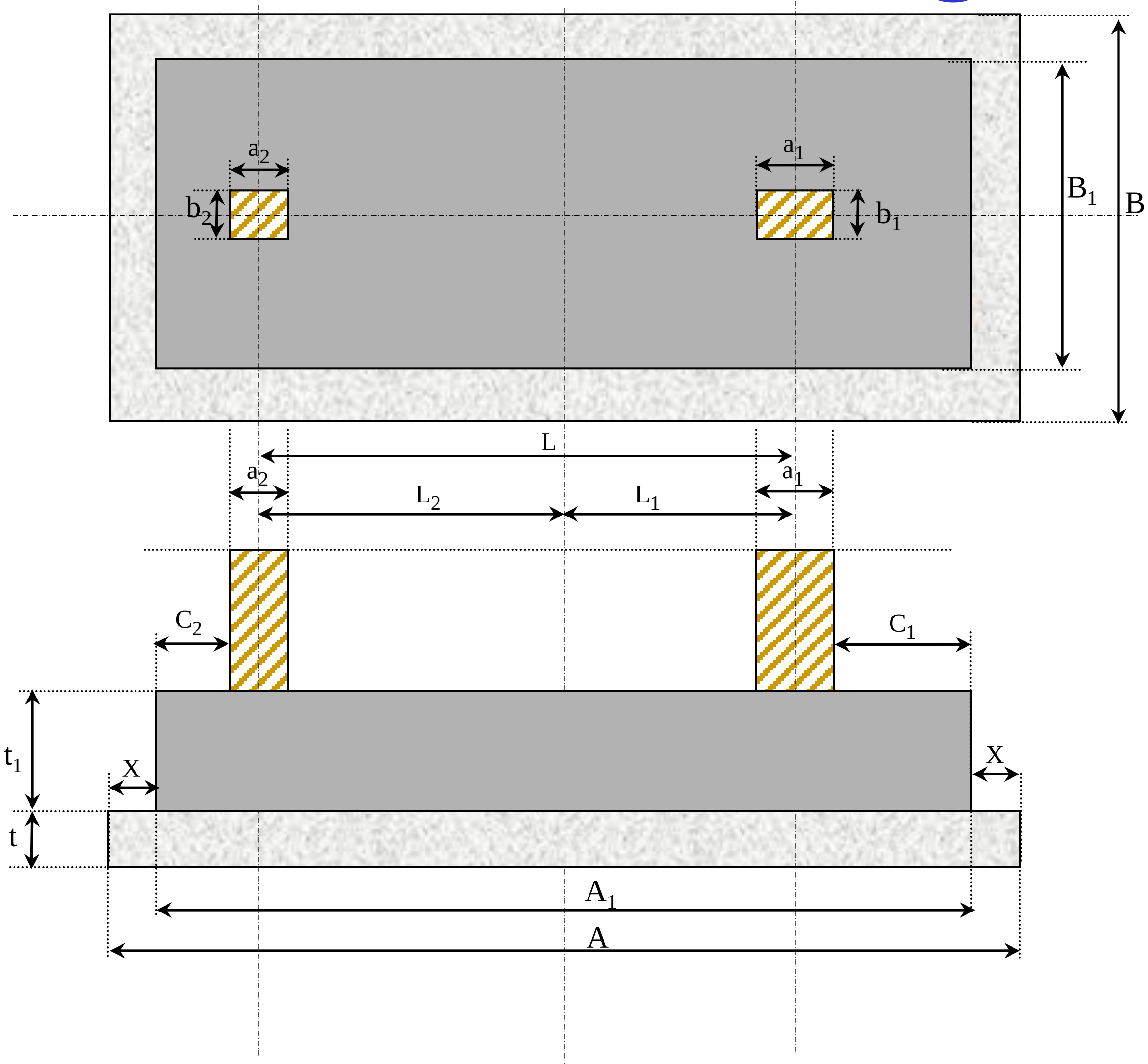
2. The soil pressure is distributed in a straight line or a plane surface such that the centroid of the soil pressure coincides with the line of action of the resultant force of all the loads acting on the foundation.

(CONVENTIONAL METHOD)

The design of combined footing requires that the centroid of the area be as close as possible to the resultant of the two column loads for uniform pressure and settlement (if possible).

i.e.: eccentricity, $e = 0.0$

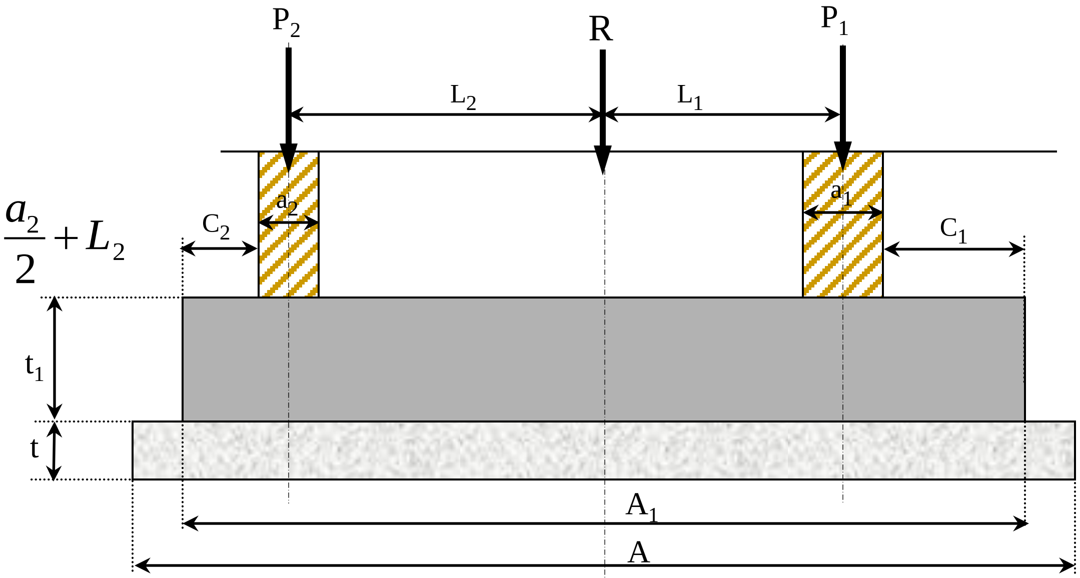
Combined Footing



Plain Concrete Footing (P.C.)

For uniform stress, Resultant should be at mid of (*A*)

$$\frac{A}{2} = X + C_1 + \frac{a_1}{2} + L_1 = X + C_2 + \frac{a_2}{2} + L_2$$



Assume thickness of P.C.:

$t = (0.25 \text{ to } 0.50)$

$X = (0.80 \text{ to } 1.0)\ t$

Assume $C_2 = 0.50m$

$$R = (P_1 + P_2)$$

$$L_2 * R = L * P_1 \longrightarrow \text{Get } (L_2)$$

$$\frac{A}{2} = X + C_2 + \frac{a_2}{2} + L_2 \longrightarrow \text{Get } (A)$$

$$Area = A * B = \frac{1.15(P_1 + P_2)}{q_a} \longrightarrow \text{Get } (B)$$

$$Dim.\ of\ P.C. = A * B * t$$

Reinforced Concrete Footing (R.C.)

$$A_1 = A - 2X$$

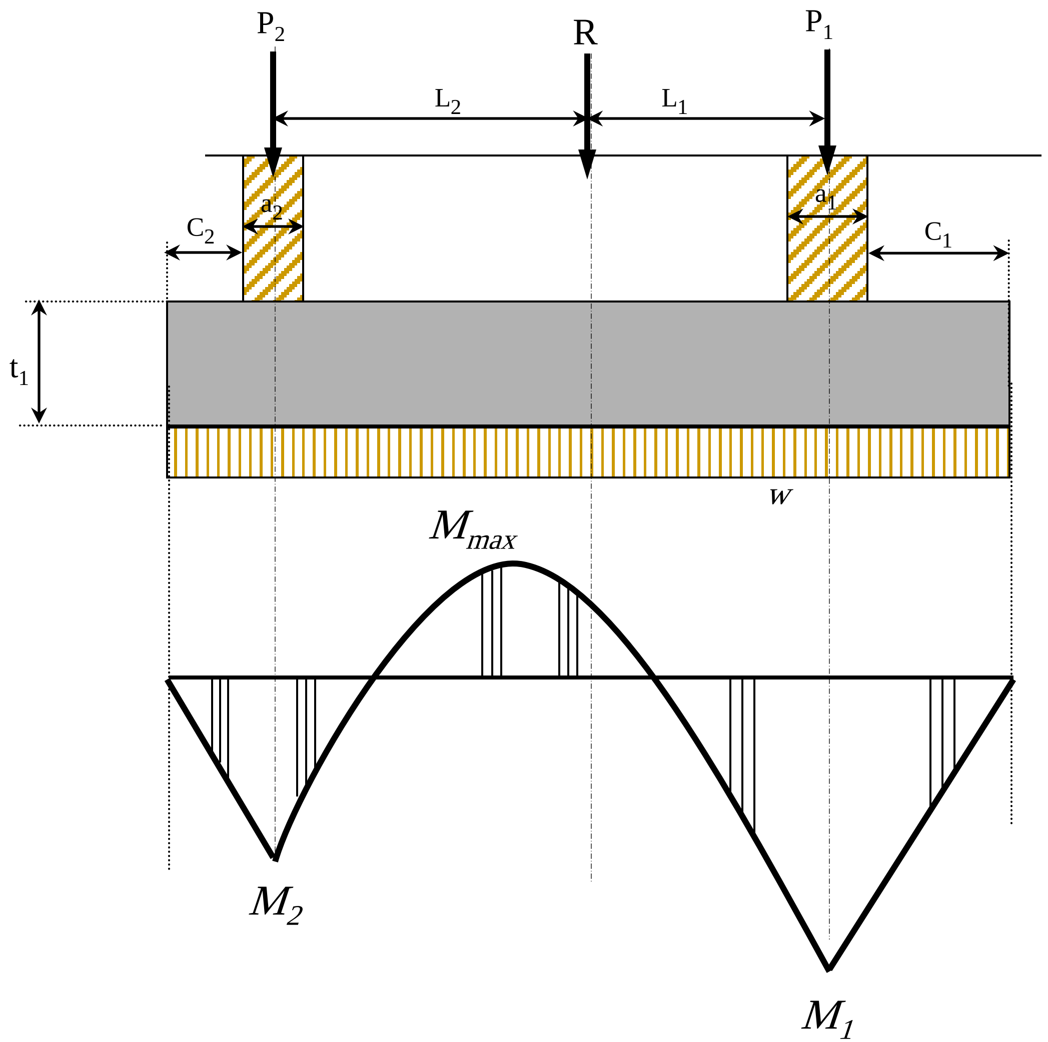
$$B_1 = B - 2X$$

$$p_n = \frac{1.50R}{A_1 * B_1}$$

$$w = \frac{1.50R}{A_1}$$

$$M_1 = w\frac{[C_1]^2}{2}$$

$$M_2 = w\frac{[C_2]^2}{2}$$



Reinforced Concrete Footing (R.C.)

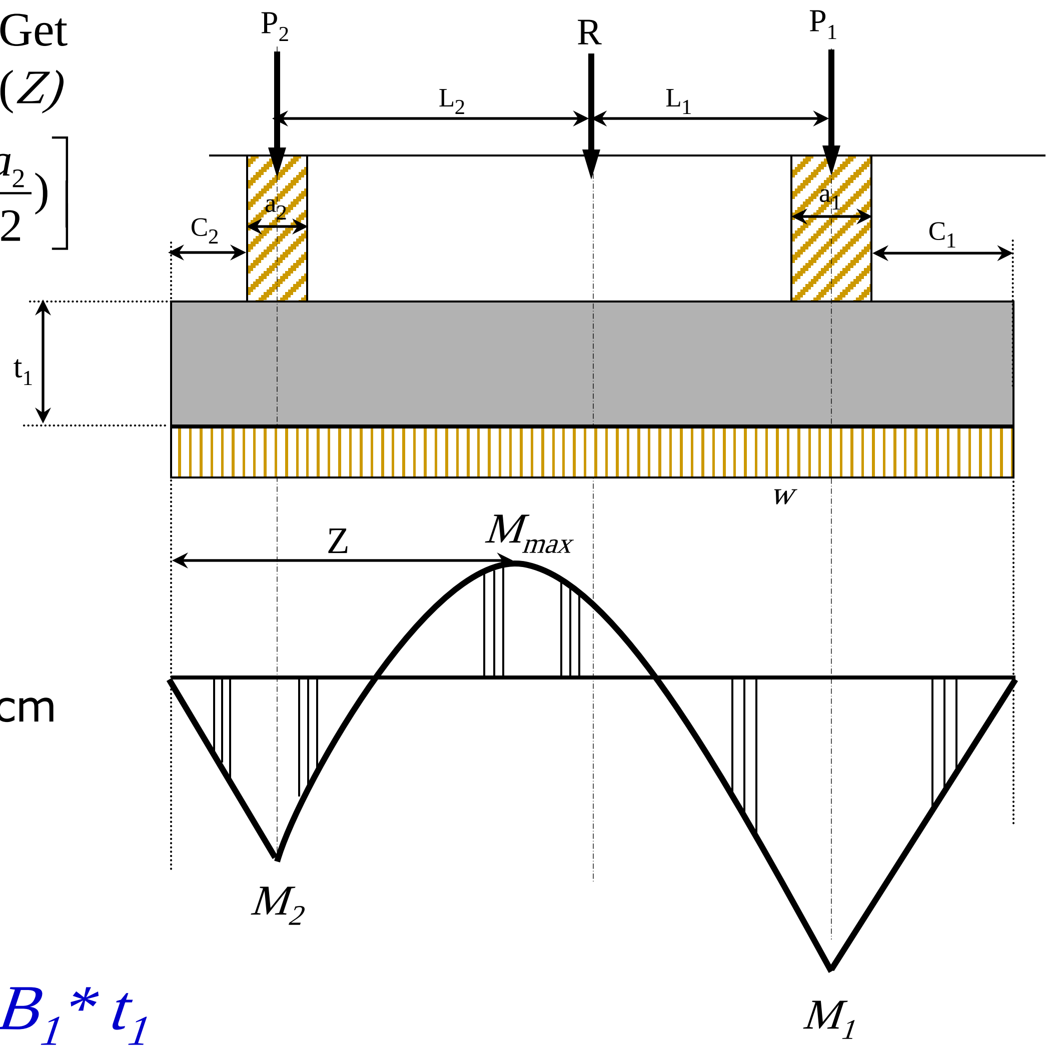
$$wZ - P_2 = 0.0 \longrightarrow \text{Get } (Z)$$

$$M_{max} = \frac{wZ^2}{2} - P_2\left[Z - (C_2 + \frac{a_2}{2})\right]$$

$$d = C\sqrt{\frac{M}{b * F_{cu}}}$$

$$t_1 = d + \text{cover}$$

Steel cover=5.0 to 7.0cm



Dim. of R.C. $= A_1 * B_1 * t_1$

Shear Stress

$$Q_1 = -w * C_1$$

$$Q_2 = P_1 - w * (C_1 + a_1)$$

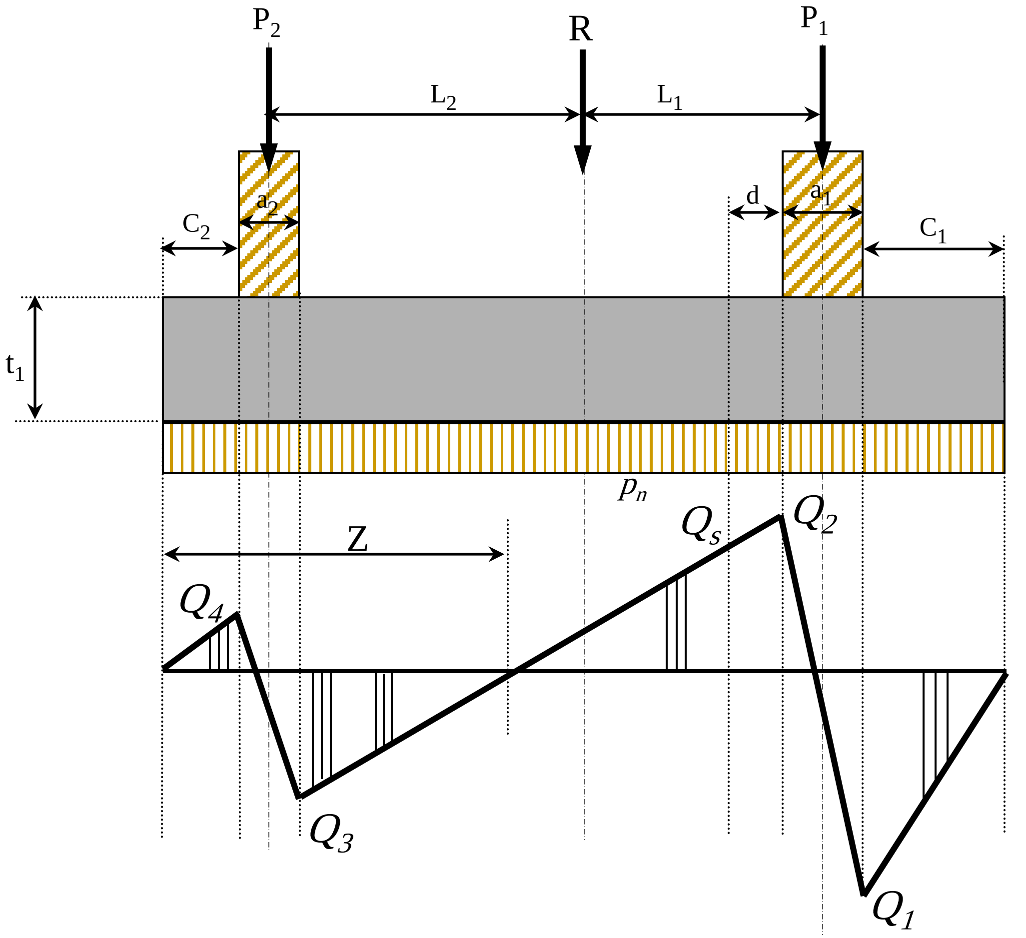
$$Q_3 = w * (C_2 + a_2) - P_2$$

$$Q_4 = w * (C_2)$$

$$Q_s = Q_2 - wd$$

$$q_s = \frac{Q_s}{b * d} \le q_{su}$$

$$q_{su} = 0.75 \sqrt{\frac{f_{cu}}{\gamma_c}}$$



If $q_s > q_{su}$, *Increase d*

Punching Stress

Column(1):

$$Q_p = P_1 - p_n * [(a_1 + d) * (b_1 + d)]$$

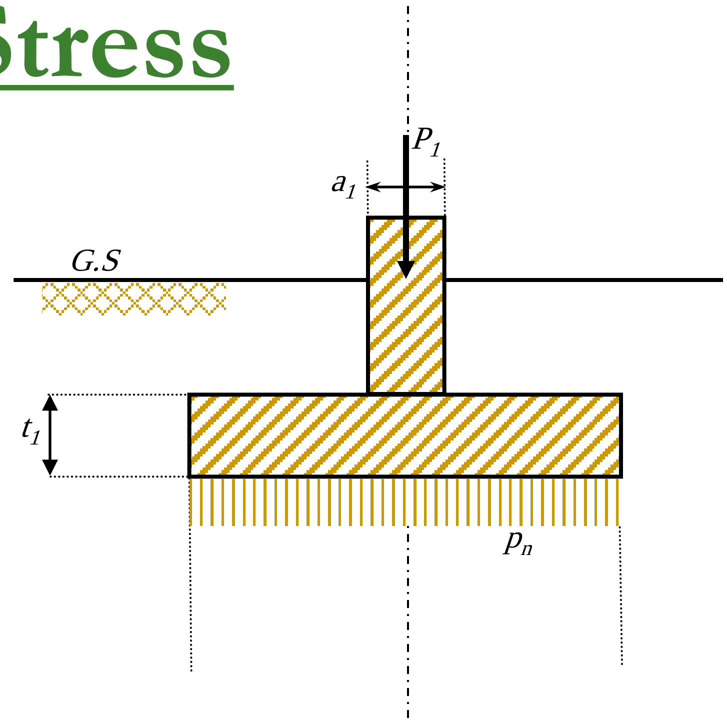
$$A_{p1} = d * 2 * [(a_1 + d) + (b_1 + d)]$$

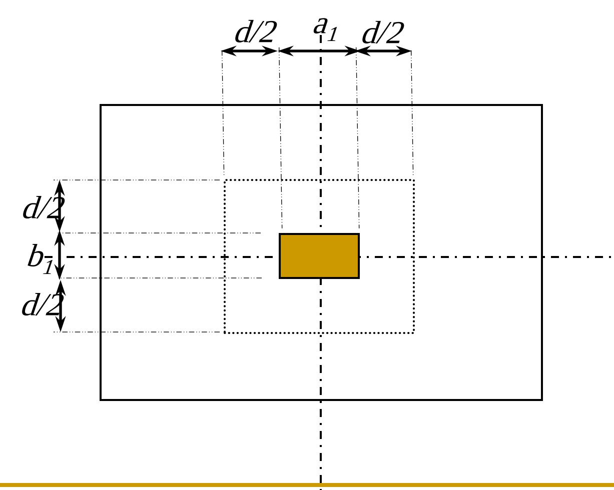
$$q_p = \frac{Q_p}{A_p}$$

$$q_{cup} = [0.5 + (a / b)] \sqrt{f_{cu} / \gamma_c} \leq \sqrt{f_{cu} / \gamma_c}$$

If $q_p > q_{cup}$, *Increase d*

Repeat Check for column (2)





Footing Reinforcement

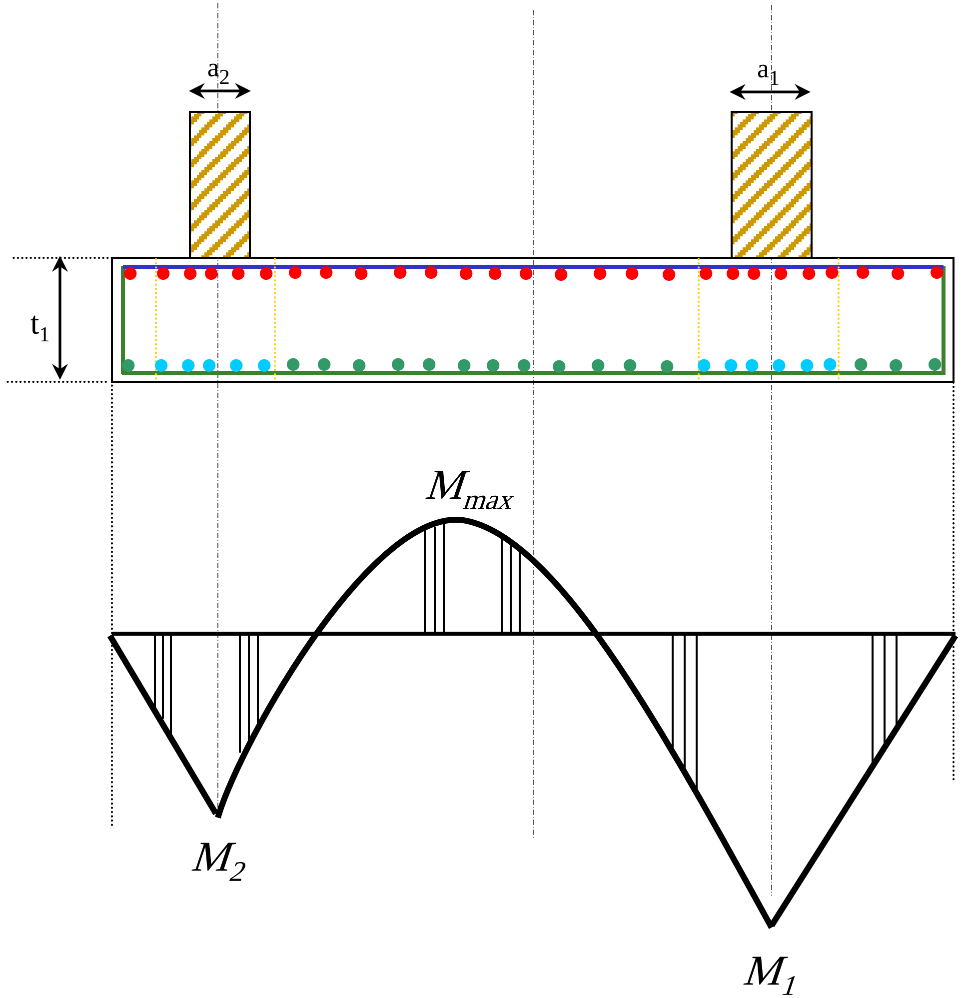
Which is required?

Top or bottom RFT

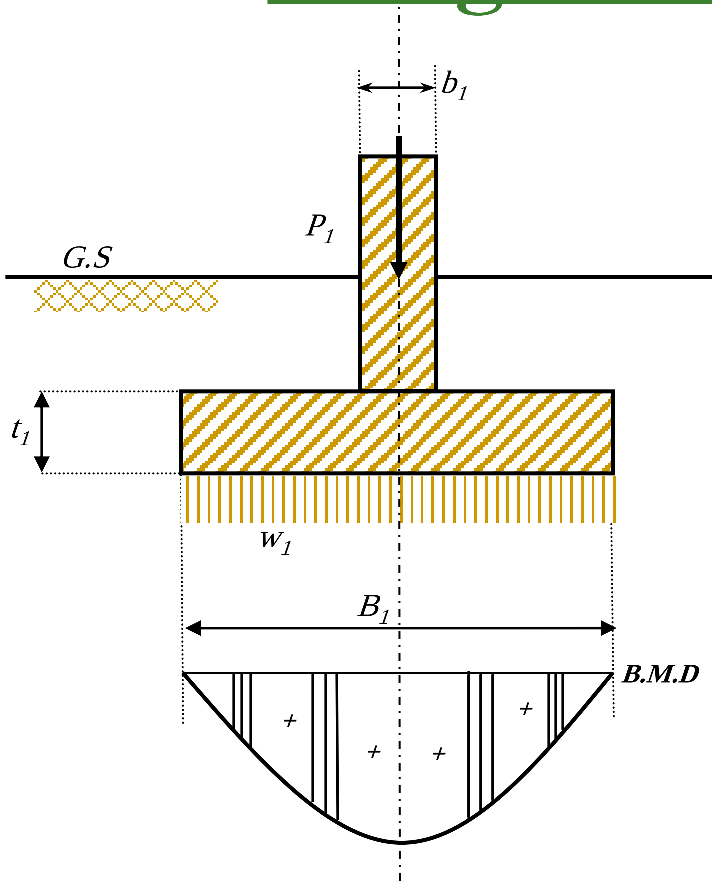
why?

$$A_{top} = \frac{M_{max}}{f_y * d * j}$$

$$A_{bot} = \frac{M_1}{f_y * d * j}$$

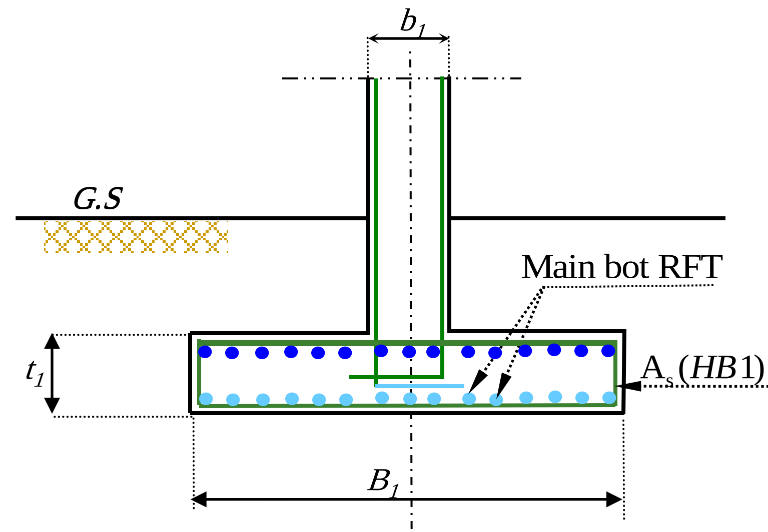


Design of Hidden Beams



$$w_1 = \frac{P_1}{B_1}$$

$$M_{HB1} = w_1 \frac{[(B_1 - b_1)/2]^2}{2}$$



$$d_1 = C\sqrt{\frac{M}{b * F_{cu}}}$$

$$b = b_1 + d$$

$$d_1 < d \rightarrow safe$$

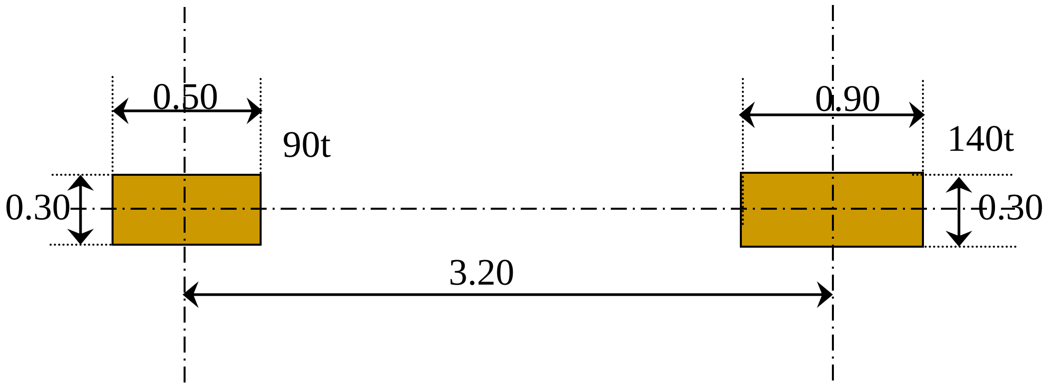
$$d_1 > d \rightarrow take\ d = d_1$$

$$A_{sH1} = \frac{M_I}{f_y * d * j}$$

Design of Combined Footing

Example(1):

Make a complete design for a combined footing for the two columns shown in figure (1). The net allowable pressure is 1.10 kg/cm^2 and the foundation level is 2.0m below ground surface



$a_1 = 0.90m.$ $b_1 = 0.30m$ $P_1 = 140t$

$a_2 = 0.50m$ $b_2 = 0.30m$ $P_2 = 90t$

$q_a = 1.10 kg/cm^2 = 11.0 t/m^2.$

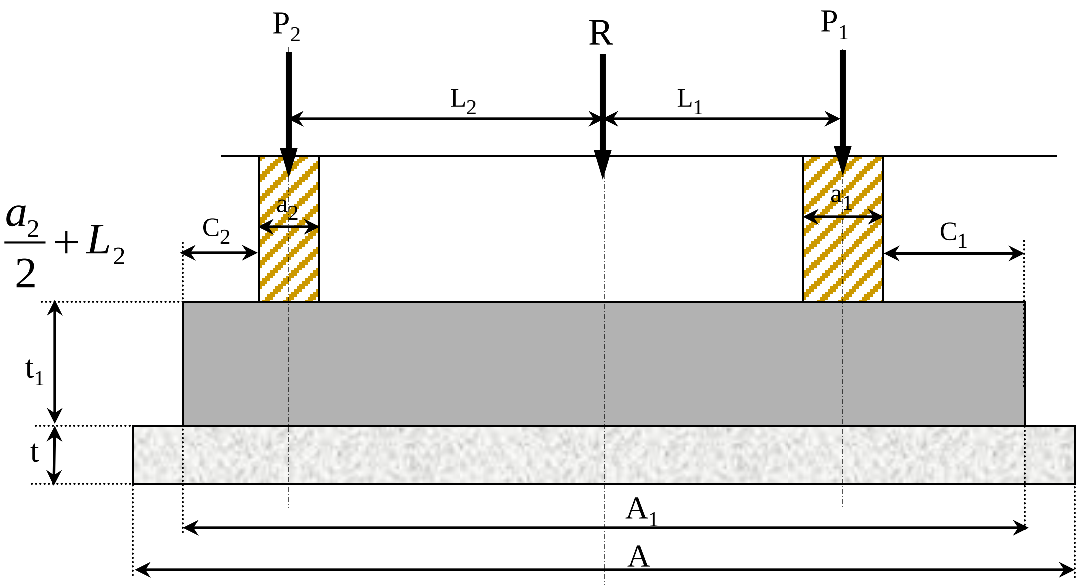
$f_{cu} = 250 kg/cm^2.$

$f_y = 3600 kg/cm^2$

Plain Concrete Footing (P.C.)

For uniform stress, Resultant should be at mid of (*A*)

$$\frac{A}{2} = X + C_1 + \frac{a_1}{2} + L_1 = X + C_2 + \frac{a_2}{2} + L_2$$



Assume thickness of P.C.:

$t = 0.30$

$X = t = 0.30$

Assume $C_2 = 0.50m$

$$R = (P_1 + P_2) = 140 + 90 = 230t$$

$L_2 * 230 = 3.20 * 140 \longrightarrow L_2 = 1.95$

$$\frac{A}{2} = 0.30 + 0.50 + \frac{0.50}{2} + 1.95 = 3.00m$$

$A = 6.00$m

$$Area = A * B = \frac{1.15(P_1 + P_2)}{q_a} = \frac{1.15 * 230}{11} = 24.10m^2$$

$B = 4.02 = 4.05$m

Dim. of P.C. = 6.00 * 4.05 * 0.30

Reinforced Concrete Footing (R.C.)

$$A_1 = A - 2X = 6.00 - 2*0.30 = 5.40m$$

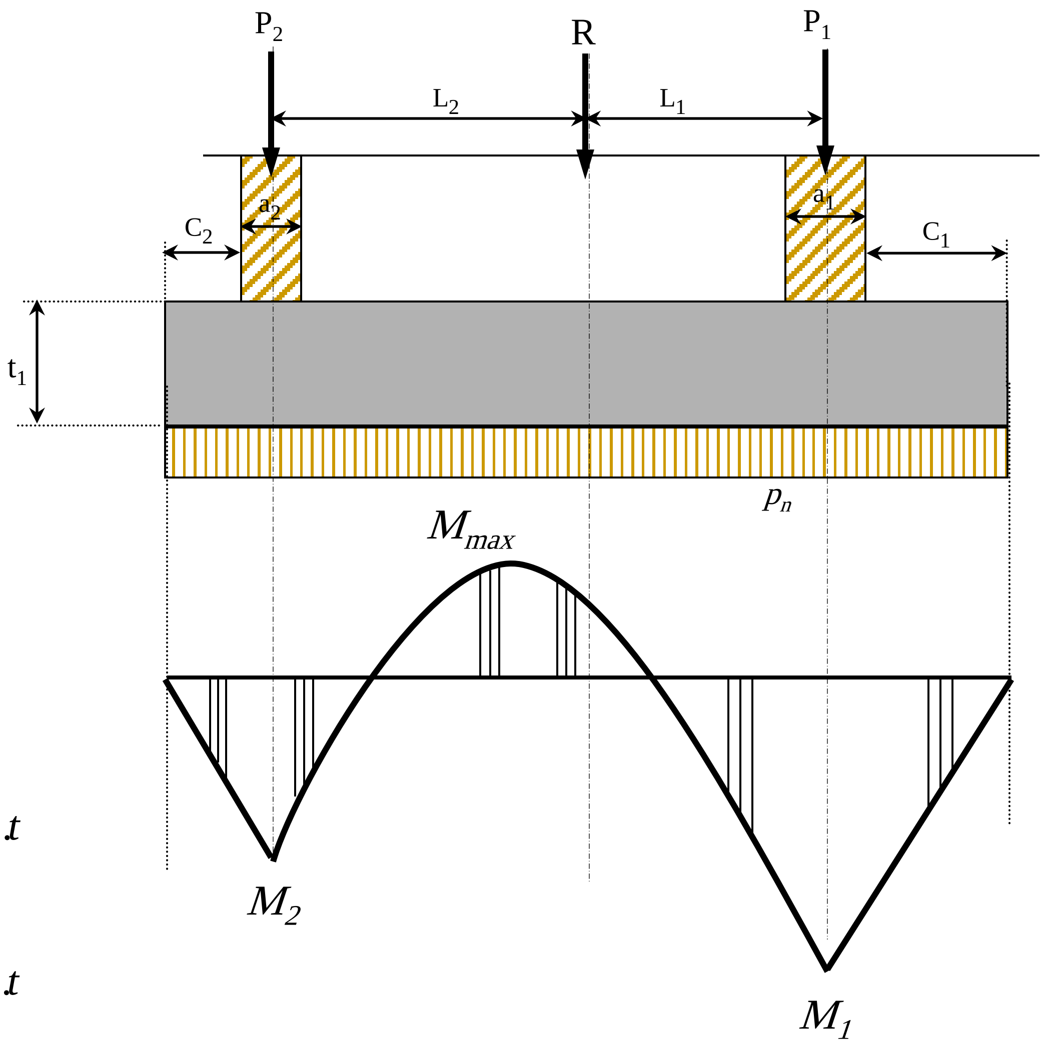
$$B_1 = B - 2X = 4.05 - 2*0.30 = 3.45m$$

$$p_n = \frac{R}{A_1 * B_1} = \frac{1.50*230}{5.40*3.45} = 18.52t/m$$

$$w = \frac{R}{A_1} = \frac{1.50*230}{5.40} = 63.90t/m^2$$

$$M_1 = w\frac{[C_1]^2}{2} = 63.90*\frac{0.90^2}{2} = 25.88m.t$$

$$M_2 = w\frac{[C_2]^2}{2} = 63.90\frac{[0.50]^2}{2} = 8.00m.t$$



Reinforced Concrete Footing (R.C.)

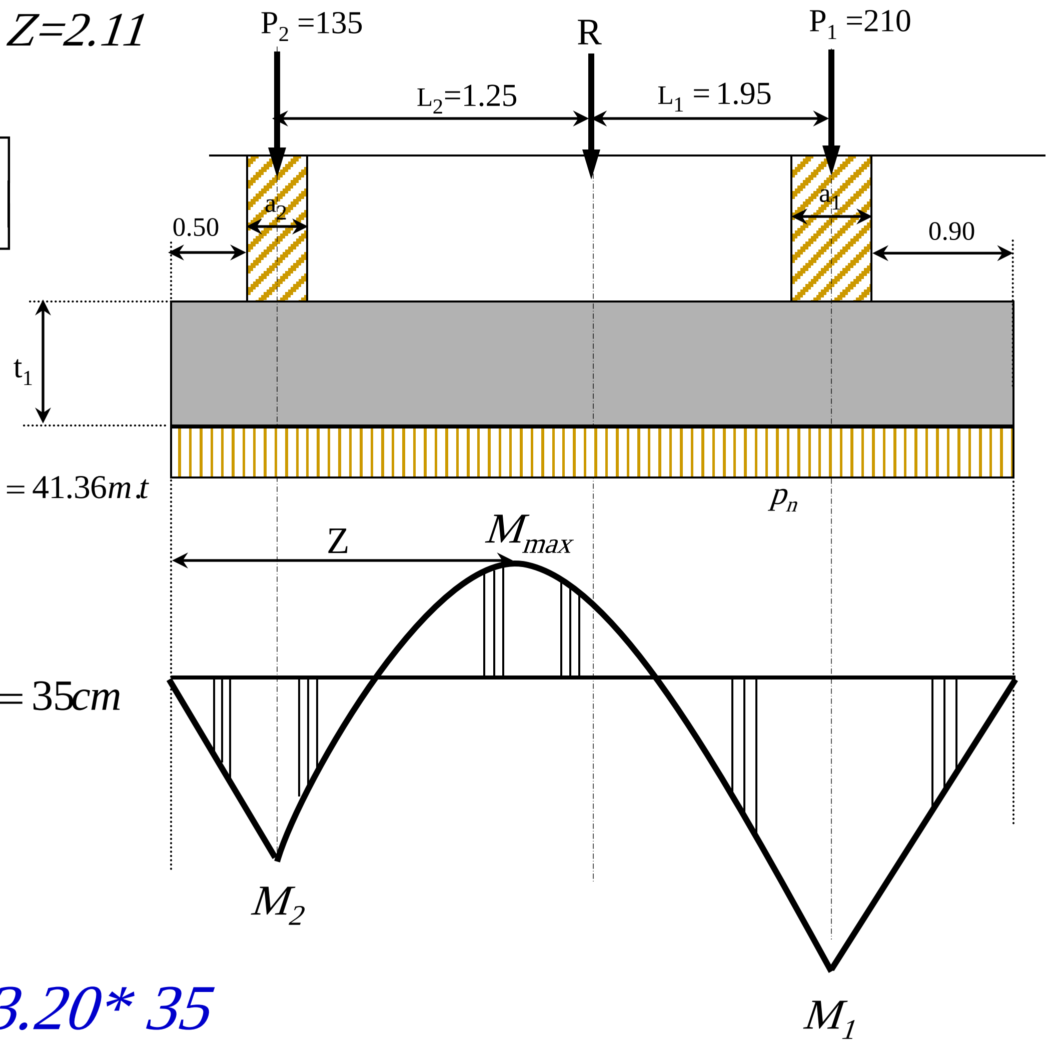
$$wZ - P_2 = 63.90*Z - 1.50*90 \longrightarrow Z=2.11$$

$$M_{max} = \frac{wZ^2}{2} - P_2\left[Z - (C_2 + \frac{a_2}{2})\right]$$

$$M_{max} = \frac{63.90*2.11^2}{2} - 1.50*90*\left[2.11 - (0.50 + \frac{0.5}{2})\right] = 41.36 m.t$$

$$d = C\sqrt{\frac{M}{b*F_{cu}}} = 5*\sqrt{\frac{41.36*10^5}{345*250}} = 34.6 = 35 cm$$

$$t_1 = d + cover = 35 + 5 = 40 cm$$



*Dim. of R.C. = 5.80 * 3.20* 35*

Shear Stress

$$Q_1 = -63.95 * 0.90 = 57.55t$$

$$Q_2 = 210 - 63.95 * (0.90 + 0.90) = 95.89t$$

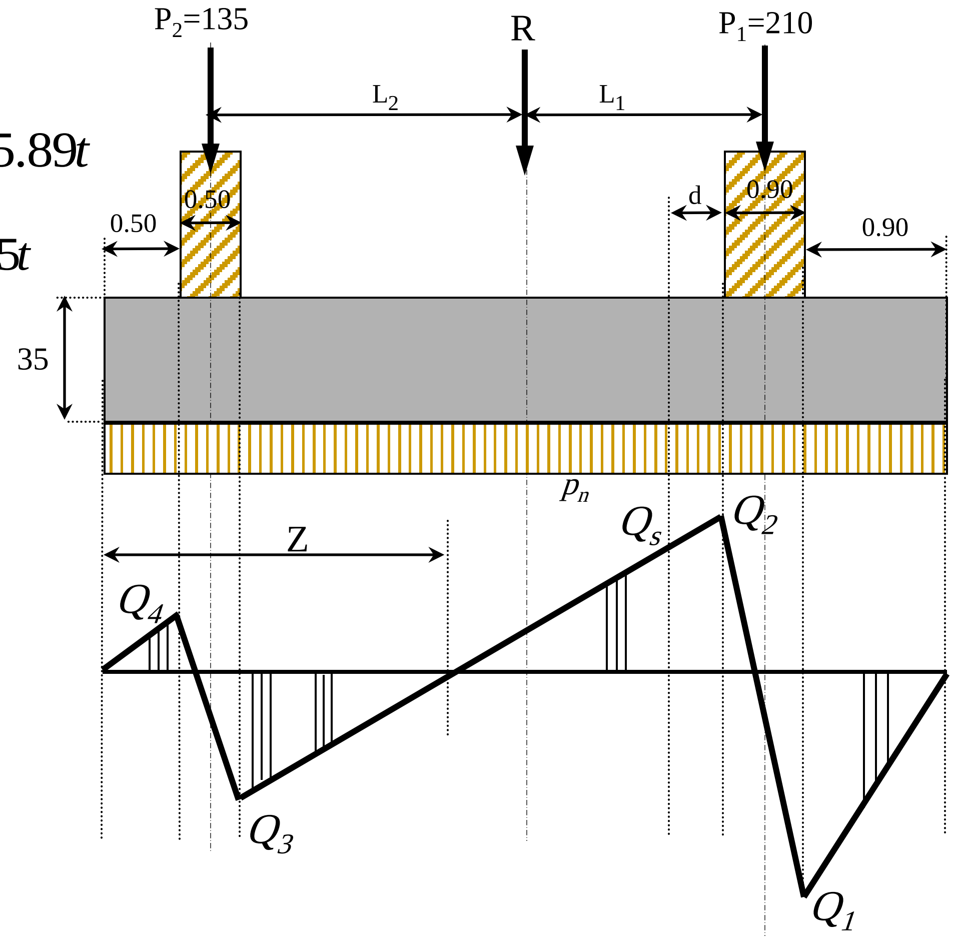
$$Q_3 = 63.95 * (0.50 + 0.50) - 135 = 71.05t$$

$$Q_4 = 63.95 * (0.50) = 31.98t$$

$$Q_s = 95.89 - 63.95 * 0.35 = 73.51t$$

$$q_s = \frac{73.51 * 10^3}{345 * 30} = 7.10 kg/cm^2$$

$$q_{su} = 0.75\sqrt{\frac{f_{cu}}{\gamma_c}} = 0.75\sqrt{\frac{250}{1.50}} = 9.68$$



Punching Stress

Column(1):

$$Q_p = P_1 - p_n * [(a_1 + d) * (b_1 + d)]$$

$$Q_p = 210 - 18.52 * [(0.90 + 0.35) * (0.30 + 0.35)] = 194.95t$$

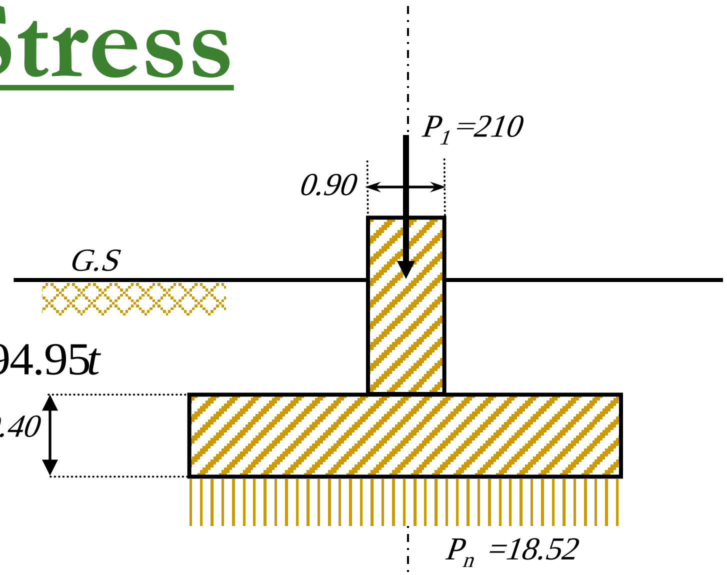
$$A_{p1} = d * 2 * [(a_1 + d) + (b_1 + d)]$$

$$A_{p1} = 0.35 * 2 * [(0.90 + 0.35) + (0.30 + 0.35)] = 1.33m^2$$

$$q_p = \frac{Q_p}{A_p} = \frac{194.95 * 10^3}{1.33 * 10^4} = 15.98kg/cm^2$$

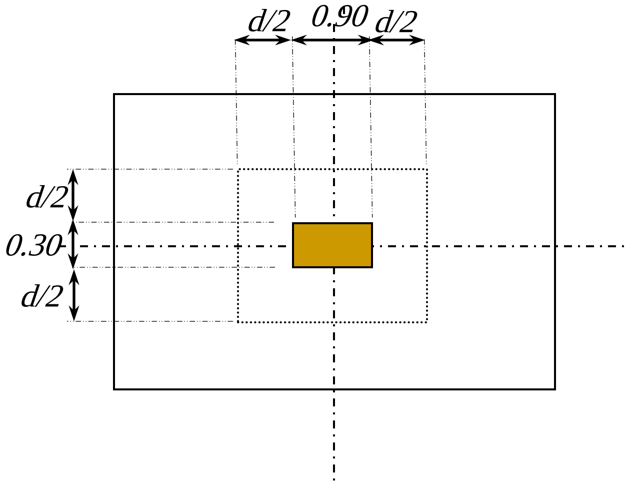
$$q_{cup} = [0.5 + (b/a)] \sqrt{f_{cu}/\gamma_c} \le \sqrt{f_{cu}/\gamma_c}$$

$$q_{cup} = [0.5 + (0.30/0.90)] \sqrt{250/1.50} = 10.75kg/cm^2$$

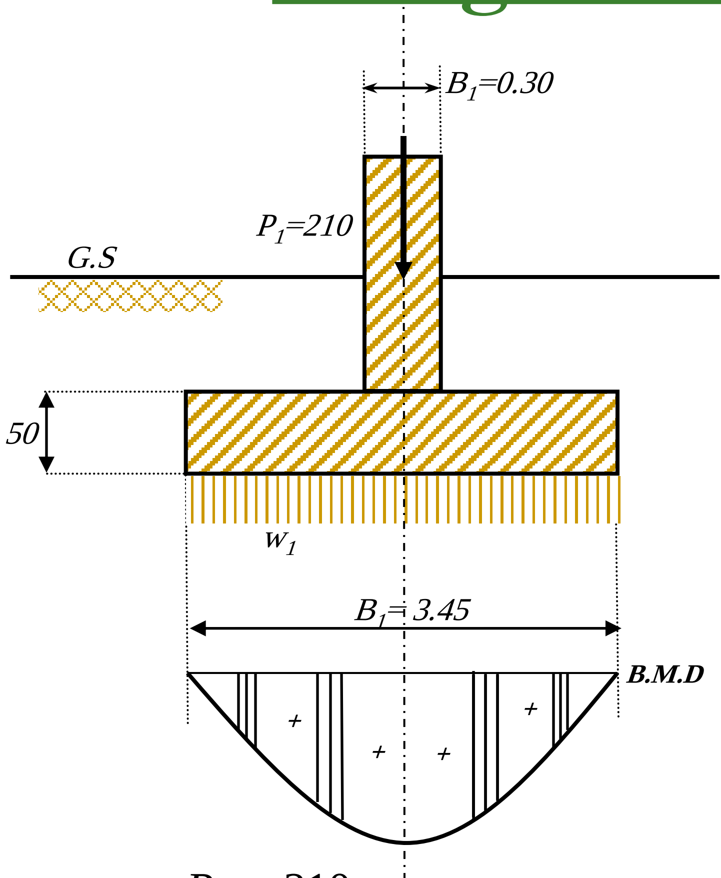


$q_p > q_{cup}$, *Increase d= 45cm*

Repeat Check for column (2)

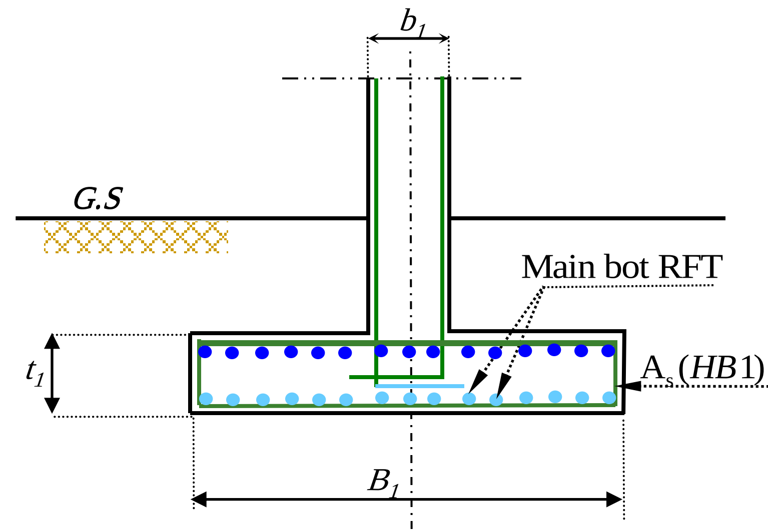


Design of Hidden Beams



$$w_1 = \frac{P_1}{B_1} = \frac{210}{3.45} = 60.87\, t/m'$$

$$M_{HB1} = 60.87 \frac{[(3.45-0.30)/2]^2}{2} = 75.50\, m.t$$



$$b = b_1 + d = 0.30 + 0.30 = 0.65$$

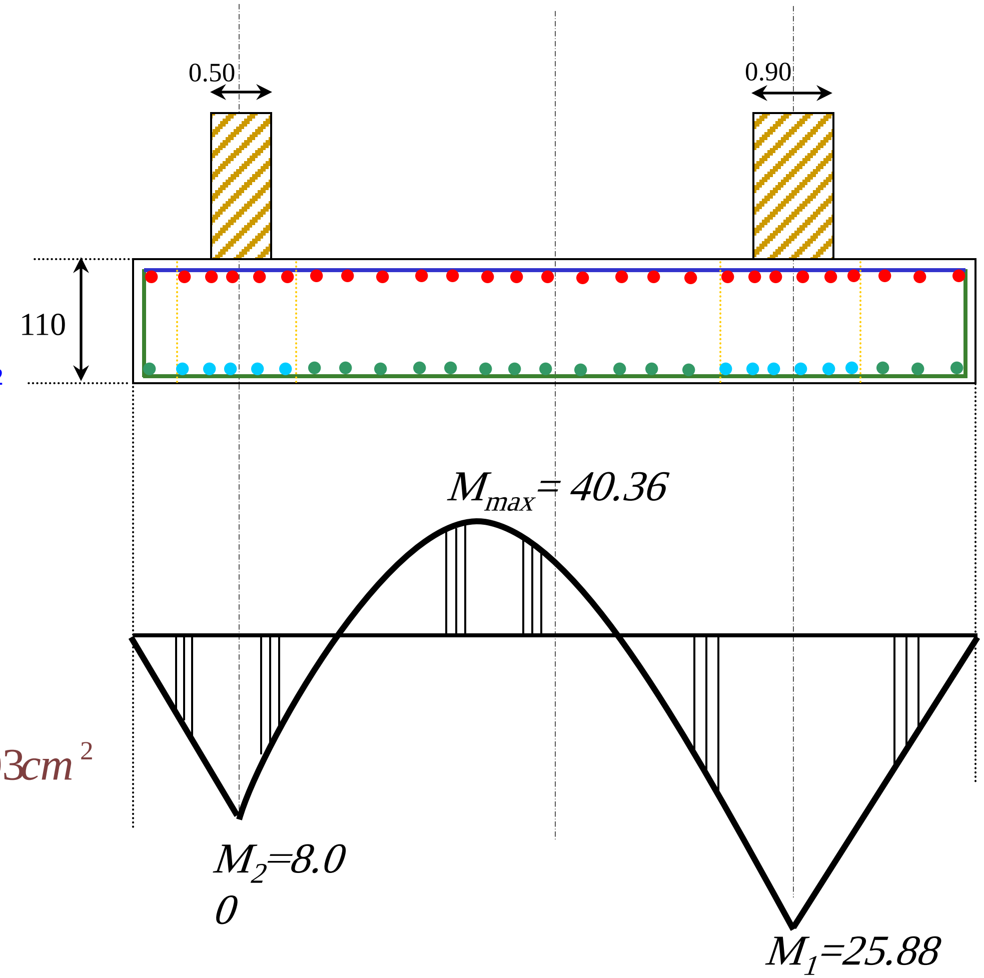
$$d_1 = 5\sqrt{\frac{75.50*10^5}{75*250}} = 100.3 = 105\, cm$$

$$d_1 > d \rightarrow take\ d = 105$$

$$A_{sH1} = \frac{M_I}{f_y * d * j} = \frac{75.5*10^5}{3600*105*0.826} = 24.2\, cm^2$$

$$7\ \phi\ 22$$

Footing Reinforcement



$$A_{top} = \frac{M_1}{f_y * d * j} = \frac{25.88*10^5}{3600*110*0.826} = 8.30 cm^2$$

$$5 \phi 12 / m'$$

$$A_{bot} = \frac{M_{max}}{f_y * d * j} = \frac{40.36}{3600*105*0.826} = 12.93 cm^2$$

$$5 \phi 12 / m'$$