Fayoum University

Faculty of Engineering

Department of Civil Engineering

CE 402: Part A

Shallow Foundation Design

Lecture No. (6): Eccentric Footing

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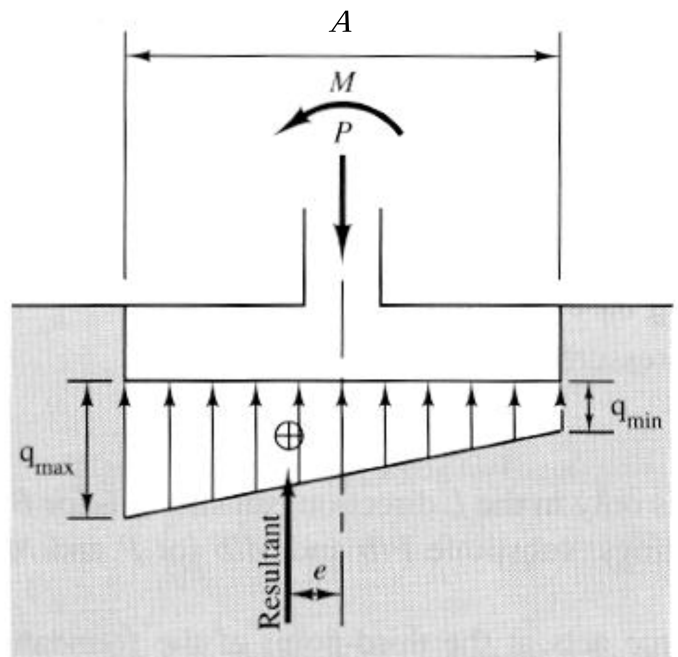
Eccentric Footing

Eccentric footing: A spread or wall footing that also must resist a moment in addition to the axial column load.

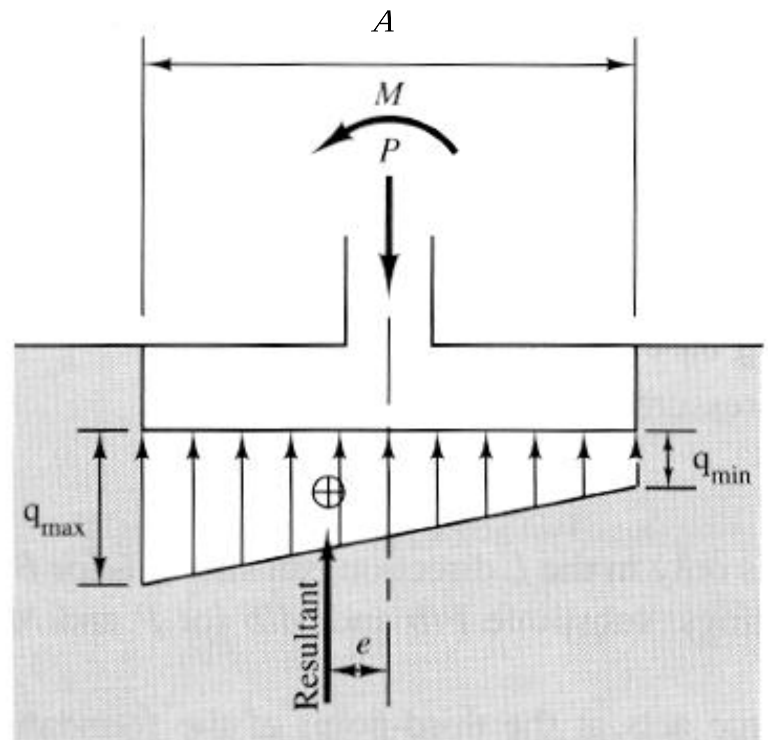


$e < A/6$

Eccentric Loads or Moments

$$P = P_{D.L} + P_{L.L}$$

$$e = \frac{M}{(P + W_f)}$$



$e < A/6$

Eccentric Footing

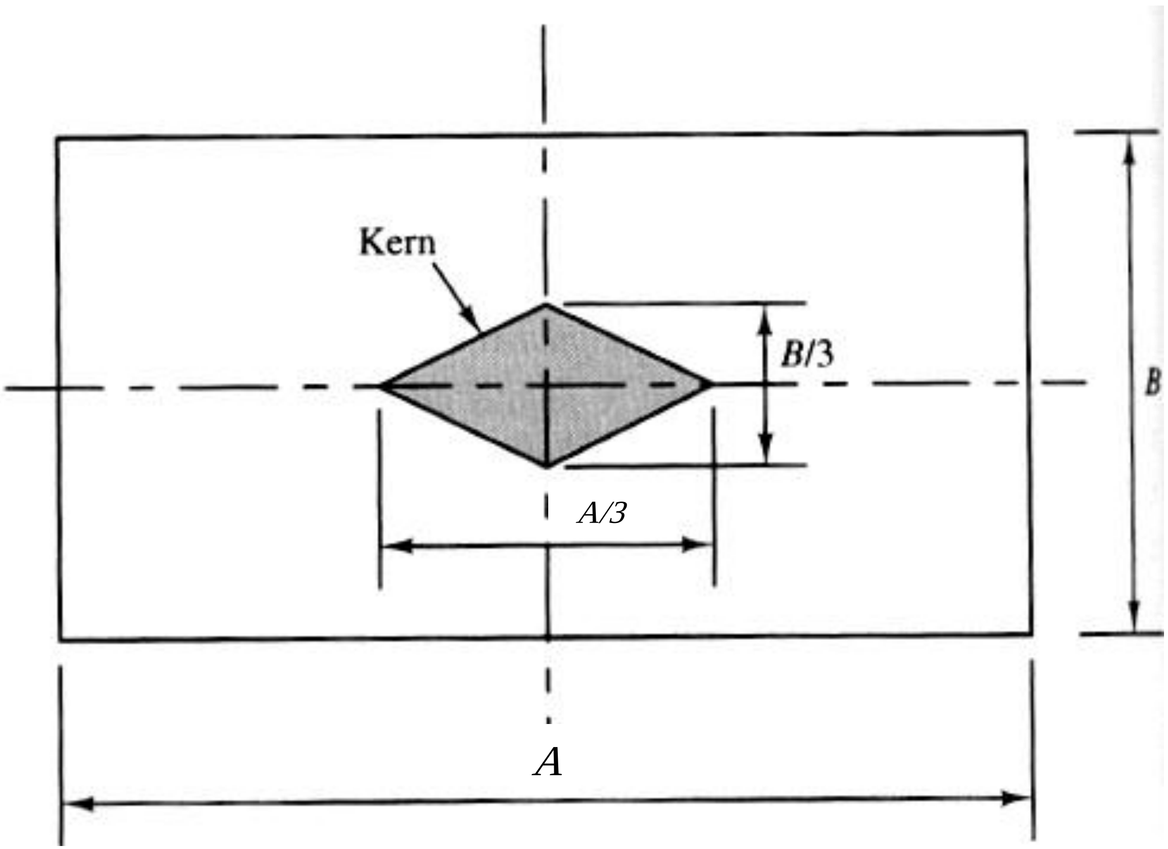
Combined axial and bending stresses increase the pressure on one edge or corner of a footing. We assume again a linear distribution based on a constant relationship to settling.

If the pressure combination is in tension, this effectively means the contact is gone between soil and footing and the pressure is really zero.

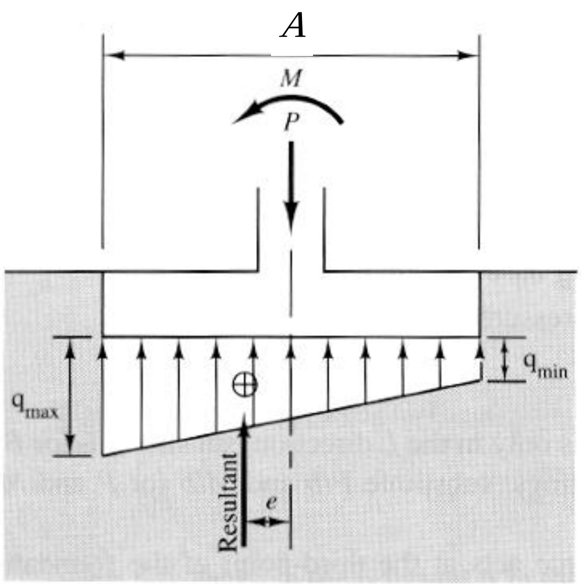
To avoid zero pressure, the eccentricity must stay within **the kern**. The maximum pressure must not exceed the net allowable soil pressure.

The kern

To avoid zero pressure, the eccentricity must stay within **the kern**.

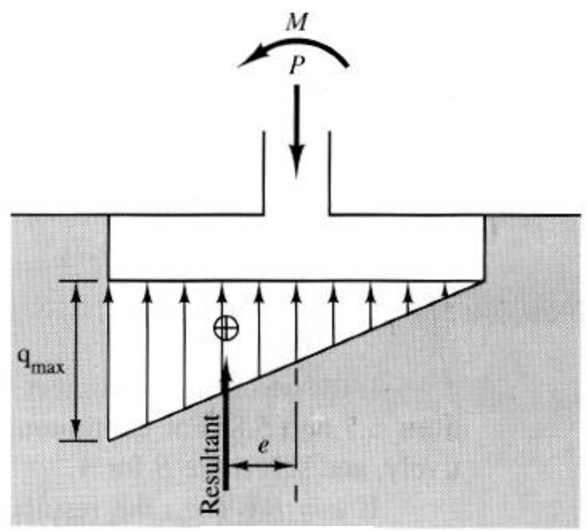


Eccentric Loads or Moments Cases



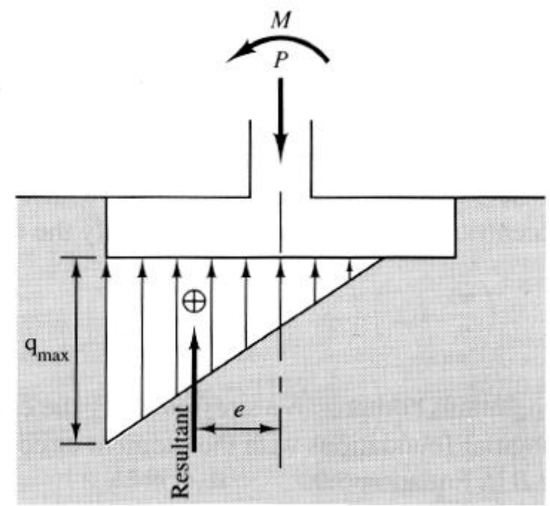
e <A/6

Case (a)



e =A/6

Case (b)



e >A/6

Case (c)

Eccentric Loads or Moments

For case A and B (not case C)

$$q_{\min} = \frac{P}{A*B}(1-\frac{6e}{A})$$

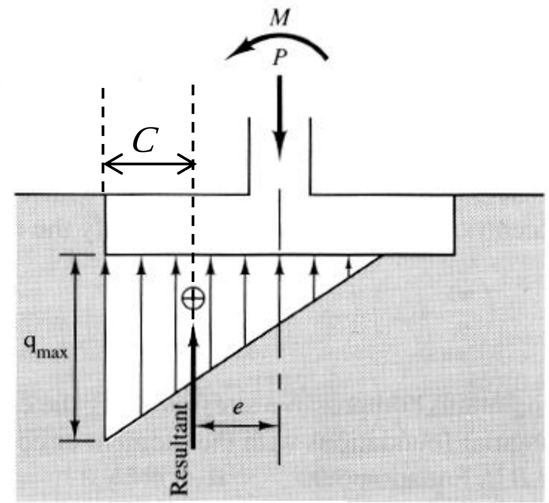
$$q_{\max} = \frac{P}{A*B}(1+\frac{6e}{A})$$

For case c

$$q_{\max} = \frac{2*P}{3*C*B}$$

$$3C \geq 0.75A$$

$$q_{\max} \leq 1.20 q_a$$



e >A/6

Case (c)

Footing Subjected to Double Moment

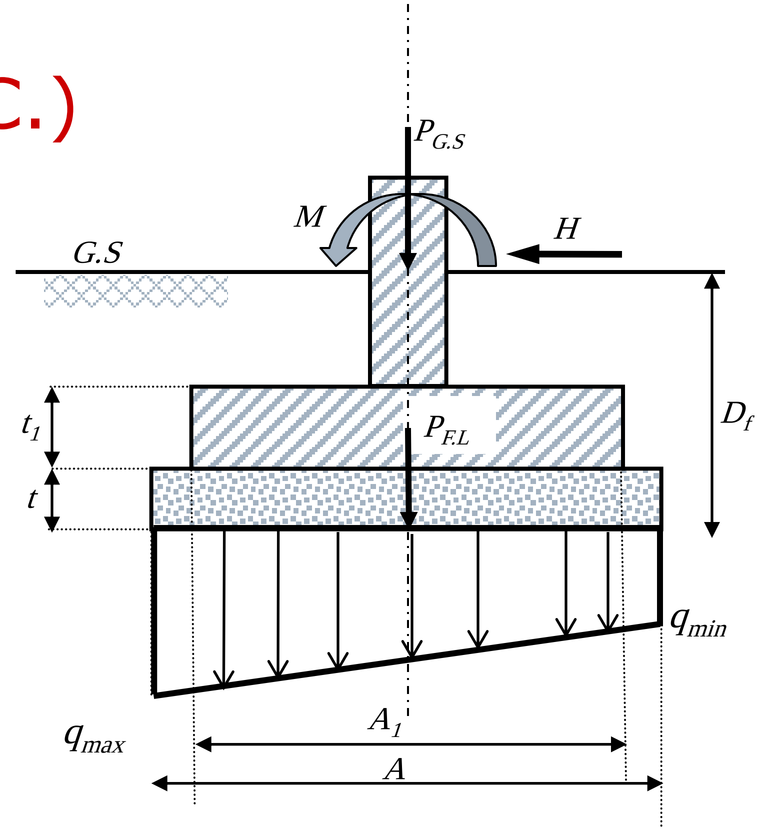
$$q = \frac{P}{A*B}(1 \pm 6\frac{e_A}{A} \pm 6\frac{e_B}{B})$$

For contact pressure to remain (+) ve everywhere,

$$\frac{6e_A}{A} + \frac{6e_B}{B} \leq 1.0$$

Design of Eccentric Footing

- Plain concrete footing (P.C.)



$$Area = A * B = \frac{1.50 P_{G.S}}{q_a}$$

Assume $A = \sqrt{Area}$

$$M_{F.L} = M + H * D_f$$

$$P_{F.L} = 1.15 * P_{G.s} \qquad e = \frac{M_{F.L}}{P_{F.L}}$$

Check $e \le \frac{A}{6}$

$$q_{\max} = q_a = \frac{P_{F.L}}{A * B}\left(1 + \frac{6e}{A}\right) \longrightarrow B$$

Assume thickness of P.C.:

t = (0.25 to 0.50)

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

Design of Spread Footing

- Reinforced concrete footing (R.C.)

$$X = (0.8 \rightarrow 1.0)t$$

$$A_1 = A - 2X \qquad B_1 = B - 2X$$

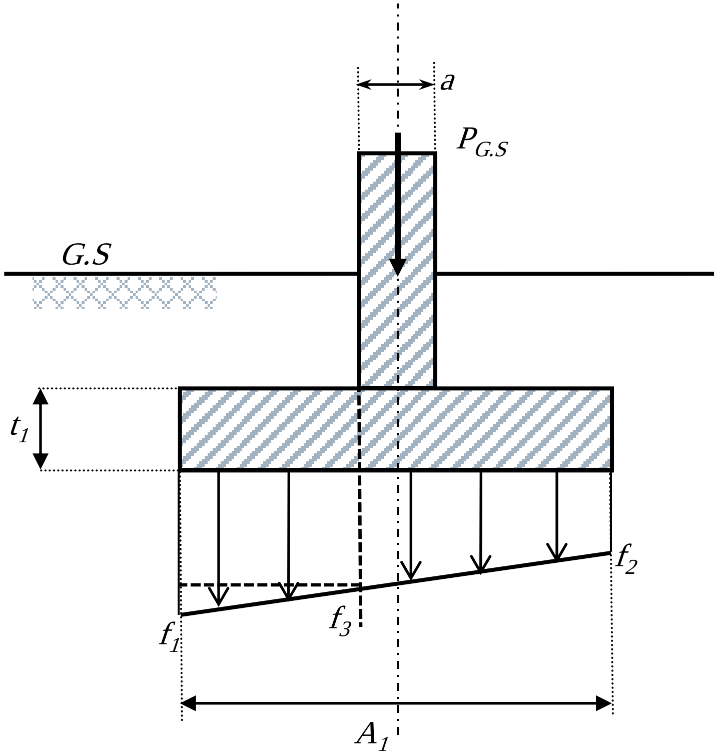
$$e_1 = \frac{M_1}{P_{G.S}}$$

$$f_{1,2} = \frac{P_{G.S}}{A_1 * B_2}(1 \pm \frac{6e_1}{A_1})$$

$$M_I = f_3(\frac{A_1 - a}{2})^2 / 2 + (f_1 - f_3)(\frac{A_1 - a}{2})^2 * \frac{2}{3}$$

$$M_{II} = (\frac{f_1 + f_2}{2}) * (\frac{B_1 - b}{2})^2$$

$$d = C\sqrt{\frac{M}{b * F_{cu}}} \qquad t_1 = d + \text{cover}$$



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

Design of Spread Footing

- Shear Stress:

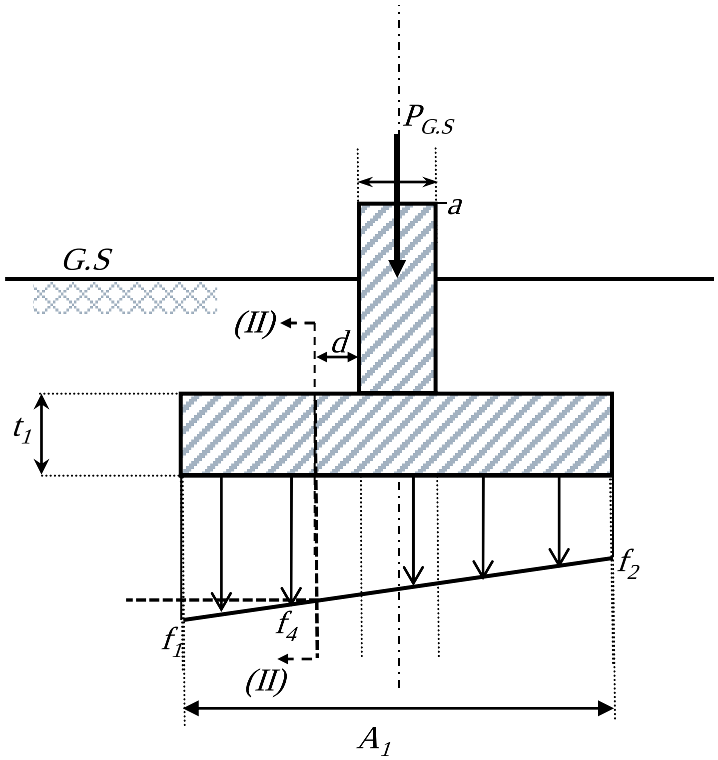
$$Q_{s(II)} = \frac{(f_1 + f_4)}{2} * (\frac{A_1 - a}{2} - d)$$

$$Q_{s(III)} = \frac{(f_1 + f_2)}{2} * (\frac{B_1 - b}{2} - d)$$

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

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

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



<u>Notes:</u>

•No shear RFT in Footing.

Q_s: shear force at critical sec. (II).

q_s: shear stress.

q_{su}: ultimate shear strength.

Design of Spread Footing

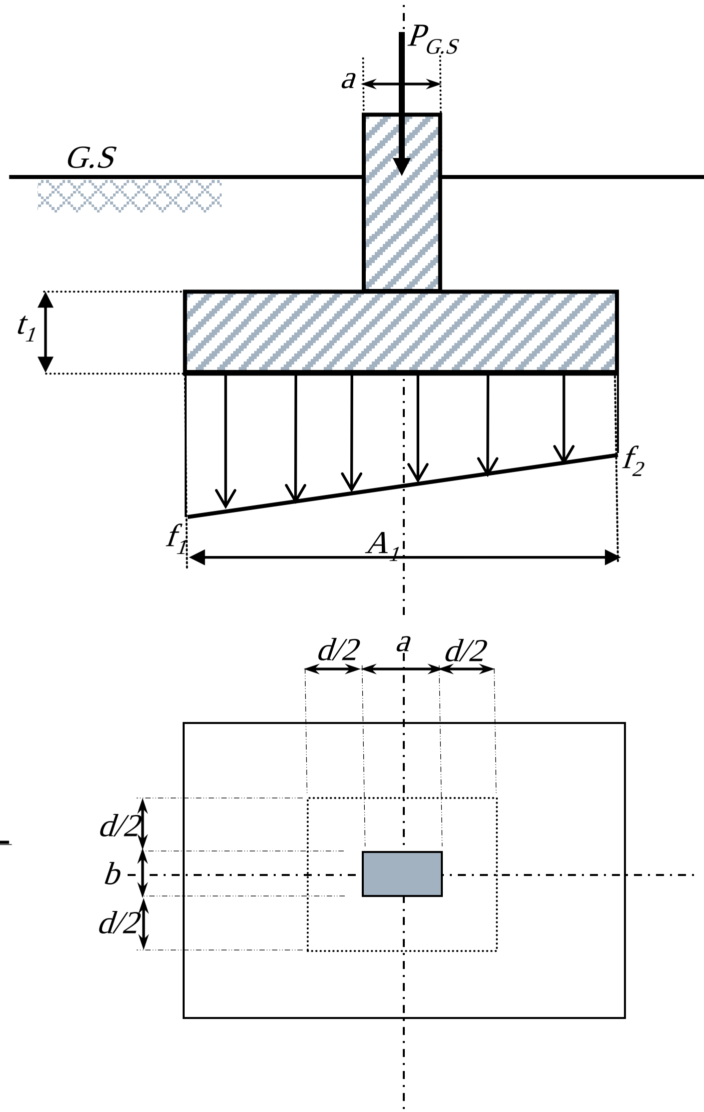
- Punching Stress:

$$Q_p = 1.50 P_{G.S} - \frac{(f_1 + f_2)}{2}[(a+d)*(b+d)]$$

$$A_p = d*2*[(a+d)+(b+d)]$$

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

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



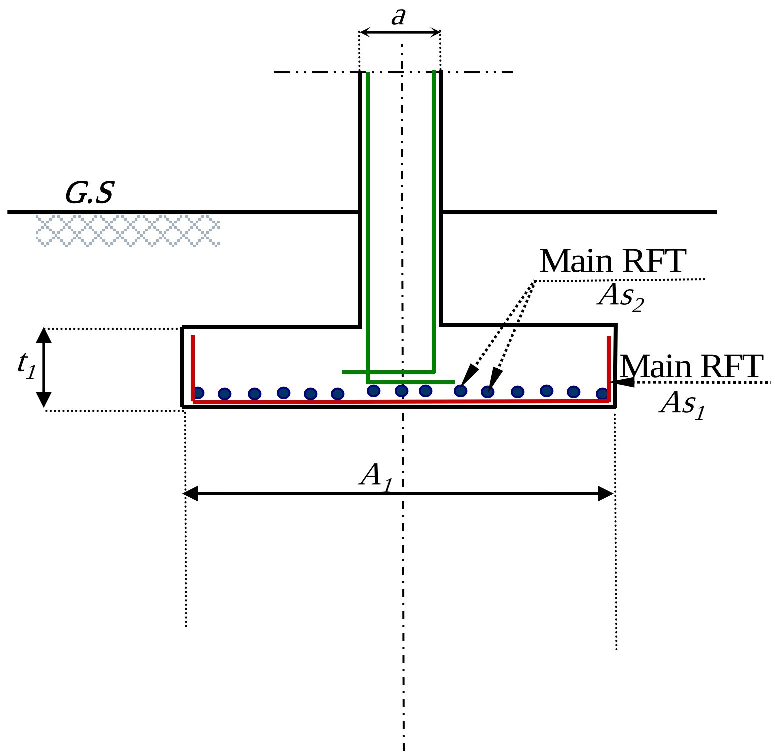
If $q_p > q_{cup}$, Increase d

Design of Spread Footing

- Footing Reinforcement:

$$A_{s1} = \frac{M_I}{f_y * d * j}$$

$$A_{s2} = \frac{M_{II}}{f_y * d * j}$$



<u>Notes:</u>

•Minimum number of bars per meter is five.

•Minimum diameter for main RFT is 12mm.

•Number of bars may be taken 5 to 8.

•Diameter of bars may be selected from 12 to 18mm.

Design of Eccentric Footing

- Example(1):

Make a complete design for a footing supporting a 30cm X 60cm column load of 120t at ground surface (G.S.), 20m.t moment and 10t horizontal force at G.S. The foundation level is 2.00 m below G.S. and the net allowable bearing capacity is 0.80kg/cm^2. Make the design considering the following two cases:

1- with plain concrete base

2- without Plain concrete base

$a = 0.60m.$ $B = 0.30m$

$p_{G.S} = 120t$ $M = 20m.t$ $H = 10t$

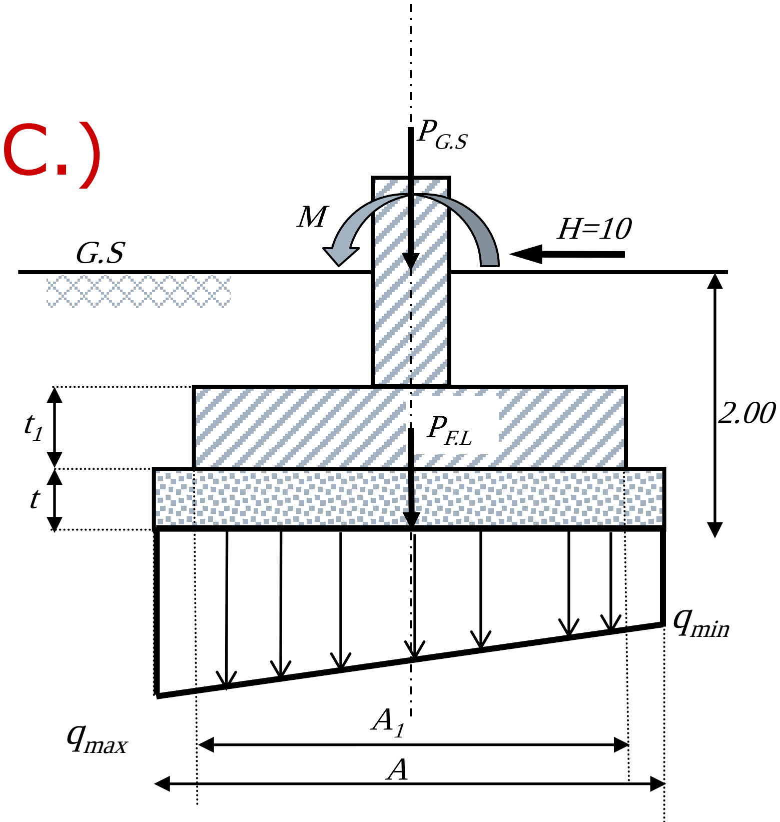
$q_a = 0.80 kg/cm^2 = 8t/m^2.$

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

$f_y = 3600 kg/cm^2$

Design of Eccentric Footing

- Plain concrete footing (P.C.)



$$Area = A*B = \frac{1.50*P_{G.S}}{q_a} = \frac{1.50*120}{8} = 22.5m^2$$

Assume $A = \sqrt{Area} = 4.75 \approx 5.00m$

$$M_{F.L} = 20 + 10*2.00 = 40m.t$$

$$P_{F.L} = 1.15*P_{G.s} = 1.15*120 = 138t$$

$$e = \frac{M_{F.L}}{P_{F.L}} = \frac{40}{138} = 0.290 \qquad e \le \frac{A}{6} = \frac{5}{6} = 0.833$$

$$q_{\max} = \frac{138}{5*B}(1 + \frac{6*0.290}{5.00}) = 8 \longrightarrow B = 4.65m$$

Assume thickness of P.C.:

t = 0.30

Dim. of P.C. = 5.00* 4.65 * 0.30

Design of Eccentric Footing

- Reinforced concrete footing (R.C.)

$$X = t = 0.30m$$

$$A_1 = A - 2X = 5.00 - 2*0.30 = 4.40m$$

$$B_1 = B - 2X = 4.65 - 2*0.30 = 4.05m$$

$$e_1 = \frac{M_1}{P_{G.S}} = \frac{20 + 10*1.70}{120} = 0.308m$$

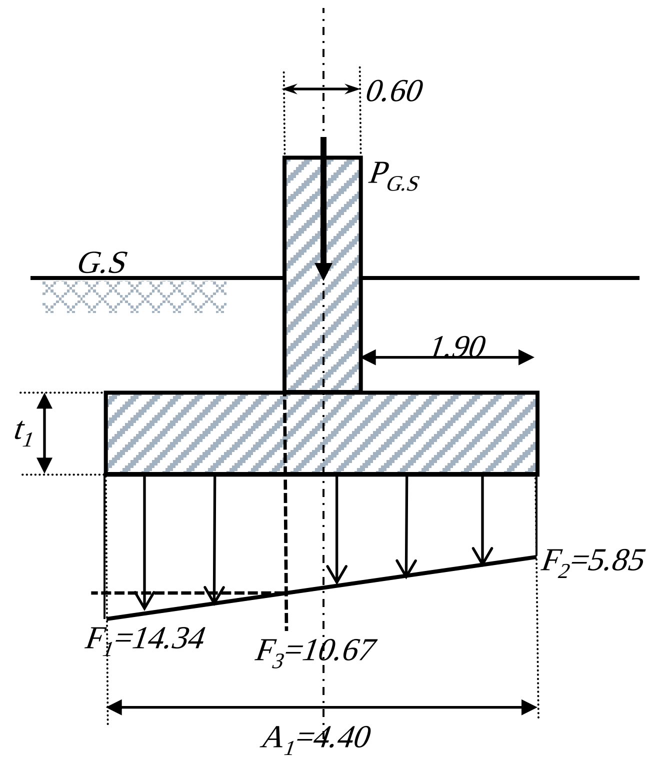
$$f_{1,2} = \frac{1.50*120}{4.40*4.05}(1 \pm \frac{6*0.308}{4.40}) = 14.34 \rightarrow 5.85$$

$$M_I = 10.67(\frac{4.4-0.60}{2})^2/2 + (14.34-10.67)(\frac{4.4-0.6}{2})^2*\frac{2}{3} = 47.36$$

$$M_{II} = (\frac{14.34+5.85}{2})*(\frac{4.05-0.30}{2})^2 = 35.33$$

$$d = 5\sqrt{\frac{47.36*10^5}{100*250}} = 68.8 \approx 70cm$$

$$t_1 = 70 + 5 = 75cm$$



Dim. of R.C. = *4.40 * 4.05* 0.75*

Design of Spread Footing

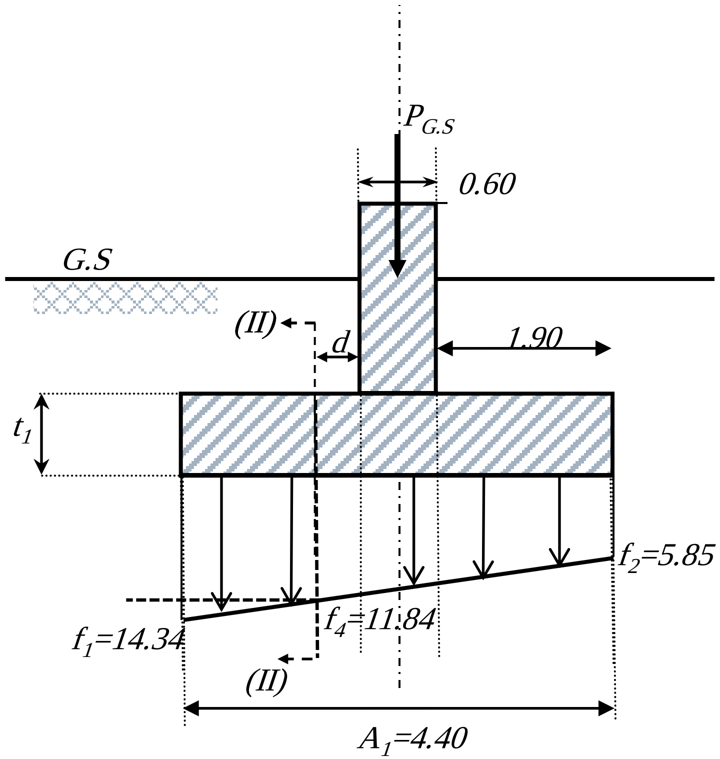
- ## Shear Stress:

$$f_4 = 5.85 + \frac{(11.84 - 5.85)}{4.40} * (1.90 + 0.60 + 0.6) = 11.84$$

$$Q_{s(II)} = \frac{(14.34 + 11.84)}{2} * (1.90 - 0.70) = 15.71$$

$$Q_{s(III)} = \frac{(14.34 + 5.85)}{2} * (\frac{4.05 - 0.3}{2} - 0.70) = 11.86$$

$$q_s = \frac{15.71 * 1000}{100 * 70} = 2.24 kg/cm^2 \leq 9.68$$



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

<u>Notes:</u>

•No shear RFT in Footing.

Q_s: shear force at critical sec. (II).

q_s: shear stress.

q_{su}: ultimate shear strength.

Design of Spread Footing

- Punching Stress:

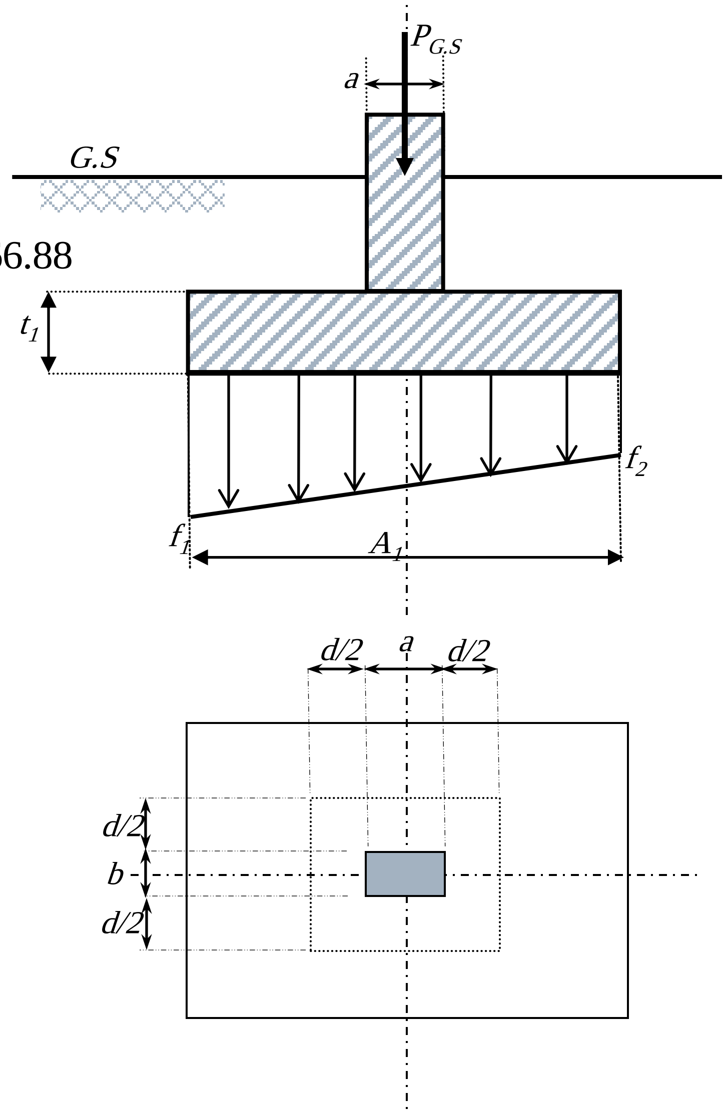
$$Q_p = 1.50*120 - \frac{(14.34+5.85)}{2}[(0.60+0.70)*(0.30+0.70)] = 166.88$$

$$A_p = 0.70*2*[(0.60+0.70)+(0.30+.70)] = 3.22$$

$$q_p = \frac{Q_p}{A_p} \qquad q_p = \frac{166.88*1000}{3.22*10^4} = 5.18$$

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

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

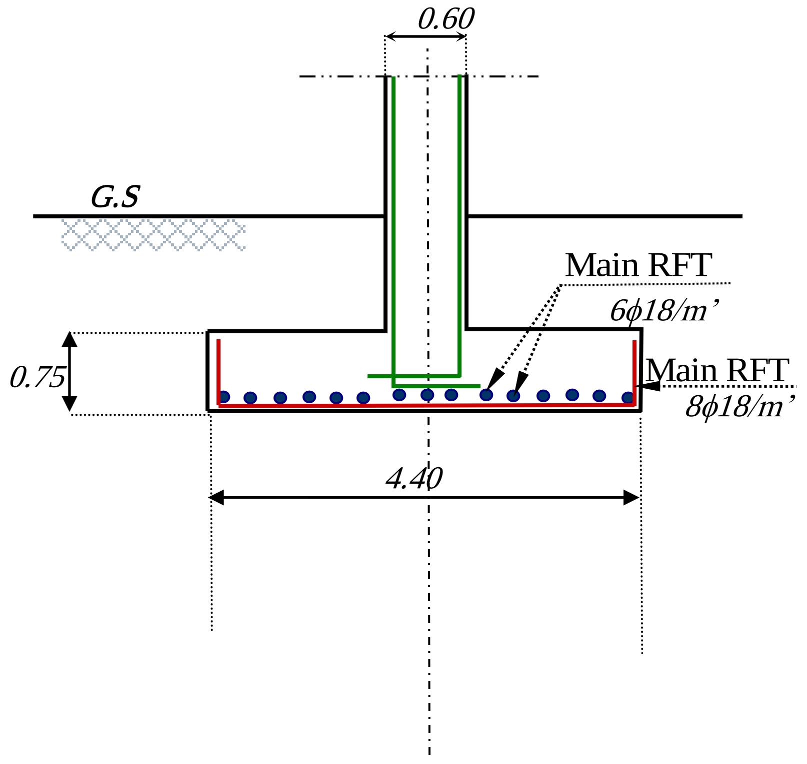


Design of Spread Footing

- Footing Reinforcement:

$$A_{s1} = \frac{47.36*10^5}{3600*70*0.826} = 22.75$$

$$A_{s2} = \frac{35.33*10^5}{3600*70*0.826} = 16.97$$



Notes:

•Minimum number of bars per meter is five.

•Minimum diameter for main RFT is 12mm.

•Number of bars may be taken 5 to 8.

•Diameter of bars may be selected from 12 to 18mm.

Crane Footing

Maximum stress on soil should be less than allowable bearing capacity

$$f_{\max} \leq q_a$$

The ratio between maximum and minimum stresses should be less than four

$$\frac{f_{\max}}{f_{\min}} \leq 4$$

$$\frac{f_{\max}}{f_{\min}} = \frac{(1+6e/A)}{(1-6e/A)} = 4$$

$$A = 10e$$

Uniform Stress below Footing Subjected to Moment

Uniform stress required that the eccentricity at foundation level equal zero

$$e = 0.0 \qquad e = \frac{M_{F.L}}{P_{G.s.}} = 0.0$$

$$\frac{A}{2} = c + \frac{a}{2} + e \longrightarrow A$$

$$A * B = \frac{1.15 P_{G.S}}{q_a} \longrightarrow B$$