Single Footing design

1- Estimate the soil reaction (q)

$$U = 1.2 * D.L + 1.6 * L.L$$

$$q = \frac{U}{BL}$$

2- Remove the eccentricity

3- Check the allowable or the ultimate bearing capacity

$$q_u = CN_C F_{Cs} F_{Cd} F_{Ci} + qN_q F_{qs} F_{qd} F_{qi} + 0.5\gamma B' N_\gamma F_{\gamma s} F_{\gamma d} F_{\gamma i}$$

Or Terzaghi's Equation

$$q_u = CN_C + qN_q + 0.5\gamma B' N_\gamma$$

$$q_{all} = \frac{q_u}{Fs}$$

$$q_{all} \geq q$$

4- Check the total settlement

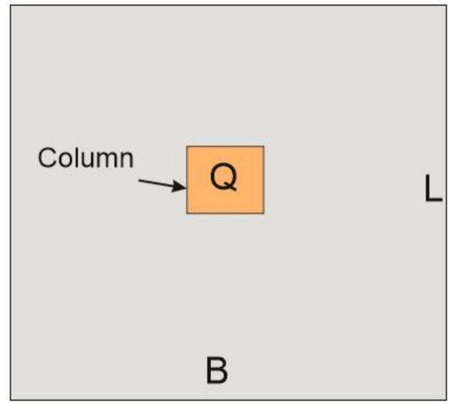
$$S_T = S_C + S_S \leq 25mm$$

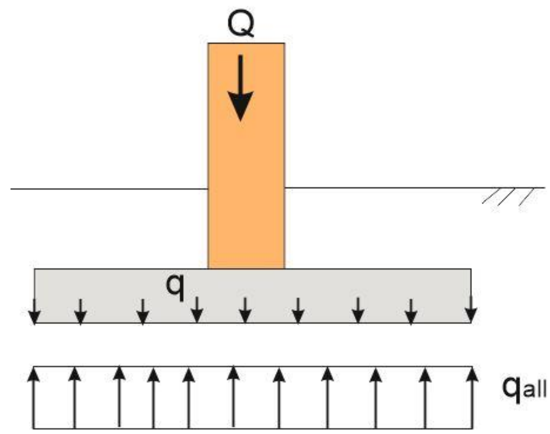
$$S_C = \frac{\Delta e}{1 + e_o} H$$

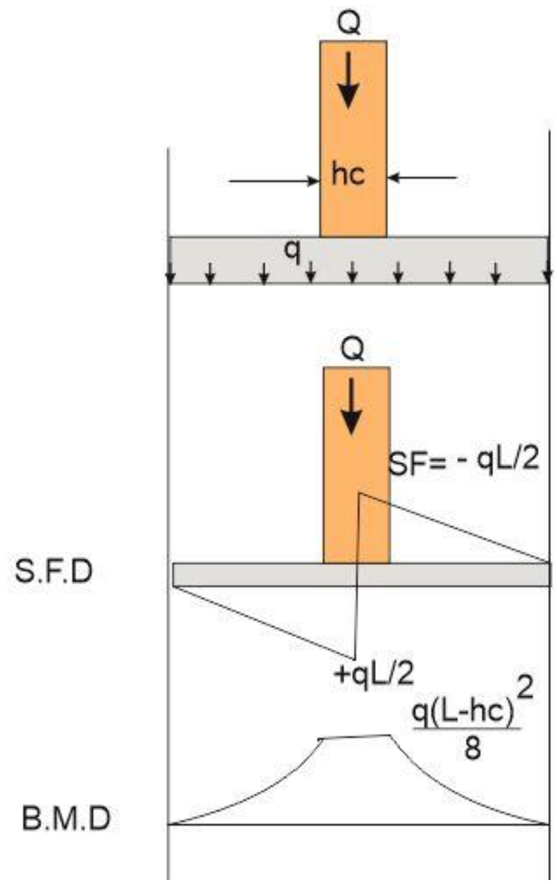
$$S_C = \frac{C_C H}{1 + e_O} log(\frac{\sigma + \Delta\sigma}{\sigma})$$

$$S_S = C'_\alpha H * log\frac{t_2}{t_1}$$

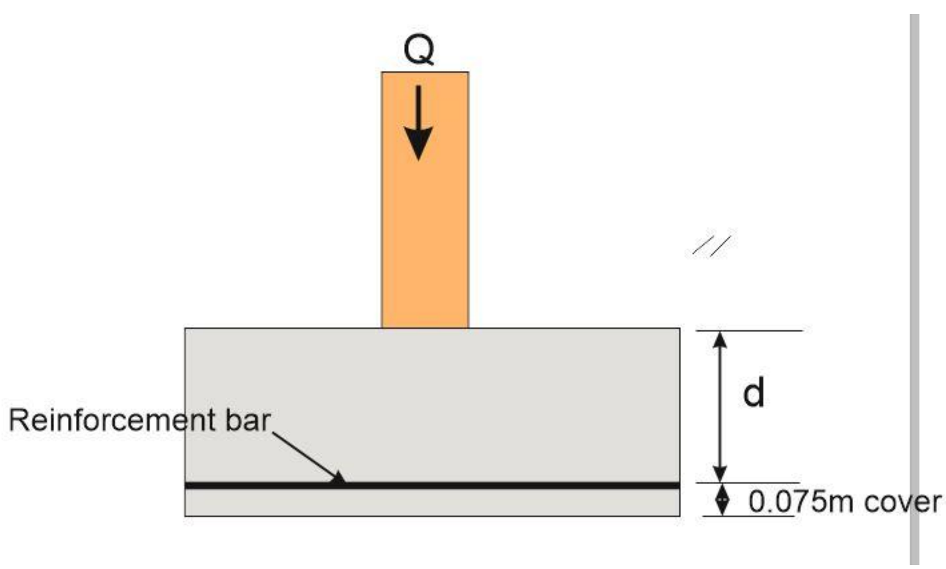
5- Draw the shear and bending moment



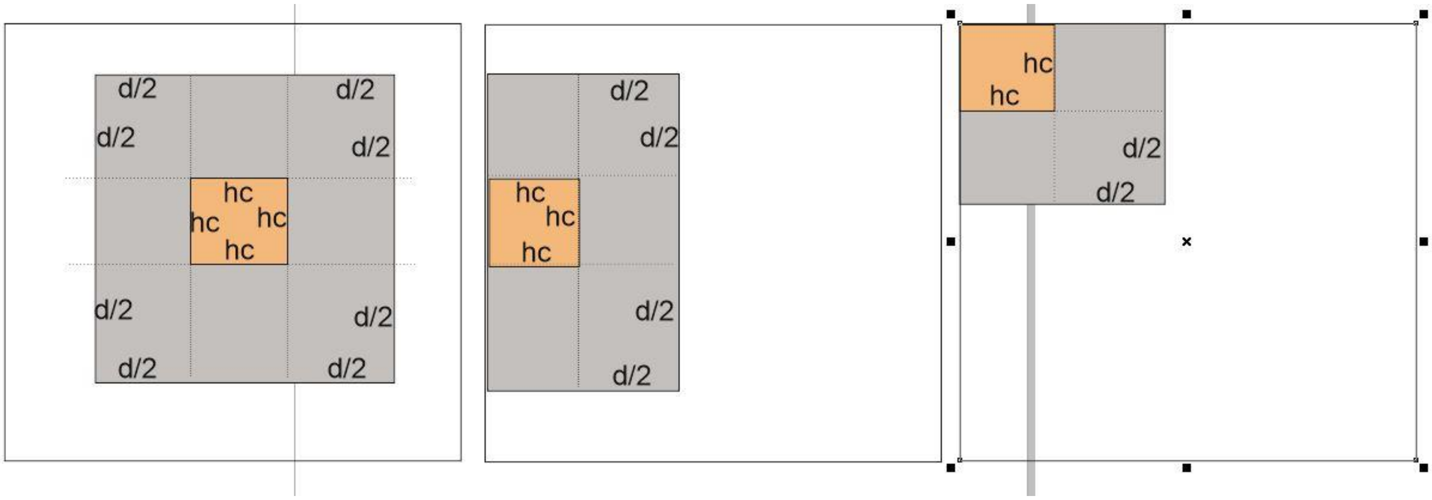



Q
hc
q
Q
SF= - qL/2
S.F.D
+qL/2
q(L-hc)^2 / 8
B.M.D

6- Estimate d


Q
d
Reinforcement bar
0.075m cover

$U = b_\circ d \varnothing (0.34)\sqrt{f'c}$



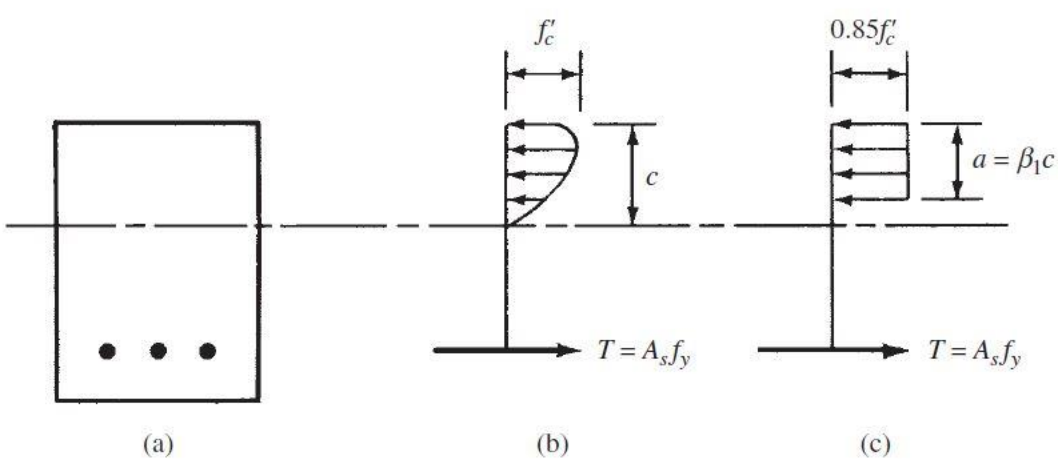
$b_O = 4d + 4h_C$ $b_O = 2d + 3h_C$ $b_o = d + 2h_C$

Check of Minimum shear

$$\frac{V_U}{b_\circ d} \leq 0.17\sqrt{f_c'}$$

Check of minimum of Punching

$$\frac{U}{b_O d} \leq 0.33\sqrt{f_c'}$$



$$a = \frac{A_S f_y}{0.85 f_C\, b} = \frac{\rho d f_y}{0.85 f_C} \quad \text{.............(1)}$$

$$\rho = \frac{A_S}{bd}$$

$M_U = \emptyset A_S f_y (d - \frac{a}{2})$ ....(2)

$M_U = \emptyset \rho b d f_y (d - \frac{\rho d f_y}{1.7 f_C})$

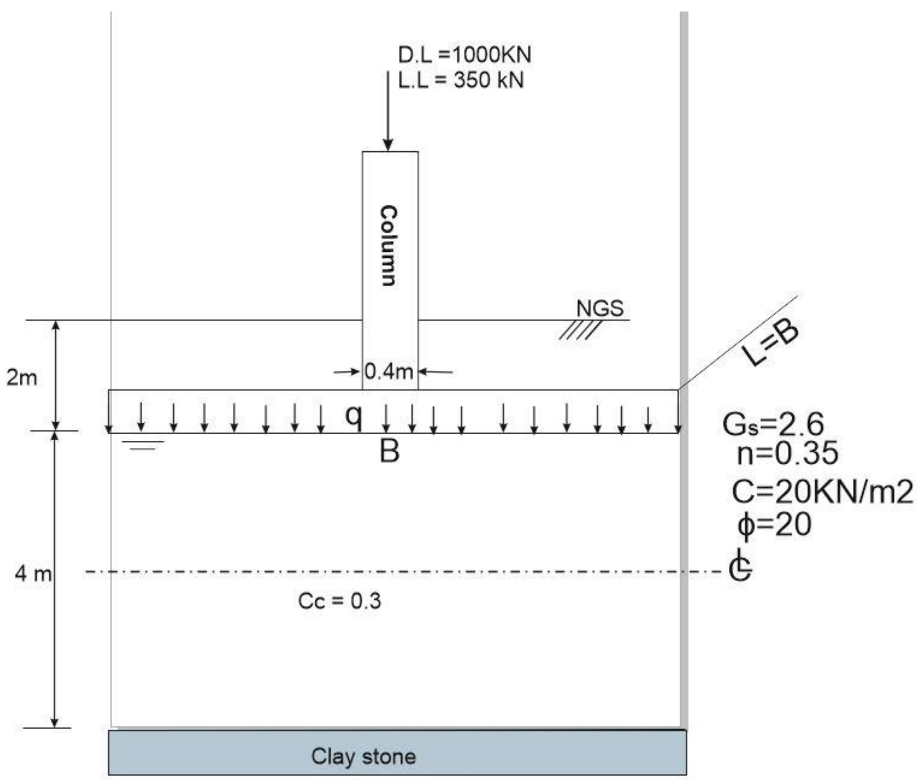
$M_U = \emptyset \rho b d^2 f_y (1 - \frac{\rho f_y}{1.7 f_C})$ ....(3)

Minimum steal area

$A_s(Minimum)$=0.0018 Bd

Example1: Design of single footing with axial load

A square single footing is required to resist 1000KN axial dead load and 350 KN live load imposed from a square column of 400 mm*400mm. The soil physical and mechanical properties are presented in the figure. $f_c' = 30\ Mpa,\ f_y = 430\ Mpa$, $\omega = 3.5\%$. The primary and secondary settlements were occurred after 0.5 and 1 year respectively.



Solution:

Determination of saturated soil density

Assume $v_t = 1m3,\ \ n = \frac{v_v}{v_t}\ \ ,\ \ 0.35 = \frac{v_v}{1m^3},\ \ \ v_s = 0.65m^3$

$G_s = \frac{w_s}{v_s\gamma_w}\ \ ,\ \ 2.6 = \frac{w_s}{0.65*10KN/m3}\ \ \ ,\ \ \ W_s = 16.9KN/m3,$

assume $\omega = 3.5\% = 0.035$

$\gamma_{sat} = \frac{w_s+w_w}{v_t} = \frac{w_s+v_v*\gamma_w}{v_t} = \frac{16.9+0.35*10}{1} = 20.4\ KN/m3$

$\acute{\gamma} = \gamma_{sat} - \gamma_w = 20.4 - 10 = 10.4KN/m3$

$$\gamma_{wet} = \frac{w_s + w_w}{v_t} = \frac{w_s + w_s * \omega}{v_t} = \frac{w_s(1+\omega)}{v_t} = \frac{16.9(1+0.035)}{1m3} = 17.5KN/m^3$$

Assume square footing of dimensions (B*L)

Terzaghi's Equation for square footing

$q_U = 1.3CN_C + qN_q + 0.4\ddot{Y}BN_q$

For $\emptyset = 20^\circ,\ \ \ \ N_C = 17.69\ ,\ \ N_q = 7.44\ \ \ ,\ \ N_\gamma = 3.64$

Since the water table is within the lower edge of the footing, therefore

$q = 2m * 17.5KN/m3 = 35$ KN/m2

To determine Ϋ , d = 0

$\ddot{Y} = \acute{\gamma} + \frac{d}{B}(\gamma - \acute{\gamma}) = \acute{\gamma} = 10.4KN/m3$

$q_U = 1.3 * 20 * 17.69 + 35 * 7.44 + 0.4 * 10.4 * B * 3.64 = 720 + 15.1B$

$\frac{1.2*1000+1.6*350}{B^2} = 720 + 15.1B$

$1760 = 720B^2 + 15.1B^3$

$1760 = 720B^2 + 15.1B^3$ B=1.53m take B=1.55m

Settlement Check

1- Sc

After width of footing has been obtained, now we have to check the total settlement as follows:-

The overburden pressure to the center of the layer is

$\sigma = \gamma_{wet} h_1 + \acute{\gamma} h_2 = 17.5 * 2m + 10.4 * 2 = 55.8KN/m2$

$$\Delta\sigma = \frac{Q}{(B+Z)(L+Z)} = \frac{1760}{(1.55+2)(1.55+2)} = 139KN/m2$$

$$\boldsymbol{S_C = \frac{C_C H}{1+e_O} log(\frac{\sigma + \Delta\sigma}{\sigma})}$$

$$\boldsymbol{e_O = \frac{0.35}{0.65} = 0.538}$$

$\boldsymbol{S_C = \frac{0.3*4}{1+0.538} log\left(\frac{55.8+139}{55.8}\right) = 0.423m = 423mm}$ **too much**

Now increase B step by step until the obtained the settlement value meets the allowable limits

Take $take\ B = 13m$

$$\Delta\sigma = \frac{Q}{(B+Z)(L+Z)} = \frac{1760}{(13+2)(13+2)} = 7.8KN/m2$$

$$\boldsymbol{S_C = \frac{C_C H}{1+e_O} log(\frac{\sigma + \Delta\sigma}{\sigma})}$$

$$\boldsymbol{e_O = \frac{0.35}{0.65} = 0.538}$$

$\boldsymbol{S_C = \frac{0.3*4}{1+0.538} log\left(\frac{55.8+7.8}{55.8}\right) = 44.4mm}$ **this is in the range 25-50mm** $\boldsymbol{ok}$

2- Ss

$C_\alpha = 0.002$

$C_C = \frac{e_O - e_p}{log\frac{\sigma + \Delta\sigma}{\sigma}}$

$0.01 = \frac{0.538 - e_p}{log\frac{71.4+67}{71.4}}$, $e_p = 0.534$

$C_\alpha{}' = \frac{C_\alpha}{1+e_p} = \frac{0.002}{1+0.534} = 0.0013$

$\boldsymbol{S_S = C_\alpha' H * log\frac{t_2}{t_1} = 0.0013 * 4 * log\frac{1}{0.5} = 1.5mm}$

$\boldsymbol{S_T = 44.4 + 1.5 = 45.9mm\ 0.k}$

Reinforced concrete design

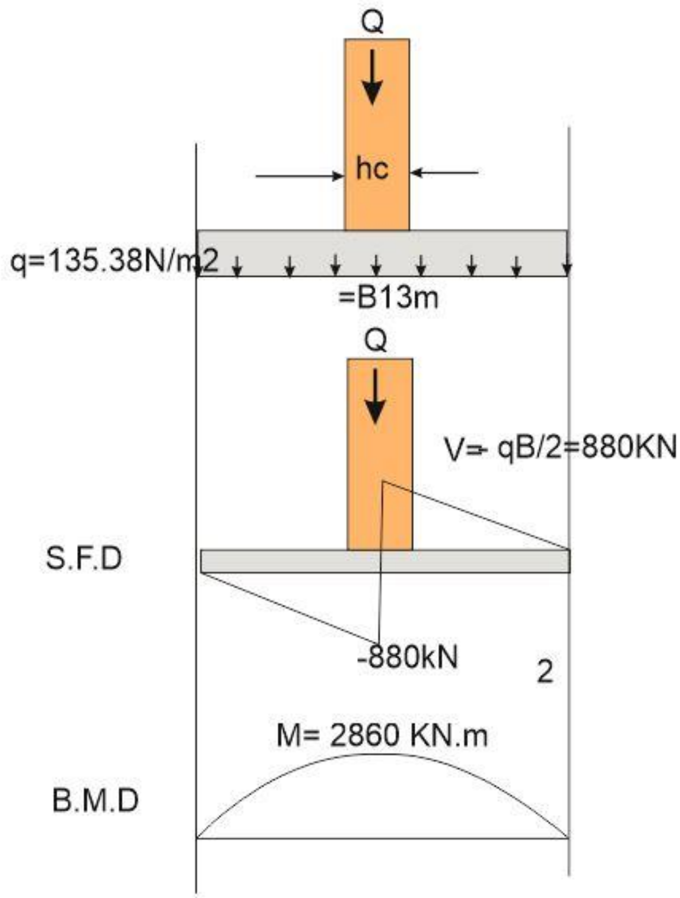
$U = b_\circ d\emptyset(0.34)\sqrt{f'c}$

$b_o = 4 * 0.4 + 4d = 1.6 + 4d$

$1760 = (1.6 + 4d)d * 0.85 * 0.34 * 1000\sqrt{30}$

$1.11 = (1.6 + 4d)d$, d = 0.36 m, H = 0.36 + 0.075 = 0.435m = 45 cm

$Net\ d = 45 - 7.5 = 37.5\ cm$



Punching Check

$V_{Max\ punching} = 0.33\sqrt{fc} = 0.33\sqrt{30} = 1.8\ Mpa$

$Vpunching = \frac{u}{b_O d} = \frac{1760/1000}{4(0.4+0.375)0.375} = 1.514\ Mpa$ < 1.8 Mpa ok

Chear Check

$V_{C\ Max} = 0.17\sqrt{fc} = 0.17\sqrt{30} = 0.93\ Mpa$

$V = \frac{V}{Ld} = \frac{880/1000}{13*0.375} = 0.18\ Mpa$ < 0.93 Mpa ok

$M_U = \emptyset \rho b d^2 f_y (1 - \frac{\rho f_y}{1.7 f_C})$ …………..(3)

2860*1.7=0.85$\rho * 13 * (0.375)^2 * 430 * 1000 \left(1 - \frac{\rho * 430}{1.7 * 30}\right)$

$0.0073 = \rho(1 - 8.4\rho)$

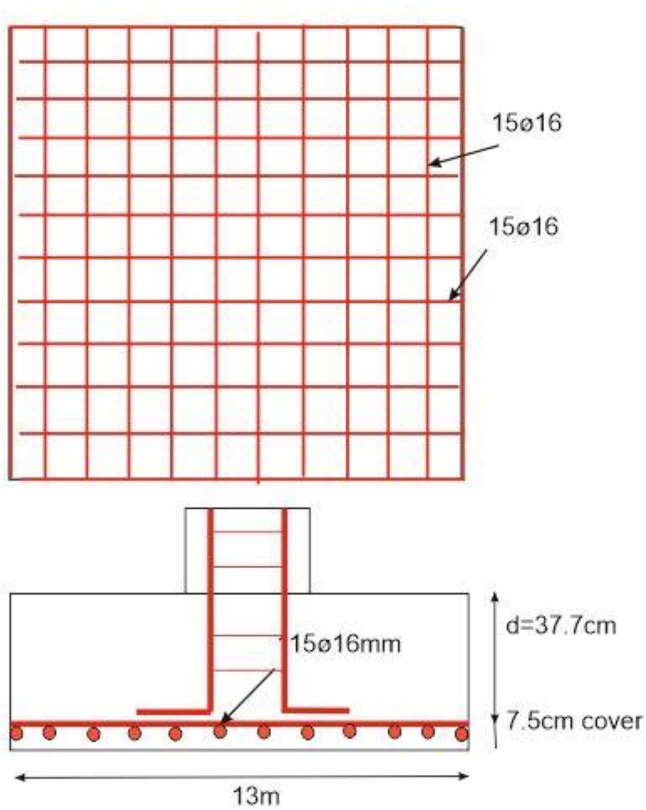
$\rho = 0.008$

$$A_S = \rho bd = 0.008 * 13 * 0.375 = 0.039m2 = 39000mm^2$$

$\boldsymbol{Min\ reinforcement = 0.0018Bd}$

$Min\ reinforcement = 0.0018 * 13 * 0.375 = 0.008775m2 < 0.039m2\ ok$

$194\emptyset\frac{16mm}{13m}\ or\ 15\emptyset\frac{16mm}{1m}\ length$



Reinforcement arrangement