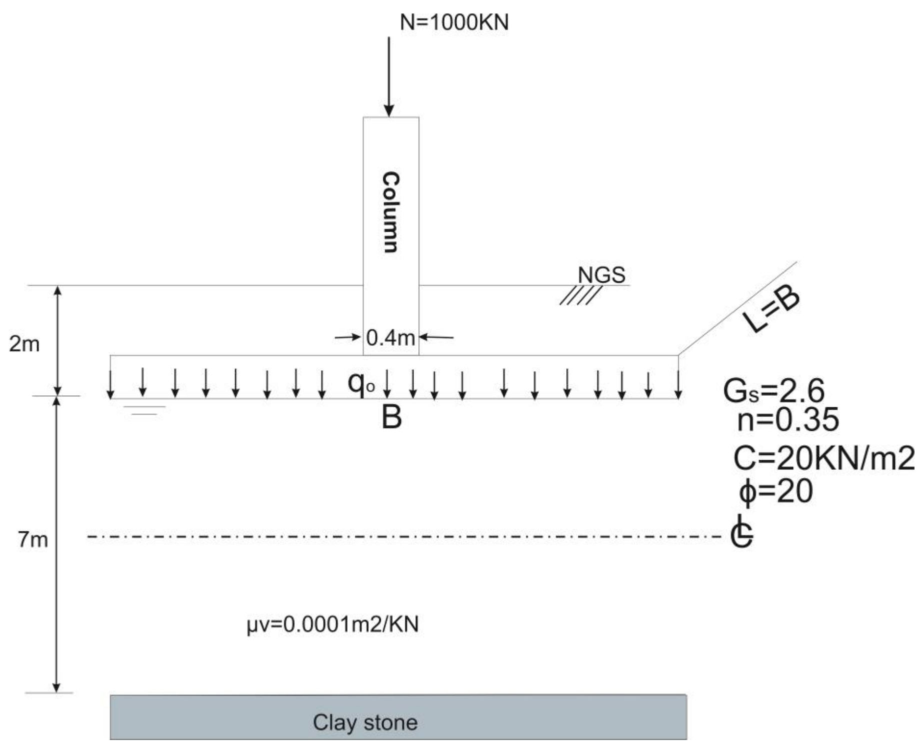
Example1: Design of single footing with axial load

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. The allowable bearing pressure 200KN/m2.
$f_{cu} = 35\ Mpa,\ \ f_y = 460\ Mpa$



Solution:

Determination of 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 and d=0

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

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

$q_{all} = \frac{720+15.1B}{3} = 240 + 5B$

Assume footing thickness = 0.6m

Weight of footing $0.6 * \frac{24KN}{m3} * BL = 14.4B^2$

Ultimate Column pressure + footing weight, $q_o = \frac{1000KN}{B^2}$, now equate the two pressures

$\frac{1350KN+14.4B^2}{B^2} = 240 + 5B$

$1350 = 225.6B^2 + 5B^3$

$1350 = 240B^2 + 5B^3$ from it B=L ≅ 2.4m,

For more checking $q_o = \frac{1350+2.4^2*0.6*24}{2.4^2} = 248.775KN/m2 \approx \mathbf{250}KN/m2$,

$q_{all} = 240 + 5B = 240 + 5 * 2.32 = \mathbf{251.6}\ KN/m2$ OK

After the allowable bearing capacity has been checked, now we have to check the total settlement as follows.

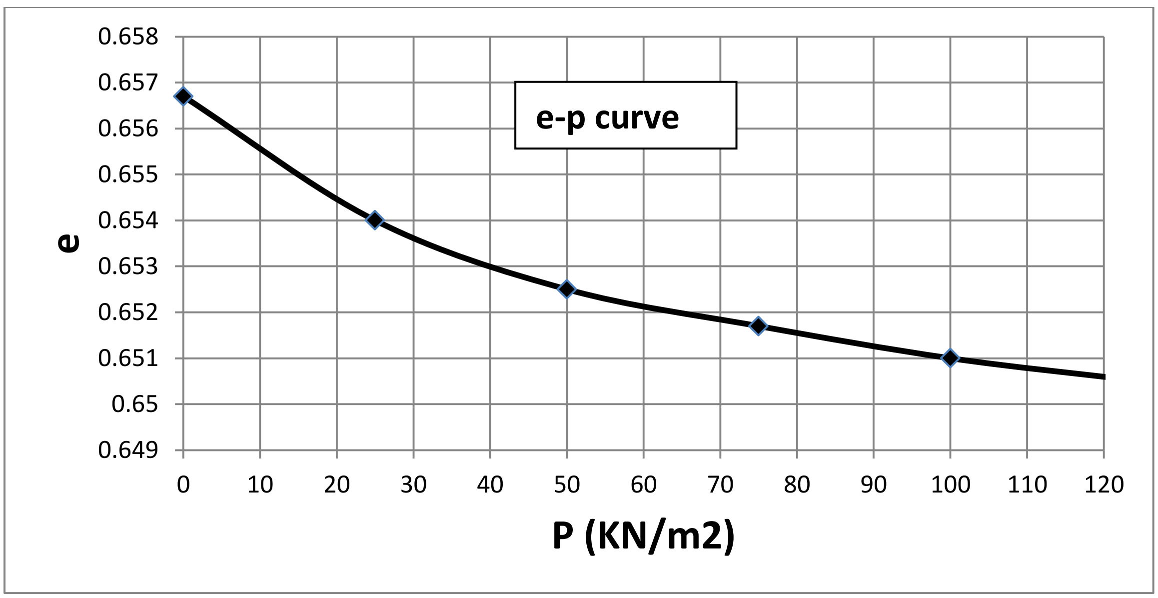
Soil pressure estimations

The overburden pressure to the center of the layer is

$$P_o = \gamma_{wet} h_1 + \acute{\gamma} h_1 = 17.5 * 2m + 10.4 * 3.5 = 71.4KN/m2$$

$$P_1 = P_o + \frac{q_o BL}{(B+Z)(L+Z)} = 71.4 + \frac{250.8 * 2.32 * 2.32}{(2.32+3.5)(2.32+3.5)} = \frac{71.4KN}{m2} + \frac{39.8KN}{m2}$$
$$= 111.25KN/m2$$

$$\delta p = p_1 - p_o = 111.25 - 71.4 = 39.8 \approx 40KN/m2$$



The total settlement (S):

Using the e-p curve to find the corresponding Void ratios as follows:-

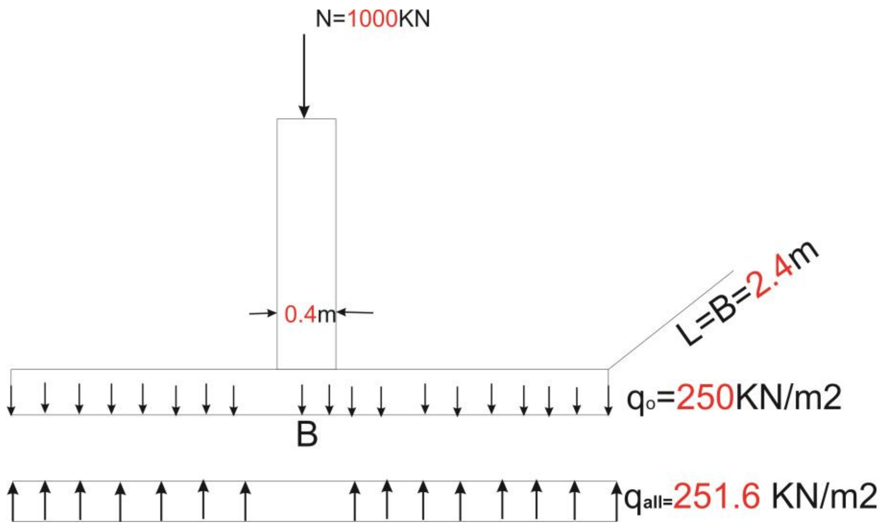
For $P_o = 71.4Kn/m2$, $e_o = 0.6518$

For $P_1 = 111.25KN/m2$, $e_1 = 0.6507$

$$S = -\frac{\delta e}{1+e_o} * H = -\frac{\delta e}{1+e_o} * H$$

$$S = -\frac{0.6507-0.6518}{1+0.6518} * 7m = 0.00466\ m = 4.66\ mm \cong \mathbf{5\ mm} < 25\ mm$$ **OK**

Results summary

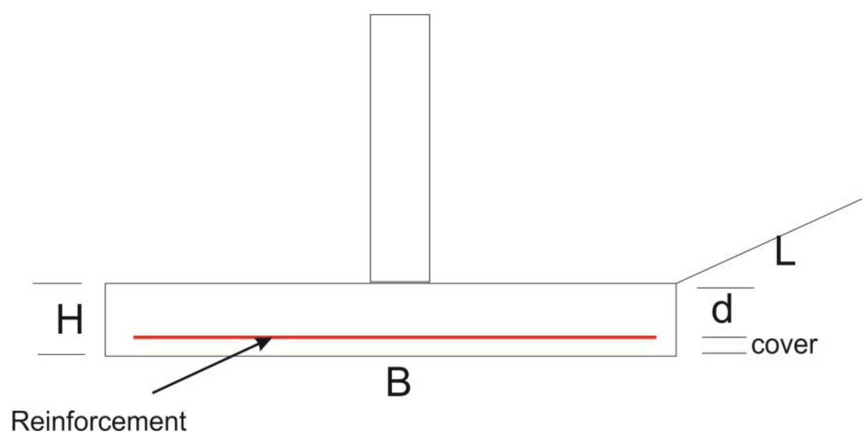


Square footing with total settlement <25mm

Reinforced concrete design

Summary of the available values
Dead load = 1000 KN
Live load = 350 KN
B = L = 2.3 m
$f_{cu} = 35\ Mpa \quad , \quad f_y = 460\ Mpa$

Determination H & d



Use the ultimate Loads

$$N_U = 1.4\ L.L + 1.6\ D.L = 1.6 * 1000 + 1.4 * 350 = 1960KN$$

$$V_U = < of\ (0.8\sqrt{f_{cu}} and\ 5\ N/mm2)$$

$0.8\sqrt{f_{cu}} = 0.8\sqrt{35} = 4.7\ N/mm2$

Perimeter of the column = 4 *400mm=1600mm

Shear stress at the face of the column = $\frac{N_u}{perimeter*d}$

Take $\frac{V_U}{2} = \frac{N_u}{perimeter*d}$

$\frac{4.7}{2} = \frac{1960KN*1000}{1600d}$, d = 521 mm

Assume to use blinding cover of concrete = 50 mm

Assume to use bar of $\emptyset 20mm$

$H = 521mm + 50mm + 20mm = 591mm \cong 600mm$

Net d = 600mm – 50 mm - 20mm = 530 mm

Reinforcement design

Max moment at the face of the column

$$M_{max} = q_o L\left(\frac{B-hc}{2}\right) * \left(\frac{B-hc}{2}\right)/2$$

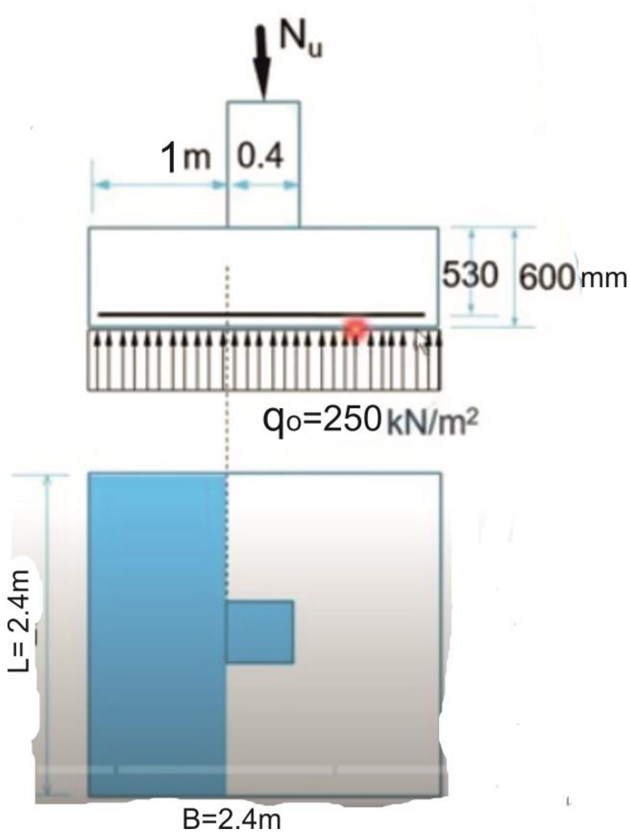
$$= 250 * 2.4\left(\frac{2.4-0.4}{2}\right)^2/2$$

$$= 300\ KN.m$$

$$K = \frac{M}{f_{cu}Ld^2} = \frac{300*10^6 N.mm}{35*240*530^2} = 0.127 < 0.156\ compression\ steel$$

$$\frac{Z}{d} = 0.5 + \sqrt{0.25 - \frac{0.127}{0.9}} = 0.83 \le 0.95$$

OK



Z = 0.83* d = 0.83 * 530 = 439.9 mm

$$A_s = \frac{M}{0.95 f_y Z} = \frac{300 * 10^6}{0.95 * 460 * 439.9} = 1{,}560 mm2$$

No. of bars = $\frac{1560mm2}{\frac{\pi 20^2}{4}} = 4.96 \cong 5$, $\color{red}{use\ 5∅20}$

Minimum reinforcement

$A_{s\,min} = \frac{0.13Lh}{100} = \frac{0.13*2400*600}{100} = 1{,}872mm$,

No. of bars = $\frac{1872mm2}{\frac{\pi 20^2}{4}} = 5.96 \cong 6$, $\color{red}{use\ 6∅20}$

Minimum spacing = $\frac{2400mm}{6} = 800mm \quad > 750mm \qquad use\ 750mm\ spacing$

Check shear at 1d from column face

$$V = q_O LC = 250 * 2.4 * 0.47 = 282\ KN$$

Shear stress $v = \frac{V}{Ld} = \frac{282KN*1000}{2400*530} = 0.221 KN/m2$

Now we have to check for shear

From table 3.8 (BS8110)

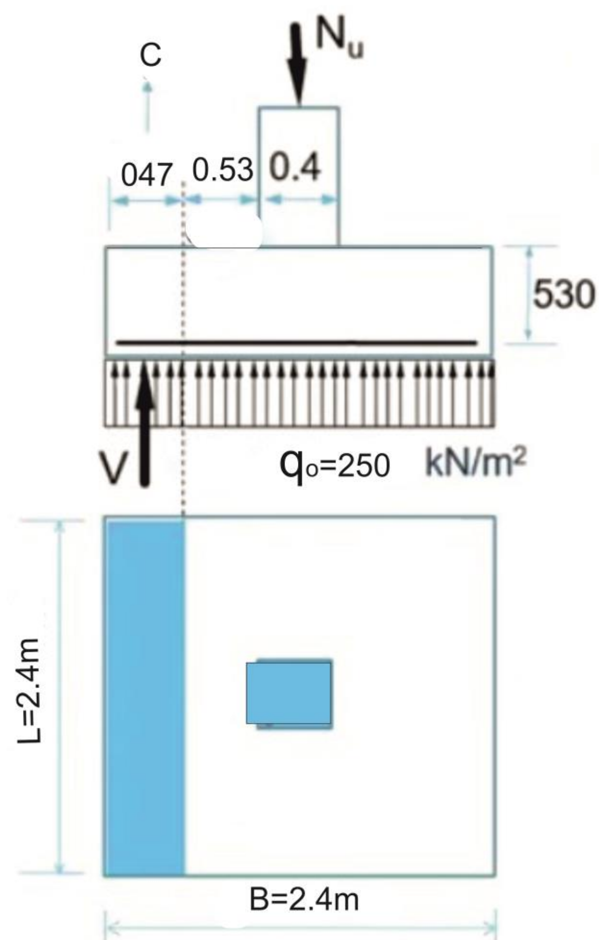
$\frac{100A_S}{Ld} = \frac{100*1872}{2400*530} = 0.147$

$\frac{400}{d} = \frac{400}{530} < 1\ take\ it\ 1$

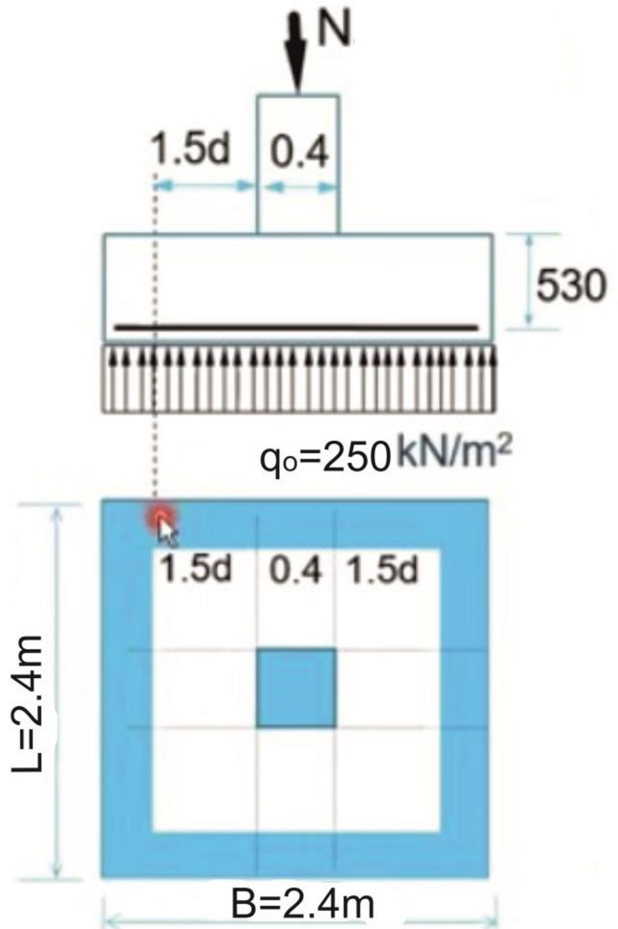
Thus:

$$V_C = [0.79 * (0.147)^{\frac{1}{3}} * 1 * (\frac{35}{25})^{\frac{1}{3}}]/1.25 = 0.373$$

OK.



Check punching shear at 1.5d from column face



Critical perimeter for punching shear

(U)= $Column\ perimeter + 8 * 1.5d$

$$U = 4 * 400 + 8 * 1.5 * 530 = 7960mm$$

Hatched $A_P = BL - (0.4 + 3d)^2$

$$= 2.4^2 - (0.4 + 3 * 0.53)^2 = 1.8m2$$

Punching shear force $V_P = q_O A_p = \frac{250KN}{m2} * 1.8m2 = 450\ KN$

Punching shear stress $v_P = \frac{V_P}{4(3d+0.4)d} = \frac{450KN*1000}{4(3*530+400)530}$ =0.1066 N/mm2

Since $v_P < V_C$

0.1066 N/mm^2< 0.373 OK

Anchorage length = 40*20mm = 800 mm

Therefore no need for bends.