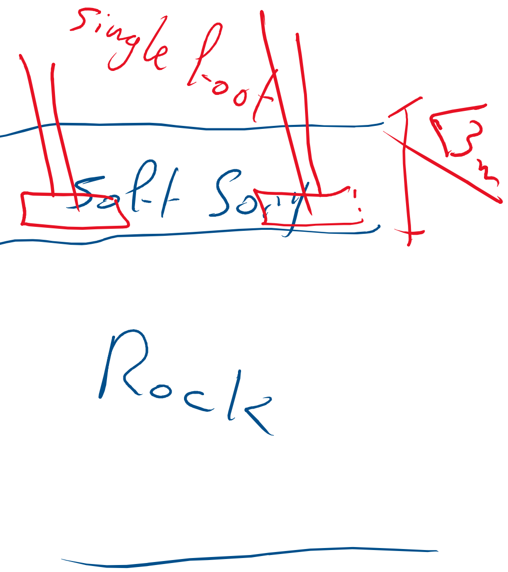
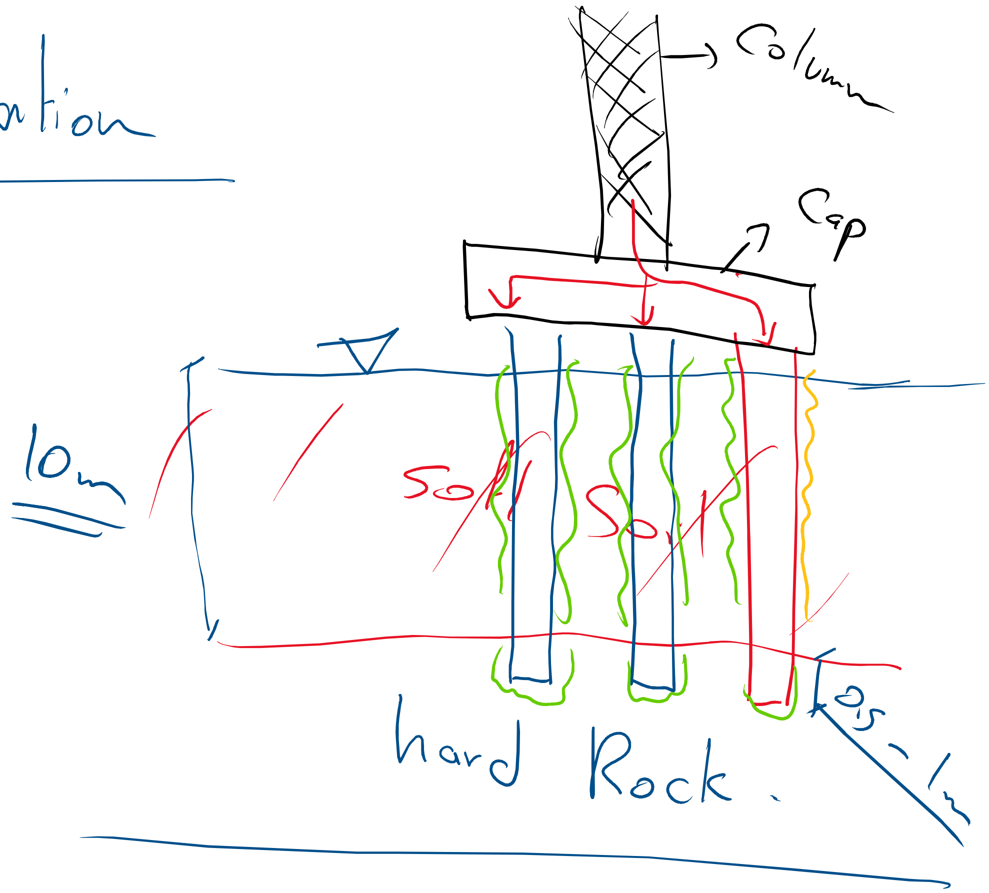
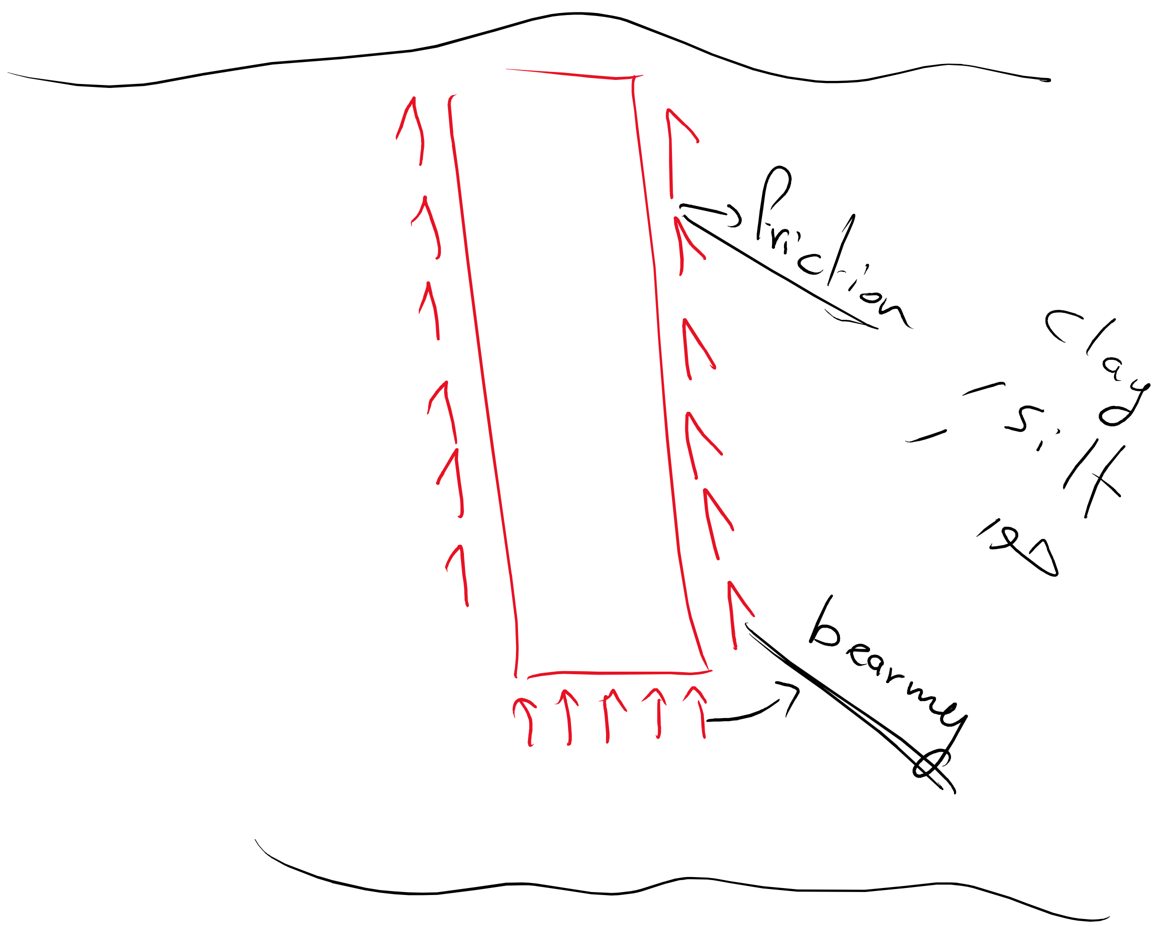
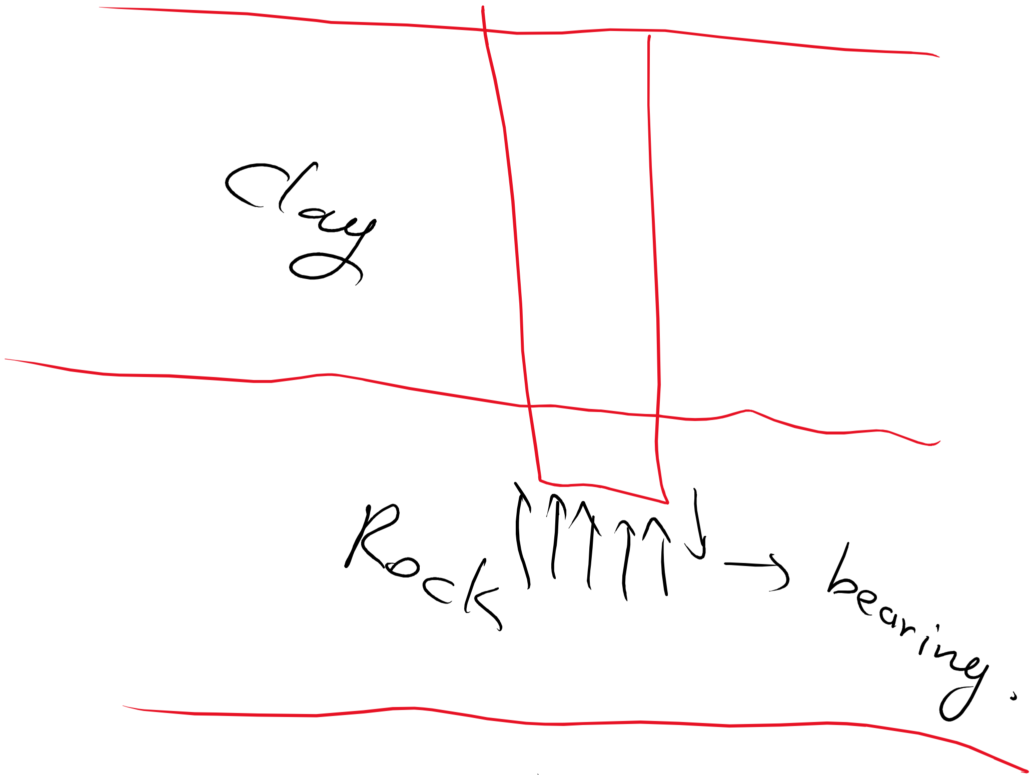
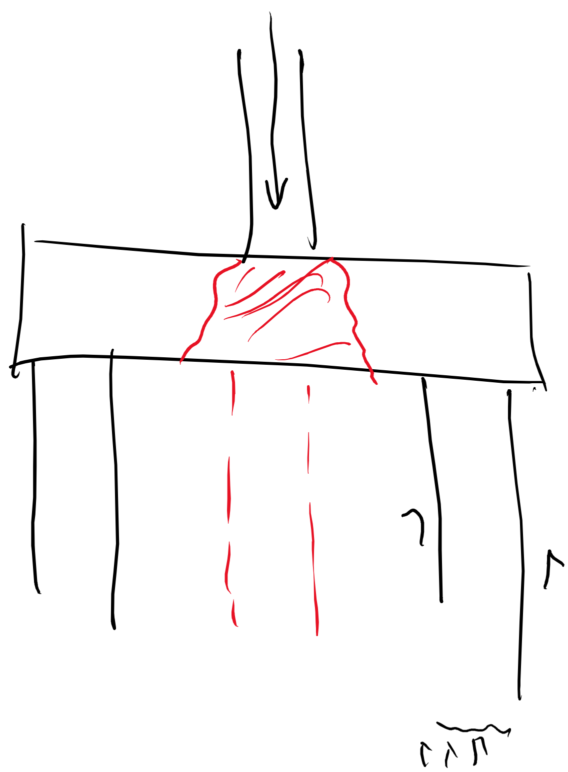
Pile foundation








Clay
Rock
bearing.



Design Steps

① number of Pile required.

example of soil report

Length	Pile Dia	Capacity.
5 m	50	1000 kN.
	60	1100
	70	1200
	80	1300
	100	1400

② Cap thickness, Dimension

③ Cap reinforcement

④ Pile design

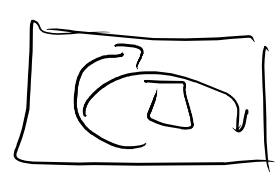
number of required piles

① case 1 : no moment

$$\#\text{Piles} = \frac{\text{total service load}}{\text{Pile Capacity}}$$

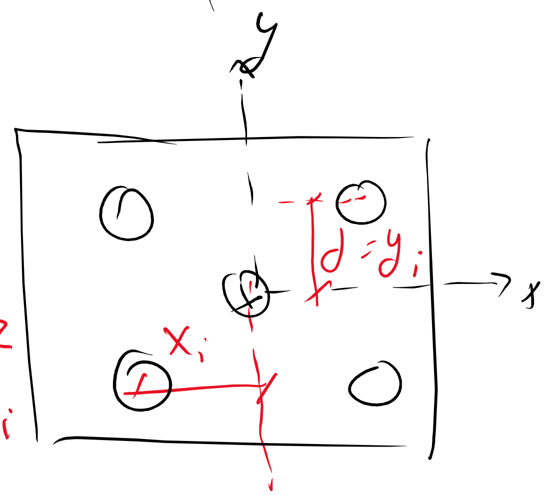
② with moment

$$\sigma_{max} = \frac{P}{A} + \frac{M_x \overset{y_{max}}{C_x}}{I_x} + \frac{M_y \overset{x_{max}}{C_y}}{I_y}$$



$$I_x = \sum I_{x_i}$$

$$= \sum\left(\underbrace{I_{x_0}}_{\text{small}} + A_i d_i^2\right) = \sum A_i y_i^2$$



$$I_y = \sum A_i x_i^2$$

$$\sigma_{max} = \frac{P}{\sum A_i} + \frac{M_x\, y_{max}}{\sum A_i y_i^2} + \frac{M_y \times X_{max}}{\sum A_i x_i^2}$$

→ if A_i constant (in most cases)

$$A_i = A_p$$

$$\sigma_{max} = \frac{P}{N \times A_p} + \frac{M_x\, y_{max}}{A_p \sum y_i^2} + \frac{M_y \times X_{max}}{A_p \sum x_i^2}$$

→ stress

→ Load

Rmax (reaction on Pile)

$$R_{max} = \sigma_{max} \times A_p = \left(\frac{P_s}{N} + \frac{M_x\, y_{max}}{\sum y_i^2} + \frac{M_y \times X_{max}}{\sum X_i^2} \right)$$

↓

for single pile.

$R_{max} < Q_{all}$

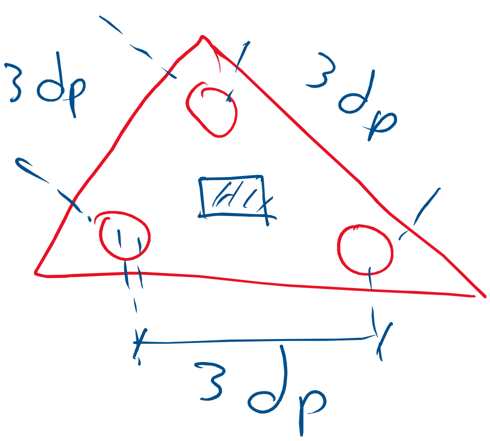
Notes

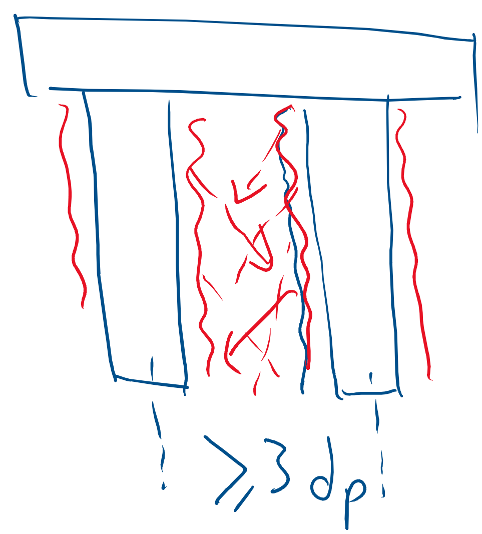
① Piles Center to Center placement $\geq 3\,d_p$

② $R_{max} = \dfrac{P}{N}$ if no moment on Column.

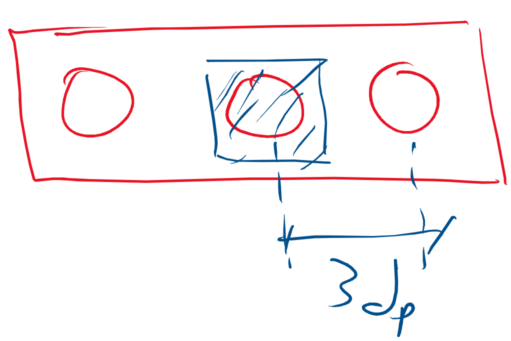
عدد البايلز

③ 3 piles

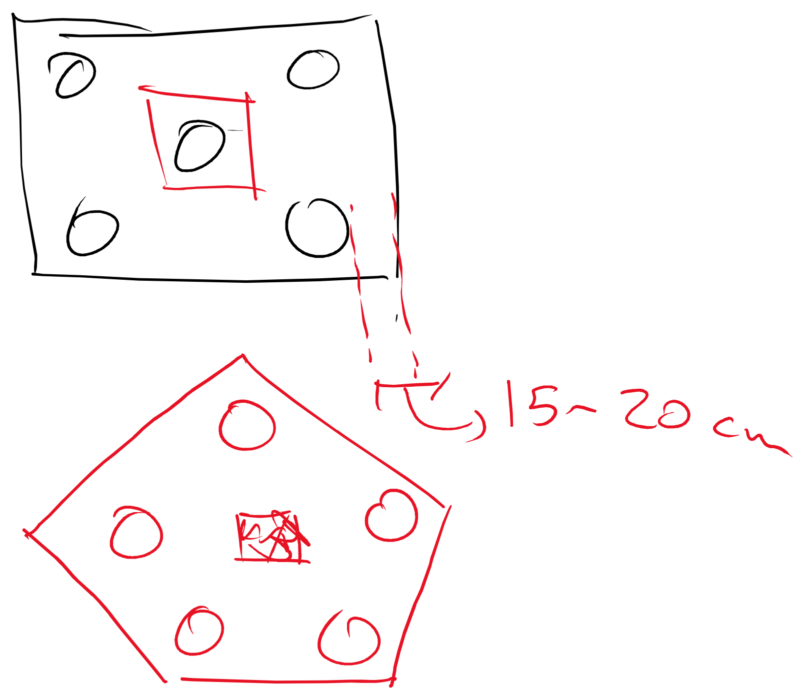




3 piles



5 pile



④ incase of tension Load on Pile (from load or moment)

$$R_{min} = \frac{P}{N} - \frac{M_x\, y_{max}}{\sum y_i^2} - \frac{M_y\, x_{max}}{\sum x_i^2} \geq Q_{all}$$ in tension

→ Pile Capacity in Compression Q_{all_C}

→ Pile Capacity in tension Q_{all_T}

Thickness (Cap)

→ Punching Shear

→ Punching of Column on Cap

→ Punching of Pile on Cap

→ Column subjected to moment

Punching load

in Pile → $V_u = P_{max} \times N$

→ no moment on Column but

eccentricity exist → normal Calculation.

→ Pile diameters → 50 cm, 60, 80, 100 cm

Eample Draw the pile Cap Showing all dimensions for pile footing supporting

$P_D = 5000$ kN $M_D = 600$ kN.m in X
$P_L = 2500$ kN $M_L = 300$ kN.m in X

$Q_{all} = 1500$ kN / Pile Diamter = 0.8m

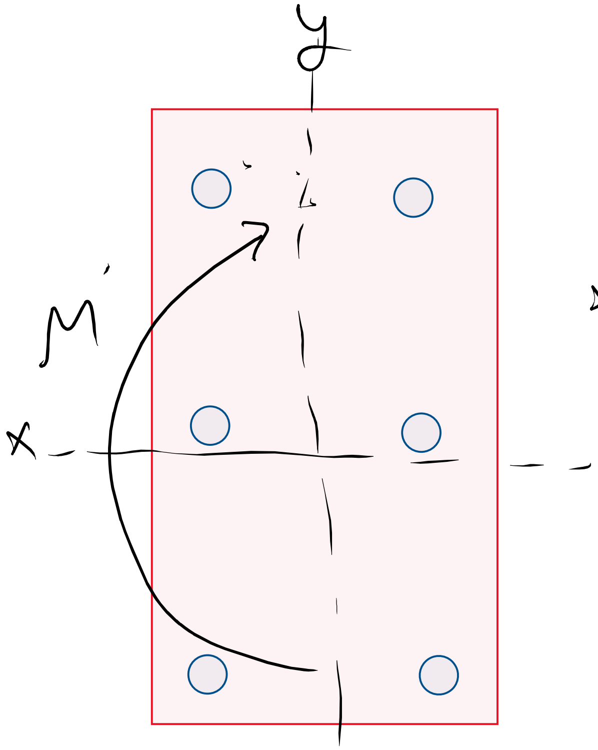
→ $P_{service} = 7500$ kN

$M_s = 9000$

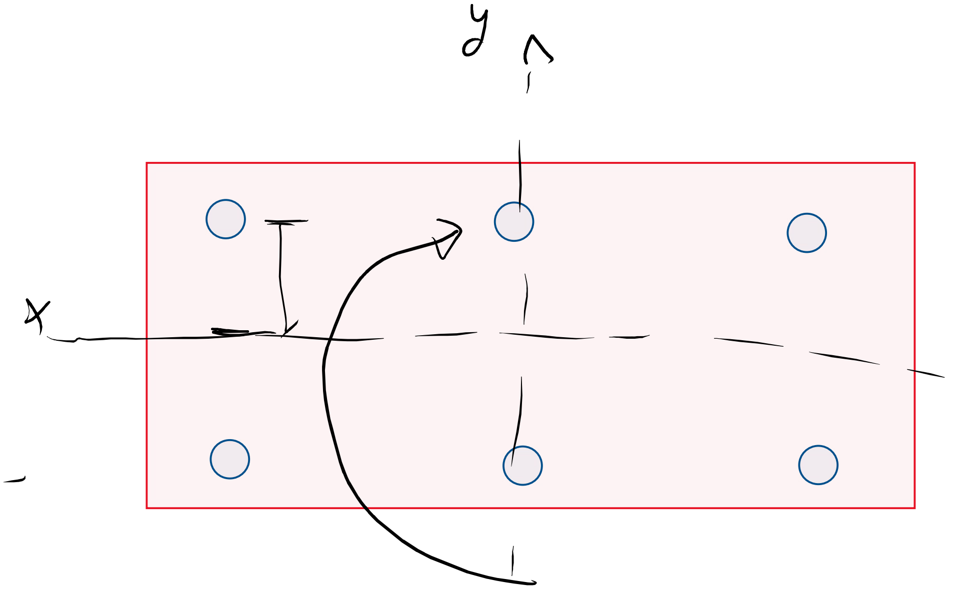
→ # of Pile

if no moment → $N = \frac{7500}{1500} = 5$

Because of moment try 6 Pile.



Case 1

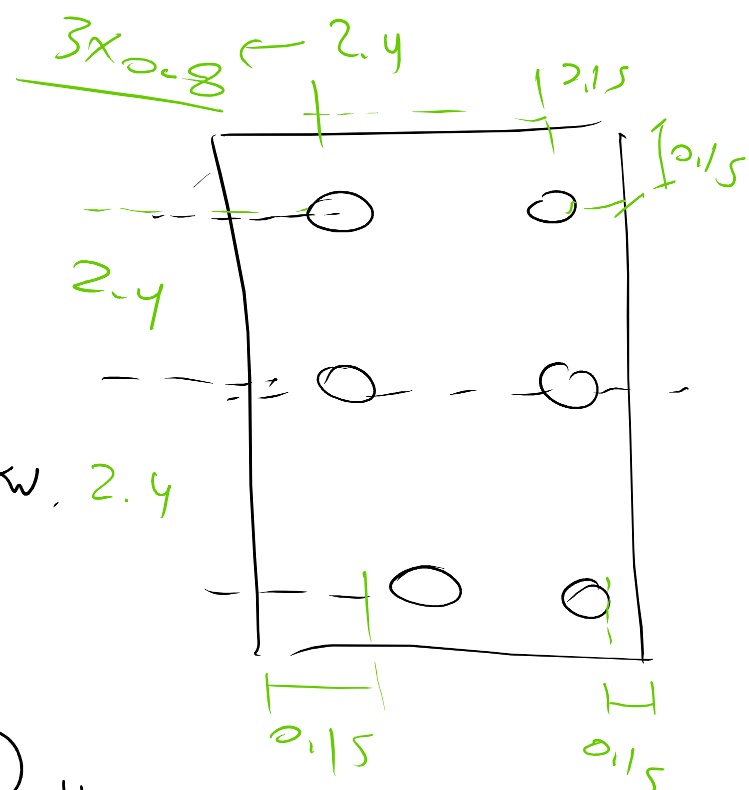


Case 2

arrangement 1 is the stronger.

$$R_{max} = \frac{7500}{6} + \frac{\overset{M_x}{900 \times 2.4}}{4 \times 2.4^2 + 2 \times 0^2}$$

$= 1344 \text{ kN} < Q_{all} = 1500 \text{ kN}.$



For Case 2 $R_{max} > Q_{all}$

Example 2

Design a pile footing for Column Carrying $P_D = 3000$ kN

$P_L = 1250$ kN, $f'_c = 40$ MPa, $Q_{all} = 1000$ kN

Column: 600x600, Pile Diameter = 0.6 m

ignore weight of footing.

Solu:

no moment

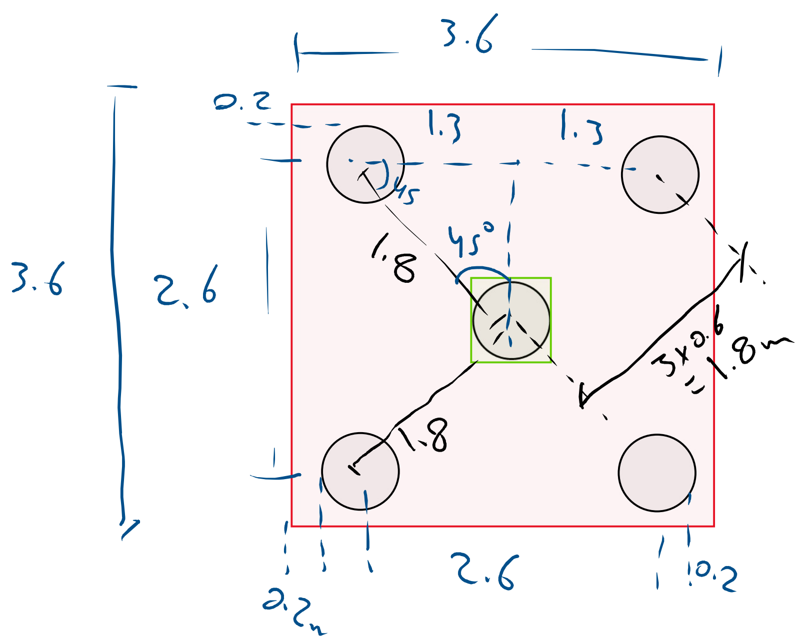
$$\rightarrow R_{max} = \frac{P_{service}}{N} = \frac{3000+1250}{N} \leq Q_{all} = 1000$$

$$N \simeq 5 \text{ piles.}$$

spacing

3dp

$$X \rightarrow 1.8 \times \sin 45 = 1.3\ m$$



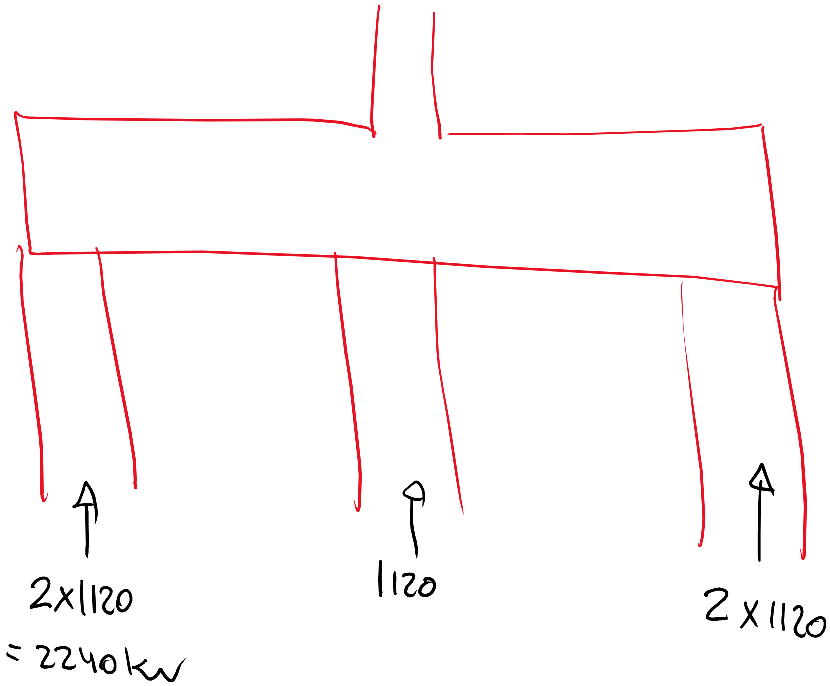
thickness

$$P_u = 1.2 \times 3000 + 1.6 \times 1250\ kN$$

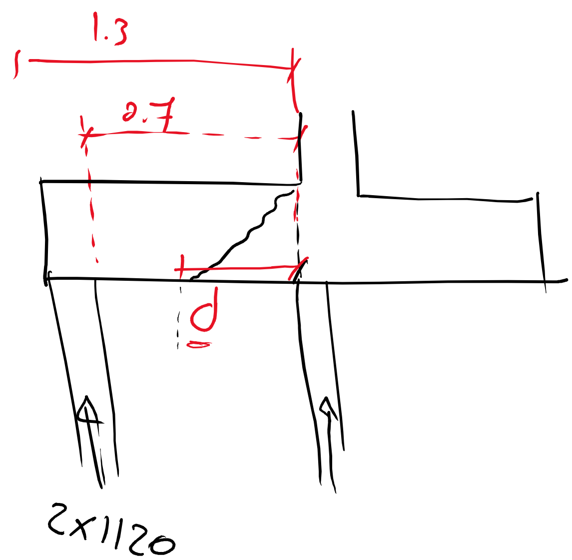
$$= 5600\ kN$$

$$R_{max_u} = \frac{P_u}{5} = \underline{1120}\ kN$$

ultimate



→ Wide Beam Shear (one way Shear)

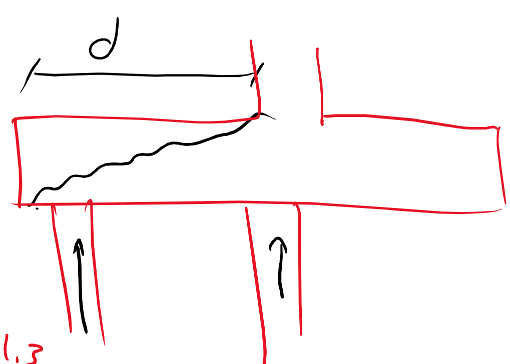


Case 1

$d \leq 0.7m$ (for this question)

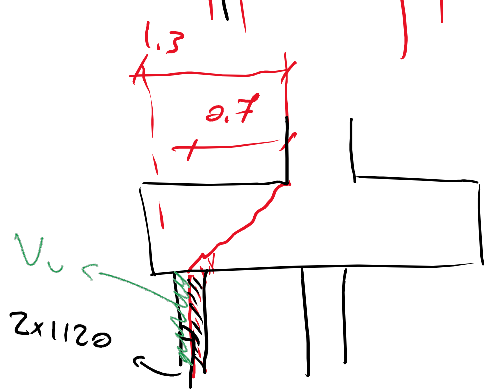
($d \leq$ distance from face of Column to face of edge pile.)

$V_u = 2240$



Case 2

$V_u = \text{zero}$



Case 3

$(0.7 < d < 1.3)$

$$V_u = 2240 - \left(\frac{\frac{d}{1000} - 0.7}{1.3 - 0.7}\right) 2240$$

its either Case 1 or Case 3

→ assume Case 1 (gives the largest shear)

$$V_u = 2240 = \phi V_c$$

$$\phi V_c = 0.75 \times \left(\frac{1}{6}\right) \sqrt{40} \times \frac{d \times \overset{b}{(3600)}}{1000} = V_u$$

$d = 787$ mm

$0.7 < d = 0.787 < 1.3$ → the true case is $\underline{\underline{\text{Case 3}}}$

$$\phi V_c = \underline{\underline{V_u}}$$

$$0.75 \times \frac{1}{6} \sqrt{40} \times \frac{d \times 3600}{1000} = 2240 - \left(\frac{\frac{d}{1000} - 0.7}{1.3 - 0.7}\right) \times 2240$$

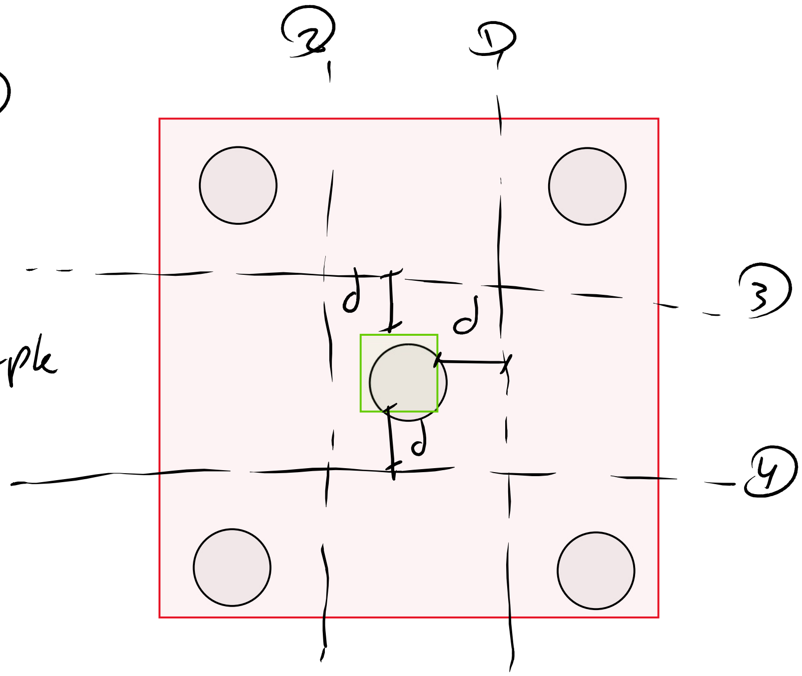
$d = 738$ mm → use $d = 790$ mm

→ $h = 950$ mm.

use cover in pile cap

150 – 250 mm

① = ② = ③ = ④

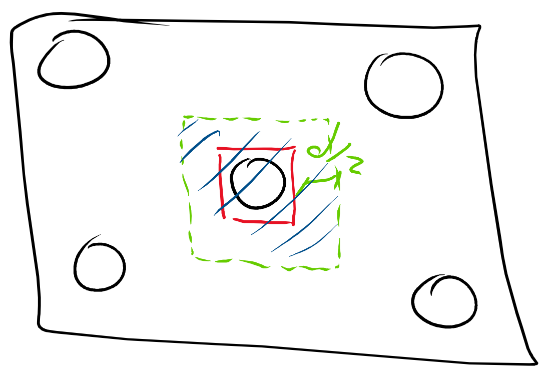


Case 1 or 2 or 3

Case 3 in example

Punching

① Punching of Column.



$h = 950$

$d = 790$

$$V_u = 5600 - \overset{R_p}{\underset{\text{reaction of pile under Colum}}{1120}} = 4480 \text{ kN}.$$

Square Column → $\left(\frac{1}{3}\right)$

$$\beta = \frac{L_c}{W_c} \leq 2 \rightarrow \frac{1}{3}$$

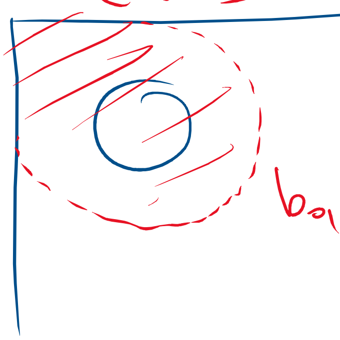
$$> 2 \rightarrow \frac{1}{2}(\text{ --- })$$

$$\phi V_c = 0.75 \times \frac{1}{3}\sqrt{40} \times \overset{b_o}{(4 \times 1390)}$$

$$= 6980 \text{ kN} > V_u \quad \underline{\underline{o/c}}$$

Punching of Pile on Cap

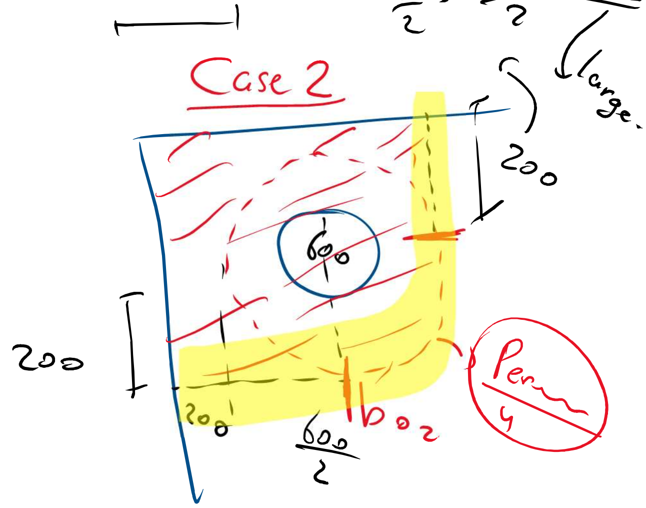
Case 1



$\phi 200$

$\frac{d}{2} = \frac{790}{2} = 395$

Case 2



The least b_o is the Critical Case

Case 2

$b_{o_2} = 500 + 500 + \frac{\pi}{4}(600 + \overset{d}{790}) = 2091$

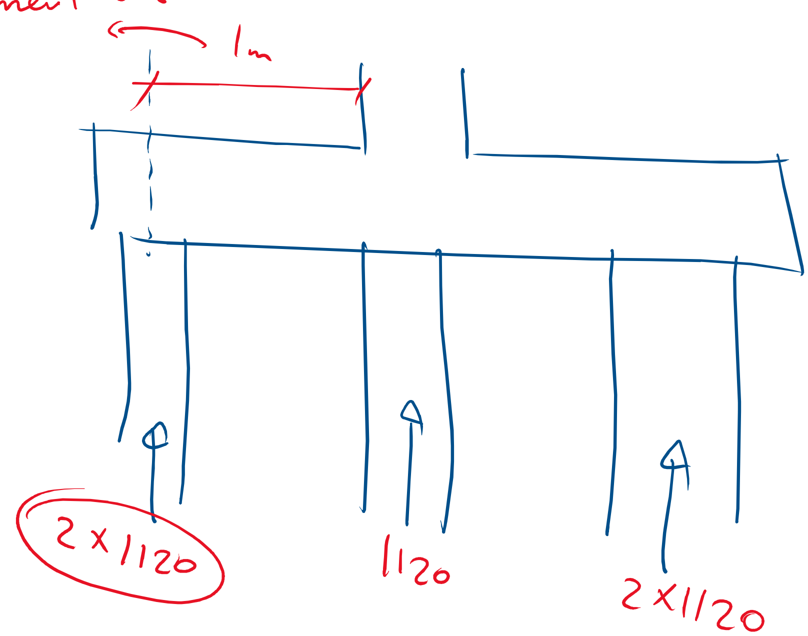
$\phi V_c = 0.75 \times \frac{1}{3}\sqrt{40} \times \frac{2091}{1000} \times 790 = 2630$ kN.

V_u = reaction = $1120 < \phi V_c$. ok

for single pile

Reinforcement

moment arm

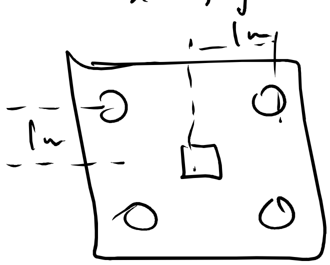


total moment

$M_u = (2 \times 1120) \times 1m$

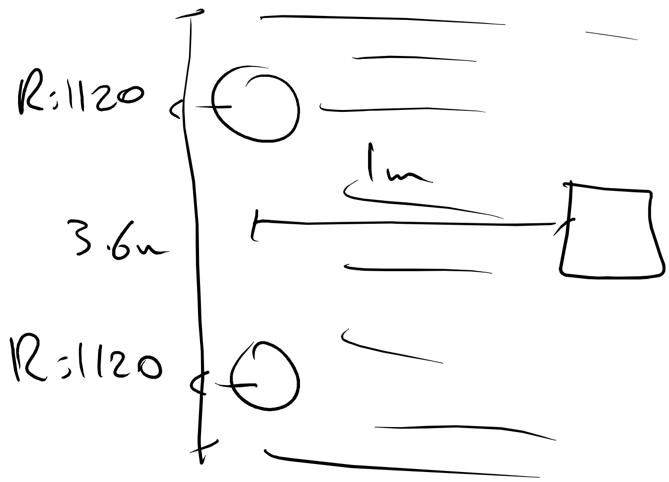
$= 2240$ kN.m

square cape $\rightarrow M_x = M_y$



$d = 790$, $b = 3600 \rightarrow \rho = 2.68\times10^{-3}$

↳ not for 1m width

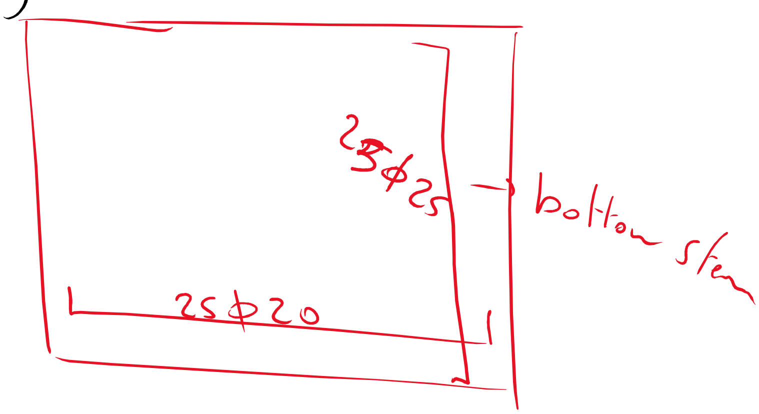


$A_s = 2.68\times10^{-3}\times3600\times790 = \underline{7615}\ mm^2$

$A_{s_{min}} = 0.0018\times \overset{h}{950}\times3600 = 6156\ mm^2 < A_s$ ok

shrinkage

$\#$ of 20mm bars $= \dfrac{7615}{\left(20^2\times\frac{\pi}{4}\right)} \approx 25\,\phi20$ mm

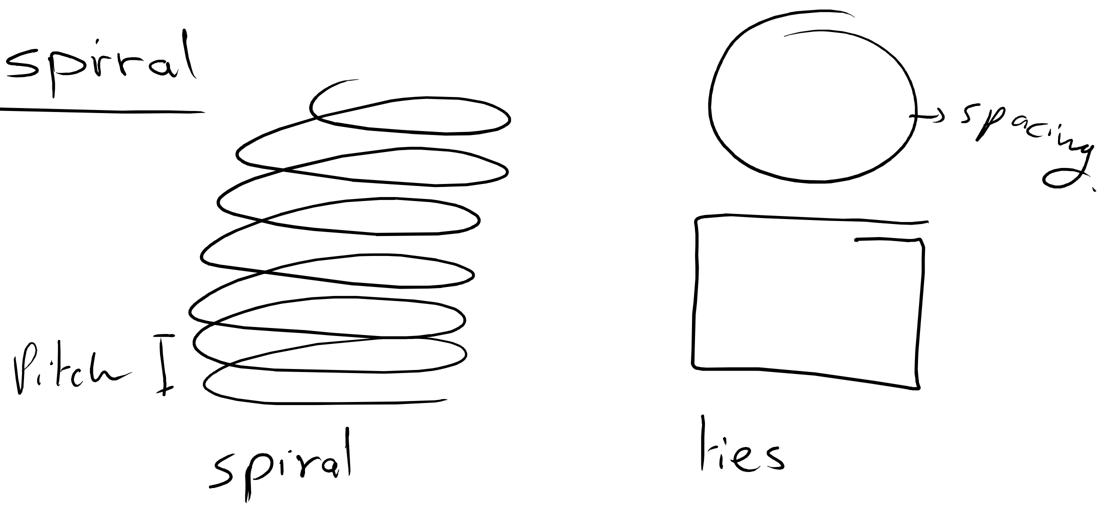


Pile design

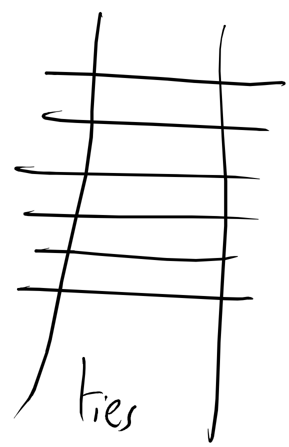
- assume piles as short column.
- ρ_{min} in piles $= 0.005 = 0.5\%$

$$A_s = 0.005 \times \left(\frac{\pi \times 600^2}{4} \right) = 1414 \rightarrow 8\phi16$$

→ ties or spiral



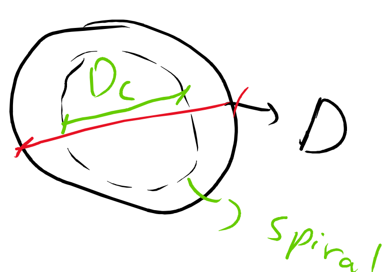
ACI for spiral Reinforcement



$$\rho_s = 0.45 \left(\frac{\pi D^2}{\pi D_c^2} - 1 \right) \times \frac{f'_c}{f_y}$$

D : outer Diameter of Pile

D_c: inner Diameter of Pile.



$D = 600$, $D_c = 600 \times 2 \times 45 = 510$ mm

↳ cover to center of Stirrups.

$$\rho_s = 0.45 \left(\frac{600^2}{510^2} - 1 \right) \times \frac{40}{420} = 0.014$$

$$\rho_s = \frac{\text{Volume of spiral Reinforcement in one revolution}}{\text{Vol of Concrete core in that revolution.}}$$

assume $\phi 12$ spiral Reinforcement

$$\overset{0.014}{\rho_s} = \frac{113\,mm^2 \times \pi \times 510}{\frac{\pi \times 510^2}{4} \times S} \quad \rightarrow S = 62.4\,mm$$

طول اللفة

Pitch.

$$\approx 60\,mm$$