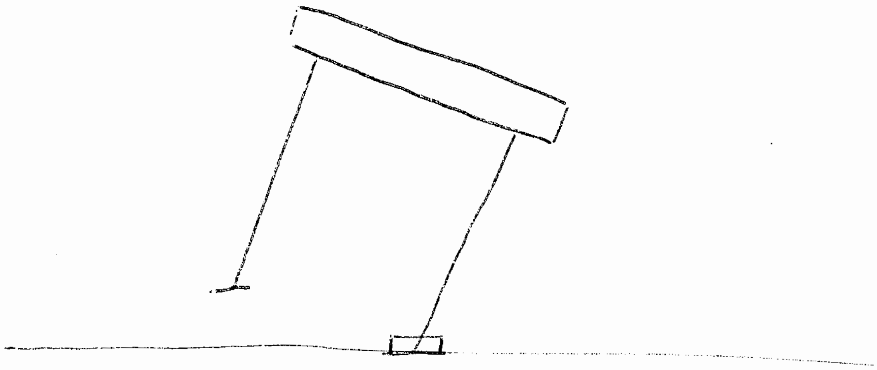
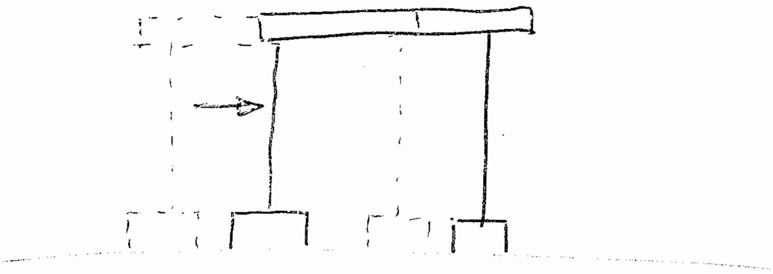
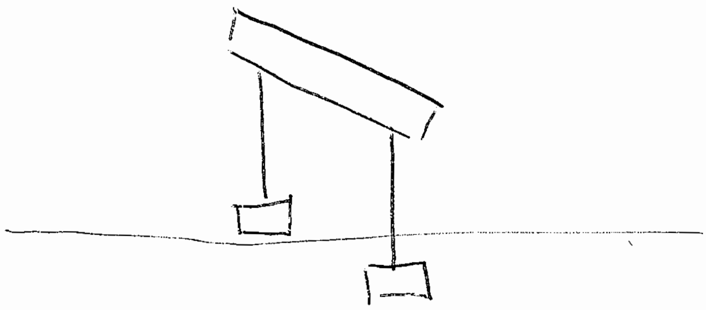
1\. a) Lift-off



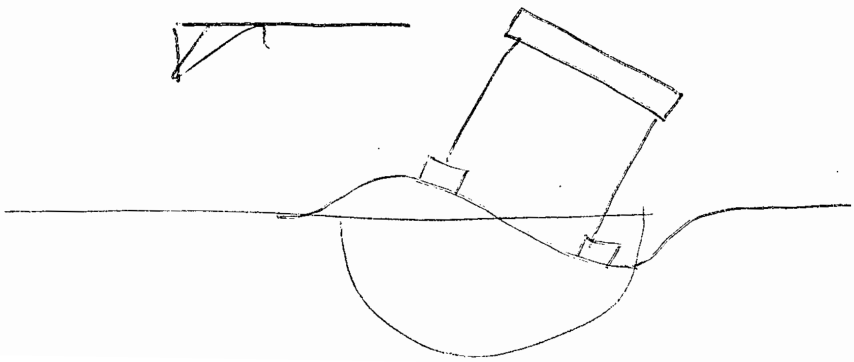
b) Sliding



c) Bearing failure of one leg



d) Rotational failure of foundation



failure mode will be influenced by:

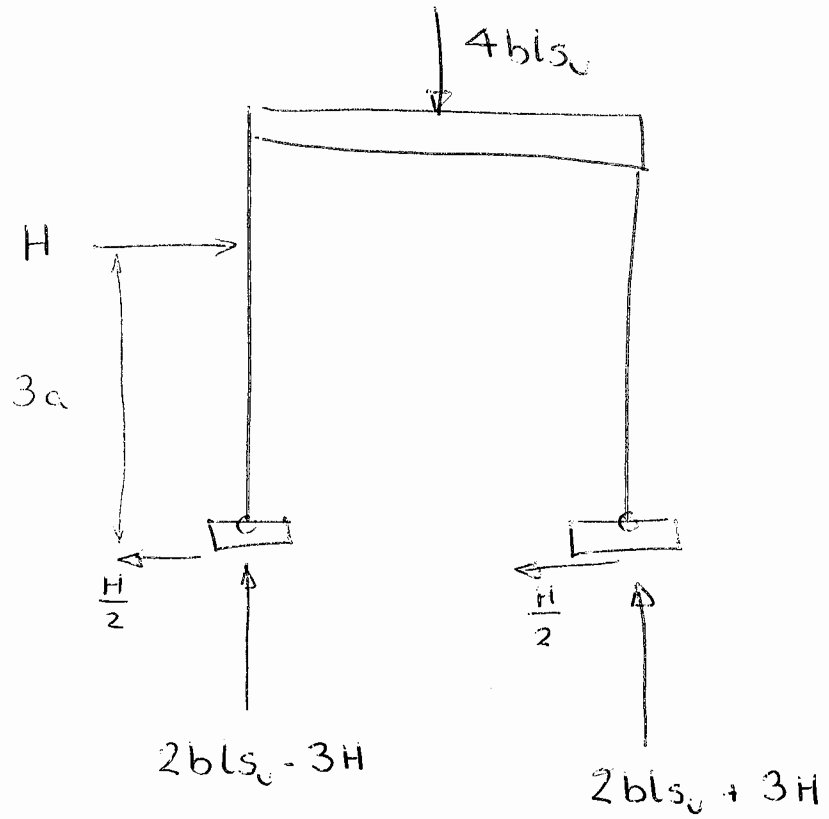
Ratio $\frac{V}{H}$

Height of applied horizontal load

Whether footings can withstand tension

$\frac{V}{S_u}$

b)



Sliding will occur if $\frac{H}{2} = bl\,s_u$ $\quad H = 2bls_u$

Liftoff will occur if $2bls_u - 3H = 0$ $\quad H = \frac{2}{3}\,bls_u$

Bearing failure will occur if

$$\frac{H/2}{2\,bls_u} \geq 1 - \left(2\,\frac{2bls_u + 3H}{(2+\pi)\,bl\,s_u} - 1\right)^2$$

Only critical if $H < \frac{2}{3}\,bls_u$

Try $H = \frac{2}{3}\,bls_u$

$$\frac{1}{6} > 1 - \left(2\,\frac{4\,\cancel{bls_u}}{(2+\pi)\,\cancel{bls_u}} - 1\right)^2 = 0.69$$

safe $\quad$ not critical

$\therefore$ failure at $H = \frac{2}{3}\,bl\,s_u$

c) With tension we need solution for bearing

$$\frac{H}{2bls_u} = 1 - \left[\frac{4}{2+\pi} + \frac{6H}{(2+\pi)bls_u} - \frac{2+\pi}{2+\pi} \right]^2$$

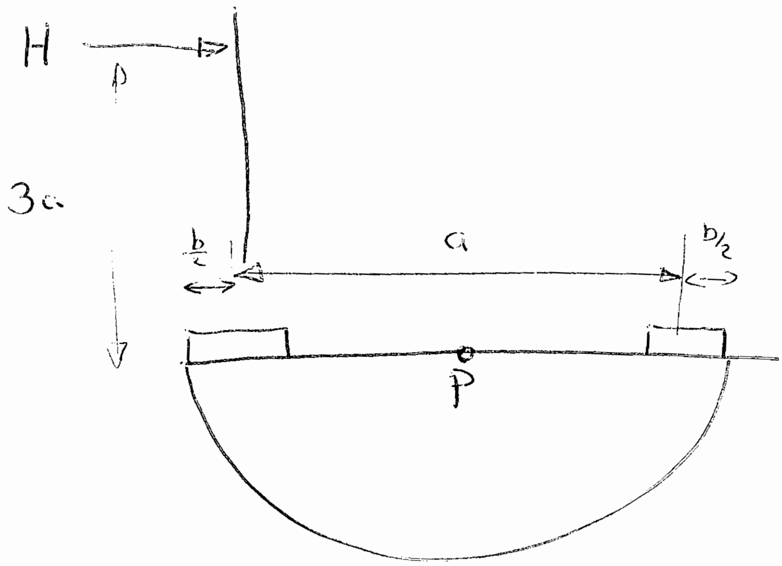
$$\frac{(2+\pi)^2 H}{2bls_u} = \underbrace{(2+\pi)^2 - (2-\pi)^2}_{8\pi} - 36\left[\frac{H}{bls_u}\right]^2 - \frac{12(2+\pi)H}{bls_u}$$

$$\frac{H}{bls_u} = \frac{0.48 \pm \sqrt{\cancel{12}\, 0.48^2 + 4 \times 36 \times 25.13}}{72}$$

$$= 0.067 \pm 0.8355$$

$H = 0.84\ bls_u$ - critical.

d)



Length of slip circle $= \frac{\pi(a+b)}{2}$

Moments about P:

$$\pi\frac{(a+b)}{2}\, s_u \,\frac{(a+b)}{2}\, l = 3a\, H$$

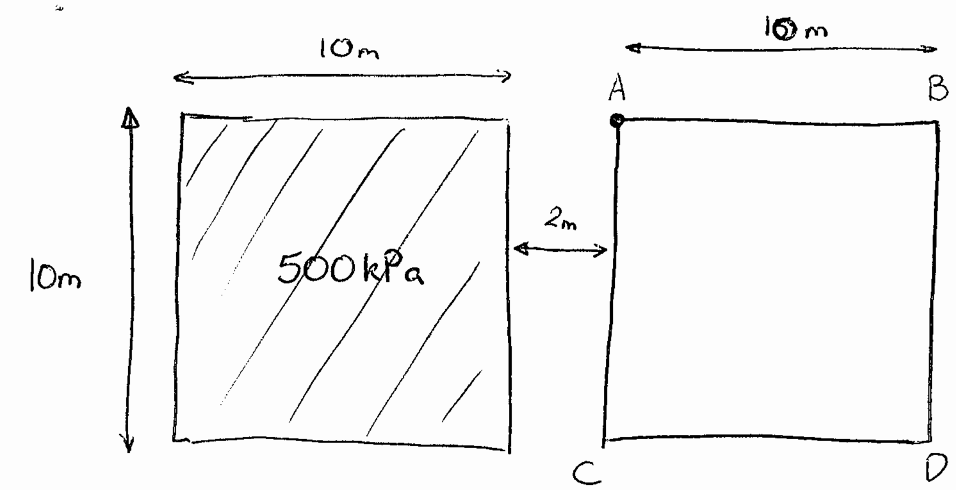
$$H = \frac{\pi(a+b)^2}{12\,a}\, l\, s_u$$

If $a = 2b$ $\qquad b = a/2$

$$H = \frac{\pi \times 9b^2 l s_u}{24\, b} = 1.18\, b l s_u$$

not critical as $> 0.84\, b l s_u$

2.

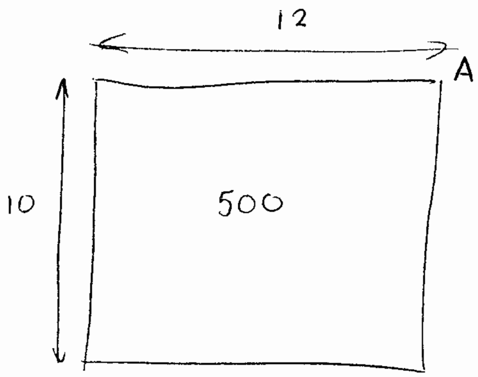


$\gamma^{*} = 20\ kN/m^3$

$G = 5MPa$

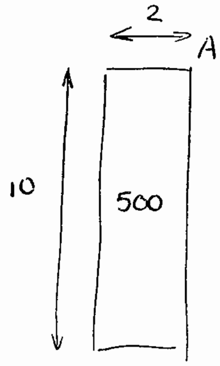
$\nu = 1/2$ (undrained)

$$\omega = \frac{1-\nu}{G}\,\frac{qB}{2}\,I_{rect}$$



$B = 10 \quad L/B = 1.2 \quad I_{rect} = 0.613$

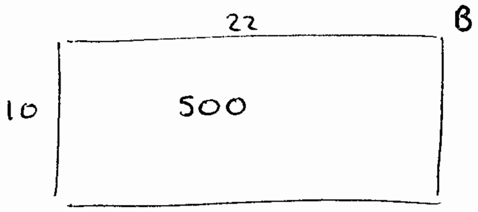
$\omega_1 =$



$B = 2 \quad L/B = 5 \quad I_{rect} = 1.052$

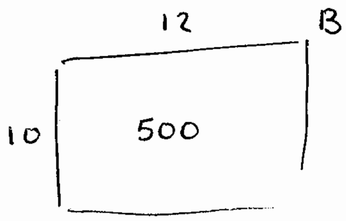
$\omega_2 =$

$$\omega_A = \omega_1 - \omega_2 = \frac{0.5}{5\times10^6} \times \frac{500\times10^3}{2}\left[6.13 - 2.104\right] = \underline{\underline{0.10065m}}$$



$B = 10 \quad \frac{L}{B} = 2.2 \quad I_{rect} = 0.795$

$\omega_3 =$



$B = 10 \quad \frac{L}{B} = 1.2 \quad I_{rect} = 0.613$

$\omega_4 =$

$$\omega_B = \omega_3 - \omega_4 = \frac{0.5}{\cancel{5\times10^6}} \times \frac{\cancel{500\times10^3}}{2}\cancel{\times10}\left[0.795 - 0.613\right] = \underline{\underline{0.0455m}}$$

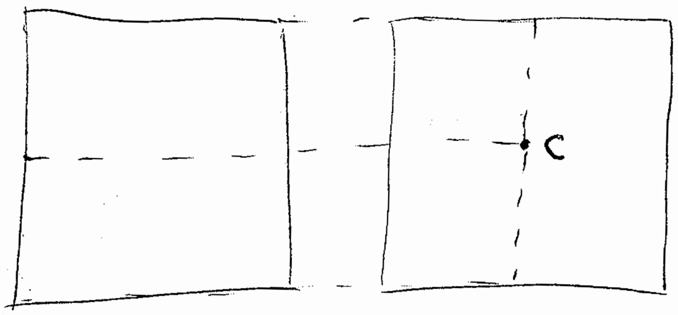
~~Average settlement = 0.0~~

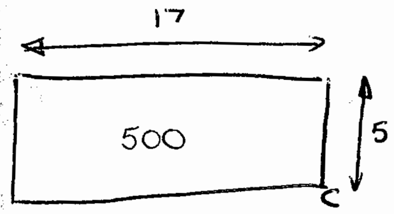
Differential settlement = 0.055 m = 55mm

b) London Clay $\quad K = 0.062$

$$v = 1.2 - \kappa \ln \sigma'$$

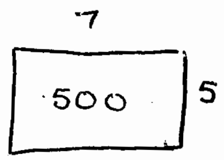
Increase in stress under centre of existing building @ 5m depth





$m = 3.4 \quad n = 1$

$\Delta\sigma_1 \qquad I_r = 0.205$



$\Delta\sigma_2 \qquad m = 1.4 \quad n = 1 \qquad I_r = 0.195$

@ 5m depth

$$\Delta\sigma = 2\Delta\sigma_1 - 2\Delta\sigma_2$$

$$= 2\left[(0.205 - 0.195) \times 500\right] = 10 \text{ kPa}$$

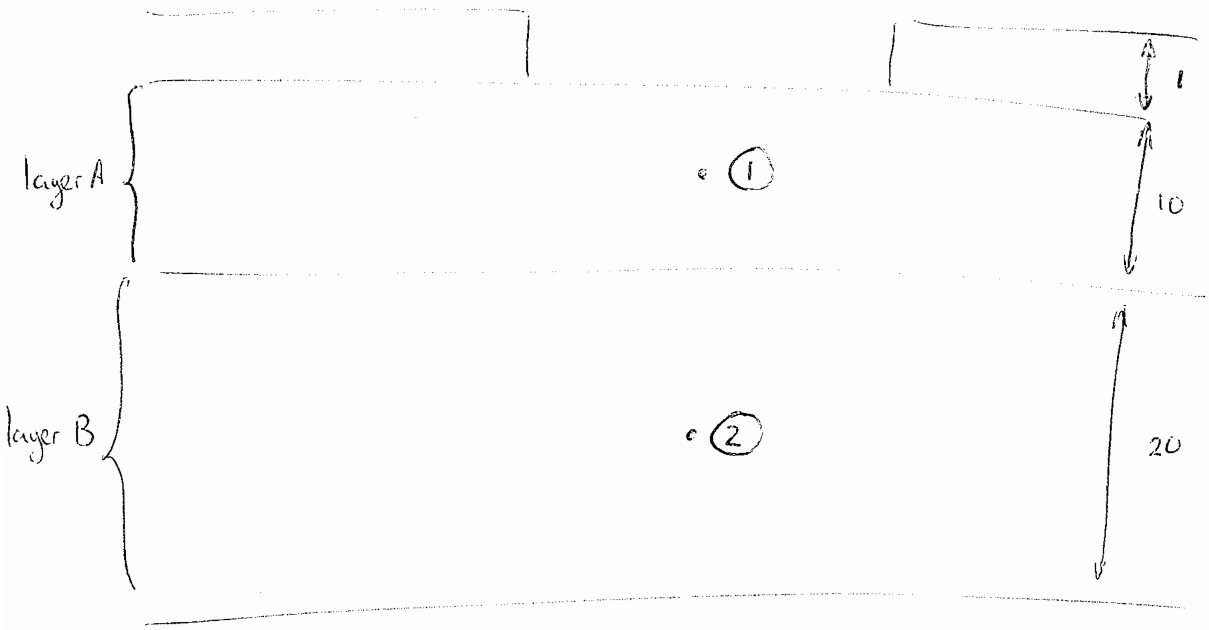
@ 20m depth $\qquad m = 0.85 \quad n = 0.25 \quad I_r = 0.062$

$\cancel{\Delta\sigma} \qquad m = 0.35 \quad n = 0.25 \quad I_r = 0.038$

$$\Delta\sigma = 2\left[(0.062 - 0.038) \times 500\right]$$

$$= 24 \text{ kPa}$$

Estimate drained settlement at centre of existing building



If existing building has bearing pressure of 250 kPa

Initial vertical eff stress at 1 is :

$m = 1 \quad n = 1 \qquad I_r = 0.175$

$\sigma' = 4 \times 0.175 \times 250 + 5 \times 10 + 1 \times 20$

$= 245\,kPa$

Initial vertical σ' @ 2 is .

$m = 0.25 \quad n = 0.25 \qquad I_r = 0.03$

$\sigma' = 4 \times 0.03 \times 250 + 20 \times 10 + 1 \times 20$

$= 250\,kPa$

---

layer A $\quad V_0 = 1.2 - 0.062 \ln(245) = 0.8589$

$V_1 = 1.2 - 0.062 \ln(255) = 0.8564$

$\varepsilon = \dfrac{0.00\cancel{3}25}{0.8589} = 0.0035 \qquad \rho = \cancel{35}\ 29\,mm$

layer B $\quad V_0 = 1.2 - 0.062 \ln(250) = 0.8577$

$V_1 = 1.2 - 0.062 \ln(274) = 0.8520$

$\varepsilon = \dfrac{0.0057}{0.8577} = \qquad \rho = 133\,mm$

$\rho_{total} = \underline{\underline{162\,mm}}$

3 a) $D = 0.5\,m$ $\quad L = 30\,m$

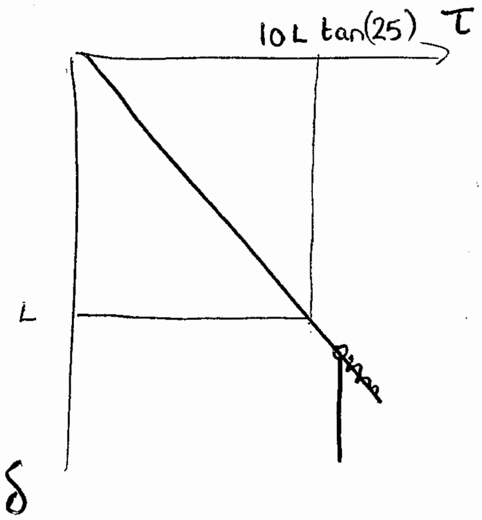
$\phi = 35^\circ$ $\quad \delta = 25^\circ$

$N_q = 20$ $\quad q_{b\,lim} = 4.8\,MPa$

$\tau_{s\,lim} = 85\,kPa$

Closed ended $\quad K = 1$

Shaft resistance: $\tau = K \sigma_{vo}' \tan\delta$



@ 30m depth

$\tau = 300 \tan\delta = 139.9\,kPa$

$> 85.$

$85\,kPa \implies \text{depth} = 18.2\,m$

$\therefore F_{shaft} = \pi D \underbrace{\int \tau \, dz}_{\left[85 \times \frac{18.2}{2} + 85 \times 11.8\right]}$

$= 2790\,kN$

q_{base} @ 30 m

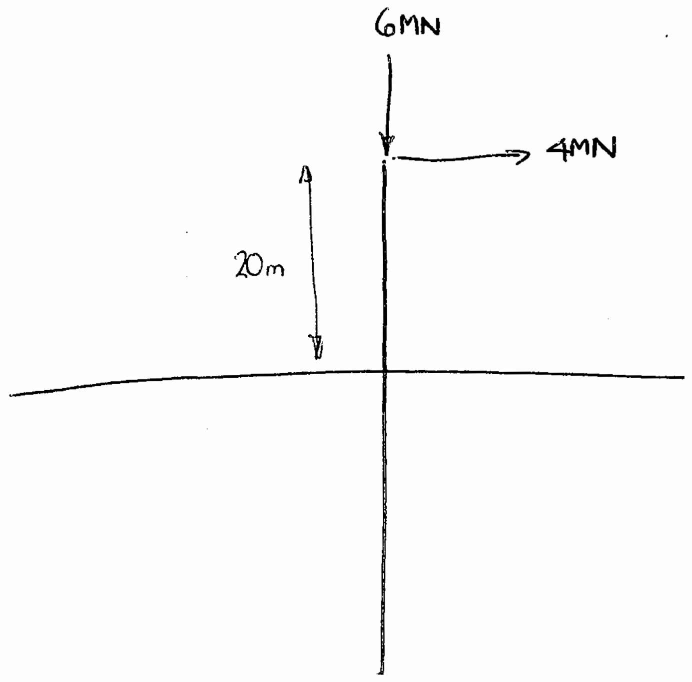
$= 20 \times 300 = 6000\,kPa = 6\,MPa$

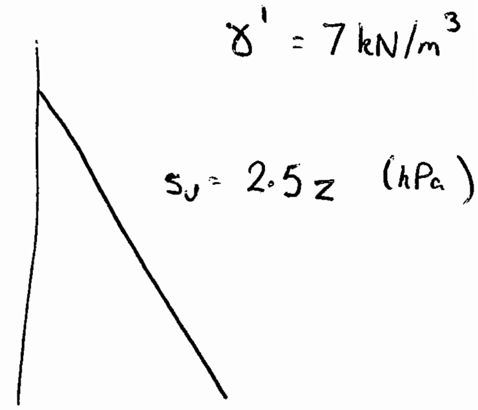
limit to 4.8 MPa

$F_{base} = 4.8\,MPa \times \frac{\pi D^2}{4} = 942\,kN$

$Q_{total} = 3732\,kN$

b)





$$\frac{\cancel{\pi} D_{eq}^2}{4} = \cancel{\pi} D t$$

$$D_{eq} = 2\sqrt{Dt} = \underline{\underline{0.8m}}$$

After 90% consolidation

$$\frac{C_h t}{D_{eq}^2} = 10$$

$$t = \frac{10 D_{eq}^2}{C_h} = \frac{\overset{0.32}{\cancel{0.08}} \text{ years}}{\underline{\underline{117 \text{ days}}}}$$

b) $s_u = 2.5z$ $\qquad \sigma_v' = 7z$

$$\tau_{sf} = 0.5\, s_u \sqrt{\frac{\sigma'_{vo}}{s_u}}$$

$$= 0.5 \times 2.5z \sqrt{\frac{7}{2.5}}$$

$$= \underline{\underline{2.09z}}$$

Shaft resistance $= \pi D L \times \overset{9}{2.09} \frac{L}{2} = 4.18\,\pi L^2 = 13.13L^2$

Base resistance $= N_c A_b s_u$

$$= 9 \frac{\pi D^2}{4} \cdot 2.5L = 90\,\pi L = 283L$$

Weight of soil $= \frac{\pi D^2}{4} L \times 7 = 28\,\pi L = 88L$

$$4.18\,\pi L^2 + (90\pi L - 28\pi L) - 6000 = 0$$

$$L = \frac{-6\overset{2}{\cancel{8}}\,\pi \pm \sqrt{(62\pi)^2 + 24000 \times 4.18\pi}}{8.36\,\pi}$$

$$= \underline{\underline{15.2m}}$$

iii) $e = 15m$ $\qquad \frac{e}{D} = \frac{15}{4} = 3.75 \qquad \frac{L}{D} = 3.8$

$$\Rightarrow \frac{H_{ult}}{nD^3} = 0.9$$

$n = 9\, k_{su} = 22.5$ kPa/m $\qquad D = 4$

$$H_{ult} = 0.9 \times 22.5 \times 4^3 = \underline{\underline{1296 \text{ kN}}}$$

Pile must be longer.

c) $H = 4kN$ $\qquad \frac{H}{nD^3} = 2.78$

~~Class~~ $\frac{e}{D} = 3.75 \Rightarrow \frac{L}{D} = 6$

$$\therefore L = \underline{\underline{24m}}$$

4.

~~4b~~

i) $$E_p = \frac{E_s A_s}{A_p} = \frac{210 \times \cancel{\pi} \times 1 \times 20 \times 10^{-3}}{\frac{\cancel{\pi} \times 1^2}{4}}$$

$$= \underline{\underline{16.8 \text{ GPa}}}$$

$$M_p = \sigma_y D^2 t = \underline{\underline{5 \text{ MNm}}}$$

ii) $\frac{e}{D} = 0$ $\quad \frac{L}{D} = 15$

Short pile $\quad \frac{H_{ult}}{s_u D^2} = 50 \quad \Rightarrow \quad H_{ult} = \underline{\underline{5000 \text{ kN}}}$

Long pile $\quad \cancel{\frac{H_{ult}}{s_u D^2}} \quad \frac{M_p}{s_u D^3} = 50 \quad \frac{H_{ult}}{s_u D^2} = 22$

$H_{ult} = \underline{\underline{2200 \text{ kN}}}$

fails at 2200 kN

$\frac{e}{D} = 4$ $\quad \frac{L}{D} = 15$

Short pile $\quad \frac{H_{ult}}{s_u D^2} = 40$

Long pile $\quad \frac{H_{ult}}{s_u D^2} = 10$ $\quad H_{ult} = \underline{\underline{1000 \text{ kN}}}$

iii) $\frac{M_p}{s_u D^3} = 50 \qquad \frac{L}{D} = 15$

Short $\frac{H_u}{s_u D^2} = 50$

Long $\frac{H_u}{s_u D^2} = 35 \quad \Rightarrow \quad H_{ult} = \underline{\underline{3.5 MN}}$

b) i) $\frac{V}{w_{head} D G_L} = \frac{2}{1-\nu} \frac{\eta}{\xi} + \frac{2\pi}{\zeta} \rho \frac{L}{D}$

$\xi = \frac{G_L}{G_{base}} = 1$

$\rho = \frac{G_{avg}}{G_L} = \frac{165}{250} = 0.66$

$\zeta = \ln\left\{5\rho(1-\nu)\frac{L}{D}\right\} = \ln\left\{5 \times 0.66 \times 0.8 \times \frac{20}{0.3}\right\}$

$= 5.17$

$\eta = 1$

$\therefore \frac{V}{w_{head} D G_L} = \frac{2}{0.8} + \frac{2\pi}{5.17} \times 0.66 \times \frac{20}{0.3}$

$= 55.97$

$\therefore w_{head} = \frac{V}{55.97 D G_L} = \frac{500 \text{ kN}}{55.97 \times 0.3 \times (250 \text{kPa} \times 150)}$

$= \underline{\underline{0.79 \text{ mm}}}$

ii) $\delta l = \frac{500 \text{ kN}}{15 \text{GPa} \times \frac{\pi \times 0.3^2}{4}} \times 20 = \underline{\underline{9.4 \text{mm}}}$