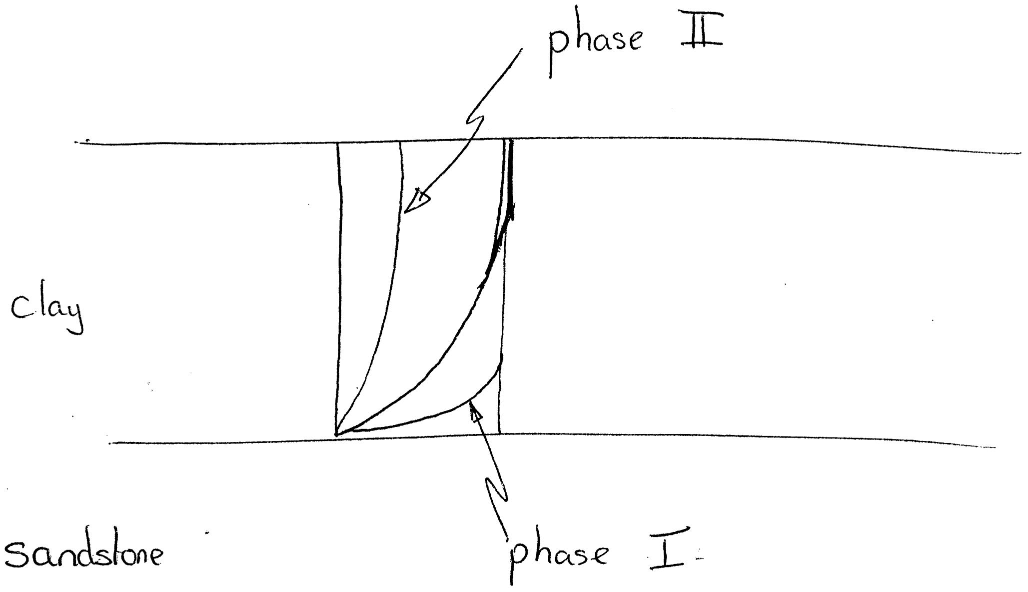
1 a) Water extraction leads to a drop in pore pressure in the permeable sandstone aquifer.

Total stress remains constant

So effective stress must rise

This leads to compression of the clay layer as the pore water pressures in the clay dissipate by seepage into the aquifer.

b)



3D1 Crib 2010

1. c) In phase II consolidation

$$\rho = \rho_{ult}\left(1 - \tfrac{2}{3}\exp\left(\tfrac{1}{4} - \frac{3C_v t}{d^2}\right)\right)$$

① $$0.046 = \rho_{ult}\left(1 - \tfrac{2}{3}\exp\left(\tfrac{1}{4} - \frac{3t_1}{25}\right)\right)$$

② $$0.062 = \rho_{ult}\left(1 - \tfrac{2}{3}\exp\left(\tfrac{1}{4} - \frac{3(t_1+2)}{25}\right)\right)$$

$$= \rho_{ult}\left(1 - \tfrac{2}{3}\frac{\exp\left(\tfrac{1}{4} - \frac{3t_1}{25}\right)}{\exp\left(\frac{6}{25}\right)}\right)$$

Let $\exp\left(\tfrac{1}{4} - \frac{3t_1}{25}\right) = x$ $\exp\left(\frac{6}{25}\right) = 1.27$

① / ②

$$\frac{0.046}{0.062} = \frac{1 - \tfrac{2}{3}x}{1 - \tfrac{2}{3}\frac{x}{1.27}} = 0.742$$

$$\therefore 0.258 = \tfrac{2}{3}x - \frac{2}{3} \times \frac{0.742}{1.27}x = 0.277x$$

$x = 0.93085$

$$\therefore t_1 = \frac{25}{3}\left(\tfrac{1}{4} - \ln(x)\right) = 2.68 \text{ yrs}$$

2 yrs 248 days

∴ Water extraction commenced in August 2005

d) $$\rho_{ult} = \frac{0.046}{1 - \tfrac{2}{3}x} = \underline{\underline{121 \text{ mm}}}$$

2.

ω	11	14	17	20	23
γ_{bulk}	1850	1920	1960	1960	1950
γ_{dry}	1667	1684	1675	1633	1585
e	0.59	0.57	0.58	0.62	0.67
S_r	0.48	0.63	0.76	0.84	0.89
A	0.19	0.14	0.09	0.06	0.04

$\omega_{optimum}$ = 14.5 %

At w = 11 % the soil has a low voids ratio, a low S_r & a high air voids ratio. It will thus be stiff but brittle & subject to wetting collapse when floods occur.

At w = 20 % the soil is less dense & so will be weaker and softer, but the saturation ratio is now high & air voids low.

Prefer the weaker material w = 20 % for reliable strength

b) At centre of clay layer σ' = 25 kPa before construction

Initial guess :- All soil at γ_{bulk}

After construction

$$\Delta\sigma' = 5 \times 19.6 = 98\,kPa \qquad \sigma' = 123\,kPa$$

@ 25 kPa v = 3.14

$$\Delta v = -0.26 \times \ln\left(\frac{123}{25}\right) = -0.414$$

$$\varepsilon = \frac{\Delta v}{v} = -0.132$$

$$\rho = 10 \times 0.132 = \underline{\underline{1.32\,m}}$$

This takes 1.32 m of soil from γ_{bulk} to γ'

$\Delta\sigma' = 3.7 \times 19.6 + 1.3 \times 9.6$

$= 85 kPa$

$\Delta v = -0.26 \times \ln\left(\frac{110}{25}\right) = -0.385$

$\varepsilon = 12.3\%$ $\rho = \underline{1.23 m}$

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c) 1st guess $h_o = 6.23 m$

$\Delta\sigma' = 5 \times 19.6 + 1.23 \times 9.6$

$= 109.8 kPa$

$\sigma' = 134.8 kPa$

$\Delta v = -0.26 \times \ln\left(\frac{134.8}{25}\right) = -0.438$

$\varepsilon = 13.95\%$ $\rho = 1.395 m$

2nd guess $h_o =$ ~~6.395~~ $6.4 m$

~~ε~~ $\Delta\sigma' = 111.44$

$\sigma' = 136.44$

$\Delta v = -0.441$

$\varepsilon =$ ~~0~~14.05% $\rho = \underline{\underline{1.4 m}}$

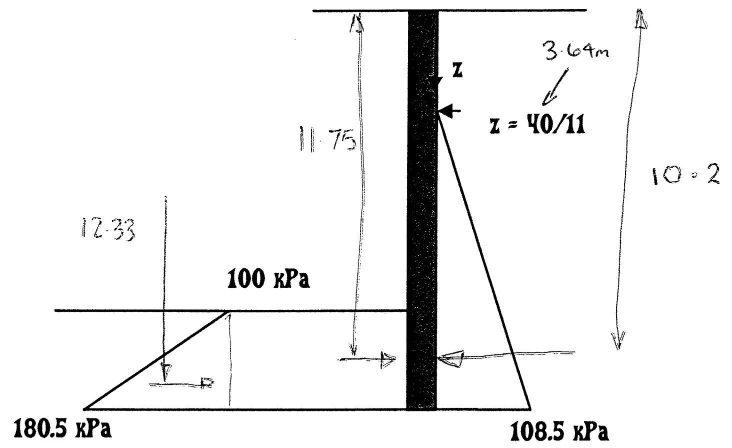
$\therefore h_o = \underline{\underline{6.4 m}}$

3.

(a) $\sigma_v = \gamma z$,

Passive side $\sigma_h = \gamma(z\text{-}10) + 2s_u = 17(z\text{-}10) + 2(20 + 3z) = 23z - 130$ (from z = 10)

Active side $\sigma_h = \gamma z - 2s_u = 17z - 2(20 + 3z) = 11z - 40$



It is assumed that dry crack is formed at the location of negative pressure on the active side. Hence, the active pressure is zero down to z = 40/11 = 3.64 m.

Rotating moment by the active zone is (1/2) x 108.5 x (13.5-40/11) x ((2/3)x(13.5-40/11)+ 40/11) = 5463 kN m/m

Counteracting rotating moment by the passive zone is 100 x 3.5 x 11.75 + (1/2) x 80.5 x 3.5 x ((2/3)x3.5+10) = 5850 kN/m

Just about ok.

(b)

The active side : $\sigma_h' = K_a \sigma'_v$; $K_a = (1-\sin25)/(1+\sin25) = 0.406$

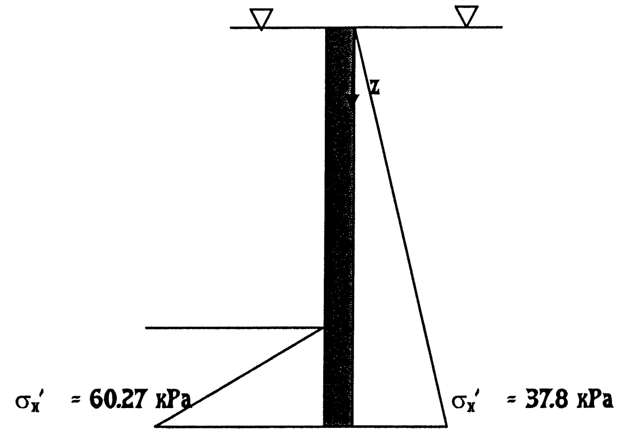
The passive side, $\sigma_h' = K_p \sigma'_v$; $K_p = (1+\sin25)/(1-\sin25) = 2.46$

Water pressures at both sides balance and hence only soil pressure needs to be considered.

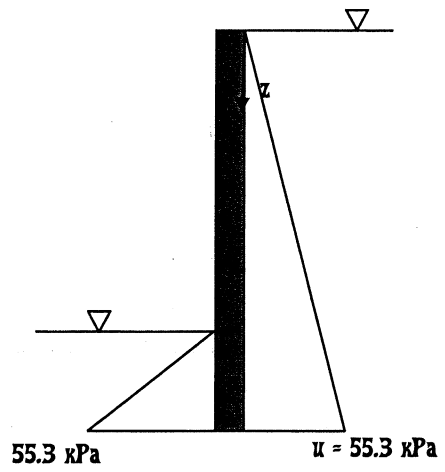
Rotating moment by the active pressure = (1/2) x (0.406 x 7 x 13.5) x 13.5 x 13.5x(2/3) = 2296 kNm/m

Counteracting moment by the passive pressure = (1/2) x (2.46 x 7 x 3.5) x 3.5 x (3.5x(2/3) +10) = 1301 kNm/m.

The wall is likely to fail.



(c) The water pressure distribution acting on the wall will change. There will be seepage flow. The pressure profile can be evaluated by seepage analysis. Possible hydraulic gradient along the wall = 10 m/(13.5 + 3.5) m = 0.58. The hydraulic head at the toe of the wall will be 0.58 x 3.5 = 2.03 (The datum is at the excavation level). Hence, the pore pressure at the toe can be estimated to be u = 3.5 x 10 + 2.03 x 10 = 55.3 kPa. At the active side, the effective horizontal stress will increase due to decrease in water pressure. At the passive side, the effective horizontal stress will decrease. With additional water pressure difference, the instability of the wall becomes greater.



(d) - Increase the embedment depth

- Add more supports
- Install ground anchors
- Increase the strength of the ground on the excavation side by soil improvement

4.

(a)Using Meyerhof's "effective area" method, the foundation width is assumed to be 5 m – 2 x 0.75 m = 3.5 m. Hence the vertical stress under the foundation (per unit thickness) will become V/3.5 (kPa).

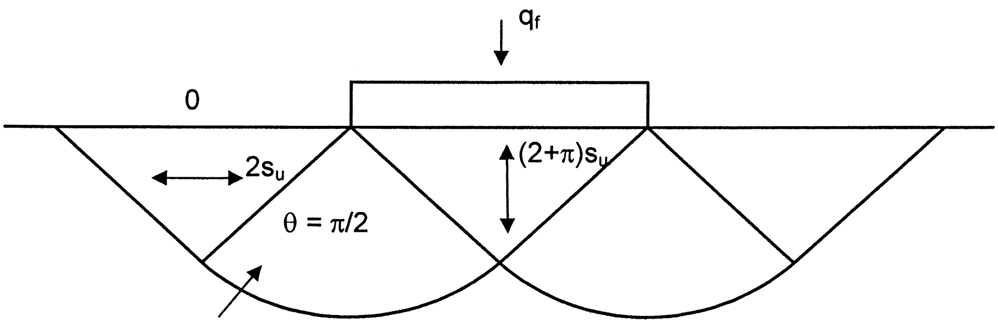
The failure stress state at the foundation level but outside the foundation is (σ_v, σ_h) = (γz, $\gamma z+2s_u$) = (16x2, 16x2 + 2x30) = (32, 92) kPa. It is assumed that the shear resistance above the foundation line is negligible.

Using the stress fan concept,

The vertical load at failure can be evaluated as follows.

$V/3.5 = 92 + 2s_u(\pi/2) = 92 + 2x30x(3.14/2) = 186.2$ kPa

V = 651 kN/m



(a) Using the same "effective area" method by Meyerhof, the foundation width is assumed to be 3.5 m.

The vertical effective stress at the foundation level outside the foundation is σ_{v0}' = (16-10) x 2 = 12 kPa.

Using the bearing capacity formula given in the databook,

$V/3.5 = N_q\sigma_{v0}' + N_\gamma\gamma' B/2$

$N_q = \tan^2(\pi/4+\phi/2)e^{\pi\tan\phi} = \tan^2(\pi/4+(25/180)/2)e^{\pi\tan(25/180)} = 10.65$

$N_\gamma = 2(N_q - 1)\tan\phi = 2(10.65 - 1) \tan (25/180) = 9.00$

V/3.5 = 10.65 x 12 + 9.00x6x3.5/2 = 127.8 + 94.5 = 222.3 kPa

Water pressure needs to be added at the base.

$V/3.5 = 222.3$ kPa + 2x10 kPa = 242.3 kPa.

$V = 848$ kN/m.

(b) The short term undrained condition is more critical. The clay consolidates during drained condition and the shear resistance increases compared to the undrained condition. The clay is likely to be normally consolidated or lightly overconsolidated.

(d) The vertical stress applied will be 186.2 kPa x 0.75 = 140 kPa

The horizontal stress will be *H/3.5*.

The principal stress will rotate at an angle of ψ.

$H/3.5 = s_u \sin 2\psi \rightarrow 2\psi = \sin^{-1}(H/105)$

Using the stress fan concept shown below,

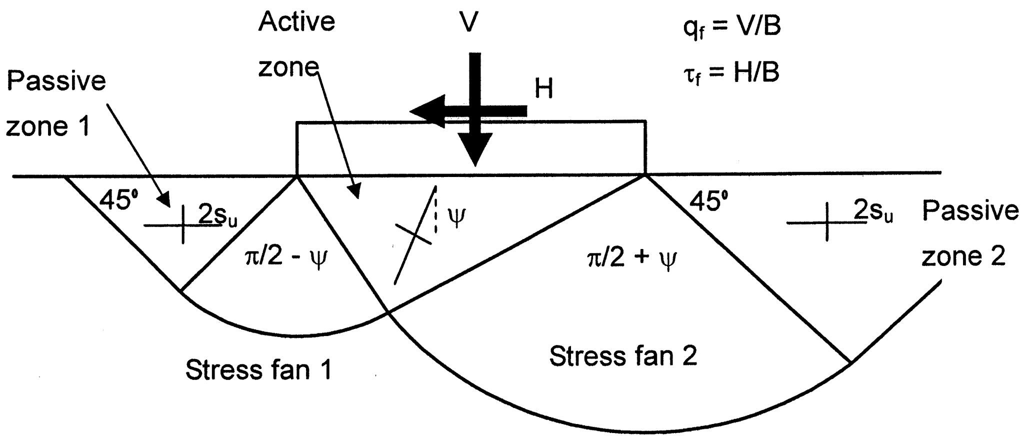
$140 = (\gamma z + s_u) + 2s_u (\pi/2 - \psi) + s_u \cos 2\psi$

$140 = 16 \times 2 + 30 + 30 \times \pi - 30 \times \sin^{-1}(H/105)) + 30\sqrt{1-(H/105)^2}$

$-16.25 = -30 \sin^{-1}(H/105) + 30\sqrt{1-(H/105)^2}$

$0.54 = \sin^{-1}(H/105) - \sqrt{1-(H/105)^2}$

H is about 84 kN/m.



Numerical Answers for 3D1 exam 2010-05-21

1) c) 2.68 years, August 2005
   d) 121 mm

2) b) 1.23m
   c) 6.4m

4) a) 651 kN/m
   b) 848 kN/m