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3D1 2008

1. a) $G_s = 2.65$

$$\gamma_d = \frac{2.65 \times 9.8}{(1+e)} = 1.70 \times 9.8 \text{ kN/m}^3 = \underline{16.7 \text{ kN/m}^3}$$

$\therefore e = 0.559$

$$\therefore \gamma_{sat} = \frac{(2.65 + 0.559)}{1.559} \times 9.8 = \underline{20.2 \text{ kN/m}^3}$$

In 1D strain, only grain breakage can give significant static compression, and quartz gravel would not offer significant breakage. But under dynamic loading the sand grains could re-arrange to give at least 100% relative density. This would exceed Standard Proctor compaction, so the sand would exhibit additional compaction under shaking.

b) $$\gamma = \frac{(G_s + e)\gamma_w}{(1+e)} = \frac{(1.75 + V)}{V} \times 9.8$$

At $\sigma'_v = 10$ kPa, $V = 3 - 0.2 \ln 10 = 2.54$
so $\underline{\gamma = 16.5 \text{ kN/m}^3}$

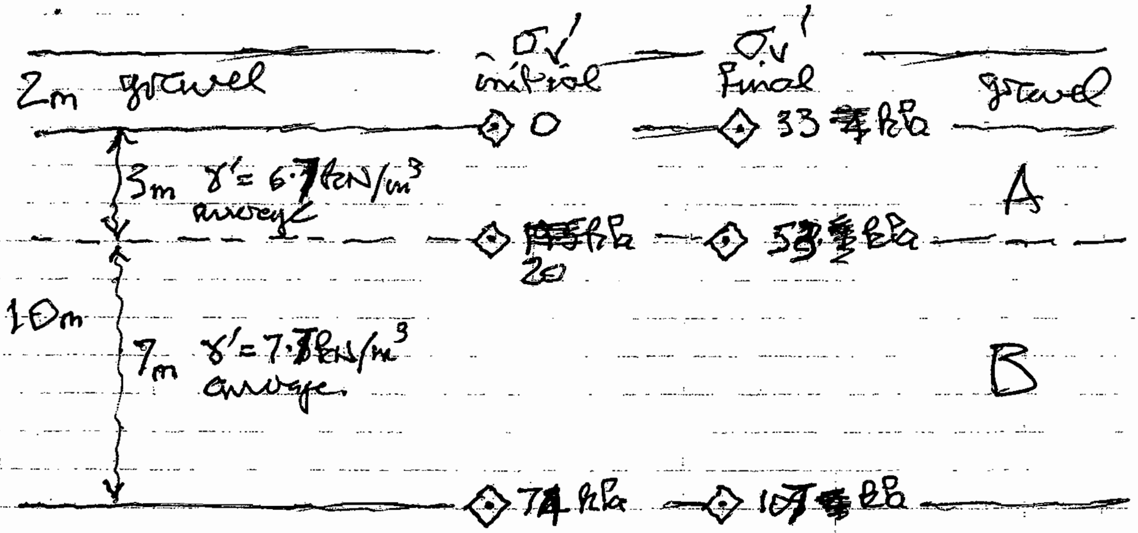
At $\sigma'_v = 100$ kPa, $V = 2.08$ so $\underline{\gamma = 18.0 \text{ kN/m}^3}$

Tangent stiffness $E_o = \dfrac{\sigma'_v V}{\lambda}$ on the ncl.

So at 10 kPa: $E_o = 10 \times 2.54 / 0.2 = \underline{127 \text{ kPa}}$

at 100 kPa: $E_o = 100 \times 2.08 / 0.2 = \underline{1040 \text{ kPa}}$

1 c) Secant stiffness is defined as $\Delta\sigma'/\Delta\varepsilon$, so it integrates up the individual tangent stiffness effects for a finite change of strain $\Delta\varepsilon$.



In (b) we calculated $\gamma = 16.5\ \text{kN/m}^3$ for clay at 10 kPa. An iteration shows that σ_v' initial $\doteq 20$ kPa at 3m depth in the clay, so this is chosen as layer A with an average unit weight of $16.5\ \text{kN/m}^3$ so that $\gamma' = 6.7\ \text{kN/m}^3$. In a similar estimation style, the unit weight of lower layer B is selected as $\gamma = 17.5\ \text{kN/m}^3$, $\gamma' = 7.7\ \text{kN/m}^3$.

Now $\quad V_{initial} = 3 - 0.2 \ln \sigma_v'{}_{initial}$

So $\quad \Delta V = 0.2 \ln(\sigma_v'{}_{final} / \sigma_v'{}_{initial})$

and $\quad \varepsilon_v = \dfrac{\Delta V}{V_{initial}} = \dfrac{0.2 \ln(\sigma_v'{}_{final}/\sigma_v'{}_{initial})}{3 - 0.2 \ln \sigma_v'{}_{initial}}$

Taking the centres of layers A and B as representative

A: $\quad \varepsilon_v = \dfrac{0.2 \ln(43/10)}{3 - 0.2 \ln 10} = 0.115$

B; $\quad \varepsilon_v = \dfrac{0.2 \ln(80/47)}{3 - 0.2 \ln 47} = 0.048$

1 c) cont.

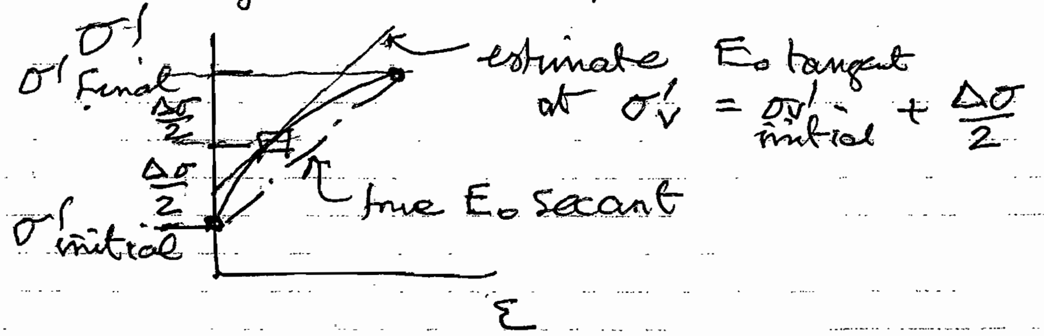
So an approximate settlement is:

$$\rho_{ult} = 3 \times 0.115 + 7 \times 0.048 = \underline{0.68\ m}$$

d) A revision will have to be made of soil properties, especially stiffness. The gravel surface after (c) was only (2.00 − 0.68) or 1.32 m above old ground surface. So an approximate linear estimate is that the true depth of placement should be $2 \times 2/1.32 = 3.03$ m. But the addition of 50% more gravel will increase the final effective stress. This will increase the operational soil stiffness, especially of layer A, so slightly less than 3 m of gravel will be required.

1 c) Alternative method

The tangent stiffness approach could be used.



For the top layer A, using $E_o = \frac{\sigma_v' V}{\lambda}$

$$E_o = \left(6.7z + \frac{33}{2}\right) \times \frac{2.54}{0.2}$$

$$\therefore E_o = 85z + 212$$

So $\varepsilon_v = \frac{d\rho}{dz} = \frac{\Delta\sigma}{E_o} = \frac{33}{85z + 212}$ $\quad 0 < z < 3\text{m}$

$$\therefore \rho_A = \frac{1}{2.54} \ln\left[\frac{85 \times 3 + 212}{212}\right] = 0.311\text{m}$$

For lower layer B,

$$E_o = \left(20 + 7.7\{z-3\} + \frac{33}{2}\right) \times \frac{2.23}{0.2}$$

$$\therefore E_o = 86z + 152$$

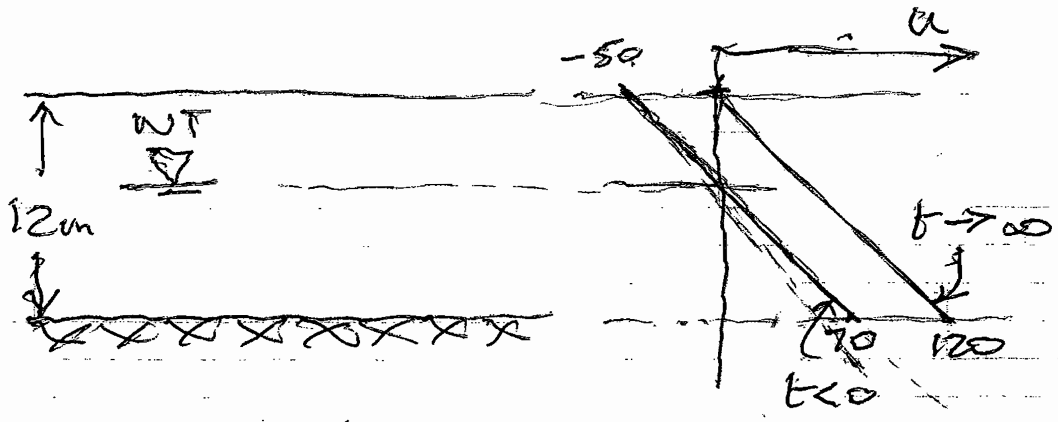
$$\therefore \rho_B = \int_3^{10} \frac{33\, dz}{(86z + 152)} = \frac{1}{2.61} \ln\left[\frac{86 \times 10 + 152}{86 \times 3 + 152}\right]$$

$$\therefore \rho_B = \frac{1}{2.61} \ln 2.47 = 0.346\text{ m}$$

So the ultimate settlement of the ground surface

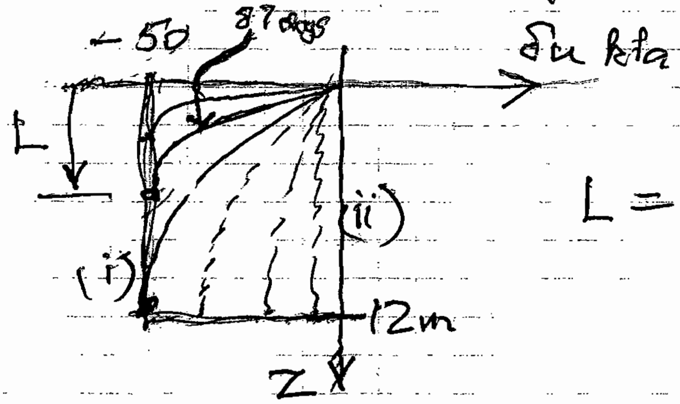
$$\rho_{ult} = \rho_A + \rho_B = \underline{0.66\text{m}}$$

2. a)



Take $\gamma_w = 10\,kN/m^3$.

b) $\Delta u = u_{t=0} - u_{t=\infty}$



$L = \sqrt{12 c_v t}$

c) Start the clock when the rainstorm starts

i) In phase I, $\rho = \frac{1}{3}\Delta u L$

So swelling heave $(-\rho) = \frac{1}{3}(-\Delta u)L/E_o$

$\therefore (-\rho) = \frac{1}{3} \cdot 50 \frac{\sqrt{12 \times 4 \times 10^{-7}}}{4000}\sqrt{t}$

So if the swelling soaks up all the rain,

$\sqrt{t} = \frac{0.025 \times 3 \times 4000}{50\sqrt{480} \times 10^{-4}}$

$= \cancel{0.866}\ 0.274 \times 10^{4}$

$\therefore t = 0.75 \times 10^{7}\,s = \cancel{0.24}$ years

or $t = 87$ days

Then, $L = \sqrt{12 \times 4 \times 10^{-7} \times 0.75 \times 10^{7}} = 6\,m$

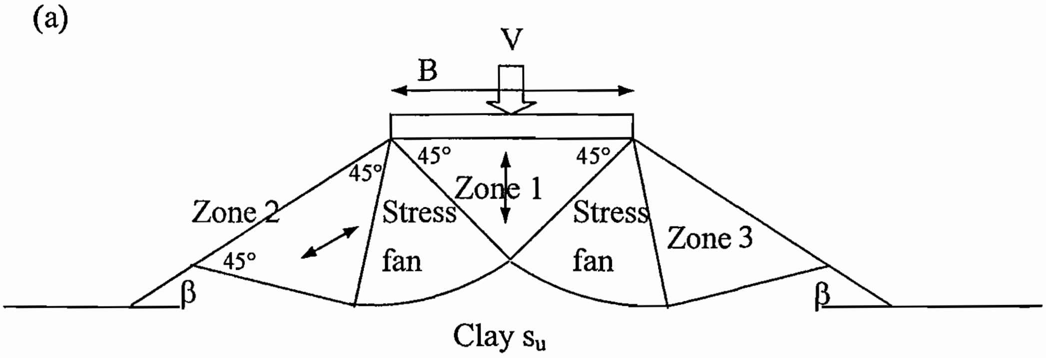
2 c ii) Since the volume remains constant after re-paving, the swept area must be constant as a new hydrostatic condition is achieved. Swept area $= \frac{1}{3} \times 6 \times 50 = 100$

So final $(-\delta u) = 100/12 = 8.3$ kPa

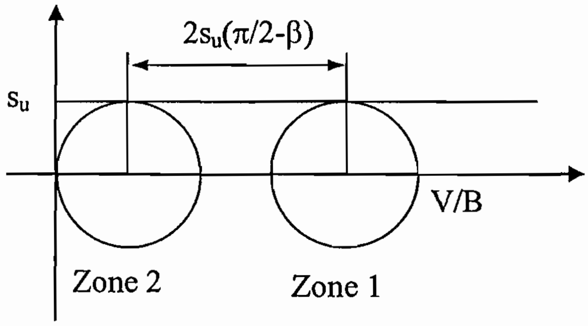
This means that the water table rises from 5 m to 4.17 m below the paved surface.

3.

(a)

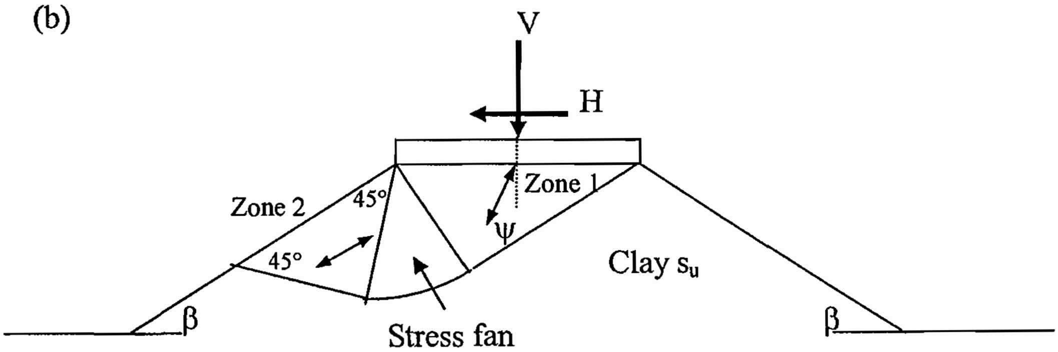


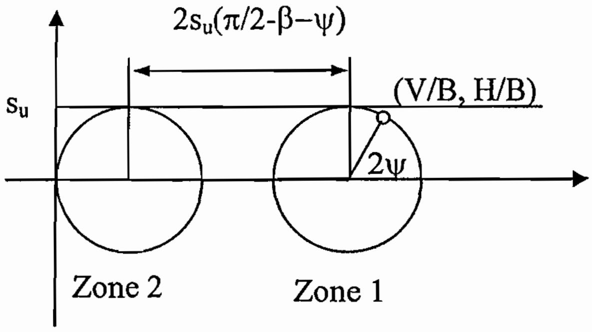
The stress fan has an angle of 90°-β.



Hence, $\underline{V/B} = 2s_u(\pi/2-\beta) + 2su = \underline{s_u(2+\pi-2\beta)}$.

(b)





From the geometry, $H/B = s_u \sin 2\psi$ or $2\psi = \sin^{-1}(H/Bs_u)$

Also,

$V/B = su + 2s_u(\pi/2-\beta-\psi) + s_u \cos 2\psi$

Or

$$\frac{V}{Bs_u} = 1 + \pi - 2\beta - \sin^{-1}\left(\frac{H}{Bs_u}\right) + \sqrt{1 - \left(\frac{H}{Bs_u}\right)^2}$$

(c) The foundation slides when $H/B = s_u$.

Substituting this into the above equation gives

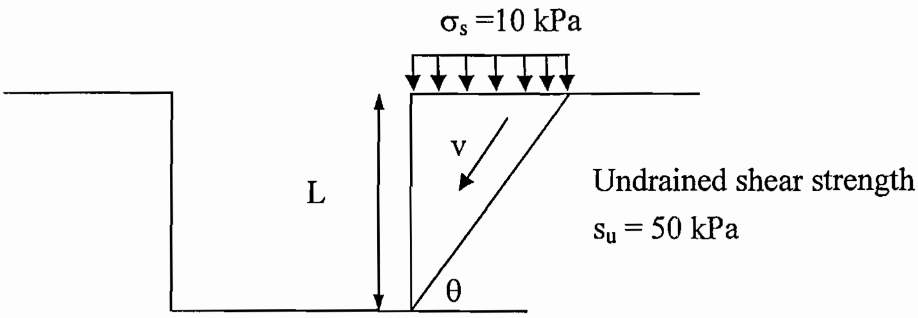
$$\frac{V}{Bs_u} = 1 + \frac{\pi}{2} - 2\beta$$

(d) The stresses evaluated are at the boundary between zone 1 and the stress fan. The stresses at the foundation level will therefore smaller. The ultimate load that can be applied is smaller. The solution is not conservative and needs to be used carefully.

(e) There will be water pressure acting as surcharge along the slope and hence the Mohr circle of zone 2 will be shifted to the right and hence the ultimate load will increase. An average water pressure can be used as the first estimate for the surcharge.

4

(a)



Work done (per unit metre)

= Weight of the sliding block x g x vertical movement + surcharge x length x vertical movement

$= \rho\ (1/2)\ L\ (L/\tan\theta)\ g\ v\sin\theta + \sigma_s\ (L/\tan\theta)\ v\ \sin\theta = (\rho g L^2/2 + \sigma_s L)\cos\theta v$

Work dissipated $= s_u\ (L/\sin\theta)\ v$

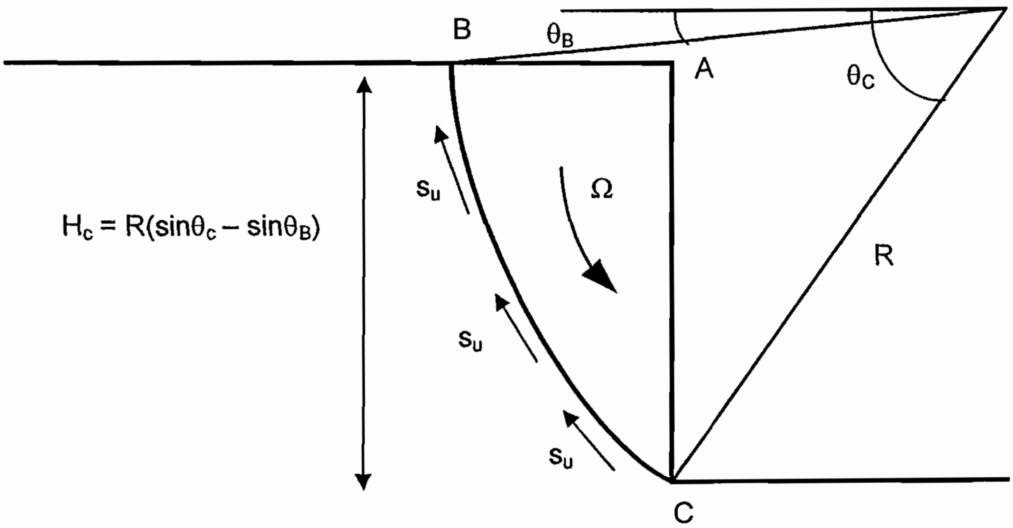
Equating the two

$(\rho g L^2/2 + \sigma_s L)\cos\theta v = s_u\ (L/\sin\theta)\ v$

$\rho g L/2 + \sigma_s = s_u/(\cos\theta\sin\theta) = 2s_u/(\sin 2\theta)$

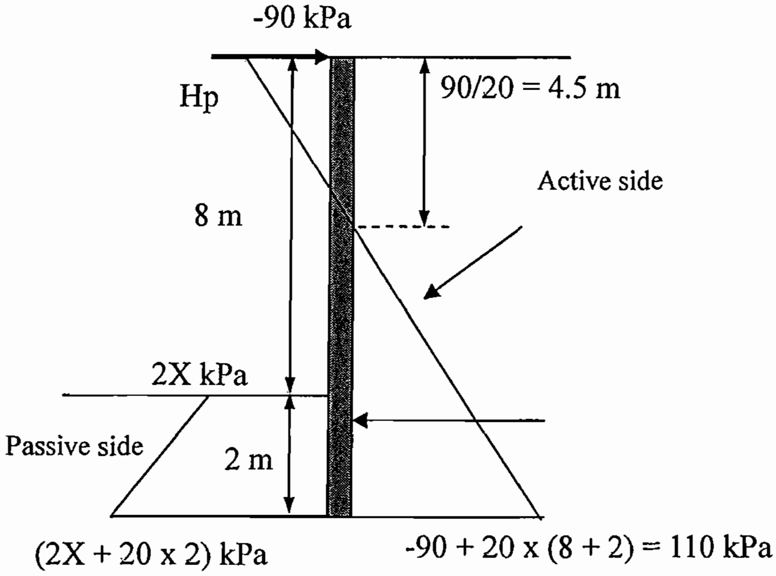
L is the smallest when $\theta = \pi/4$. $L = 2(2s_u - \sigma_s)/\rho g = 2\ (2\text{x}50 - 10)/20 = \underline{9\text{ m}}$

(ii)



Find θ_B and θ_C that give the smallest H_c.

(b) (i)



(ii) Ignore the negative section of the active side.

By taking the moment at the top,

Clockwise = (1/2)(8+2 – 4.5)(110)(4.5 + (2/3)(5.5)) = 2470

Counter clockwise = 2X x 2 x (8 + 2/2) + (1/2) x (20 x 2) x 2 x (8+ 2/3x2) = 36X + 373

X = 58.3 kPa

Resolving the forces horizontally.

H_p + 2 x 58.3 x 2 + (1/2)x40x2 = (1/2) x 110 x 5.5

H_p = 29.3 kN/m