CV2014 – GEOTECHNICAL ENGINEERING AY21/22 SOLUTION

DONE BY: KEALEON LEE

Q1.

(a)(i) $peak\ deviator\ stress, (\sigma_1' - \sigma_3')_f = 100kPa$

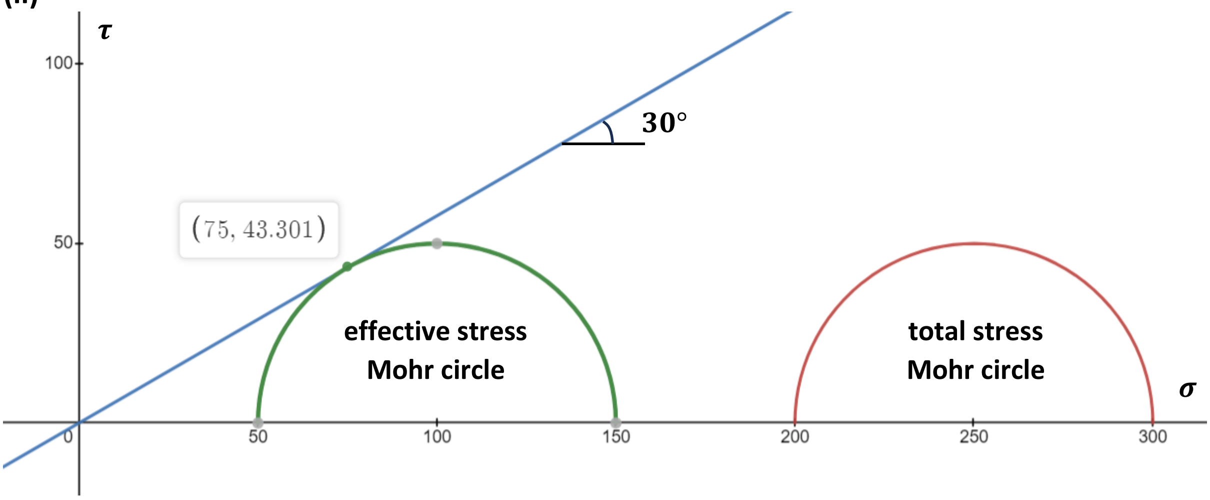
$peak\ pore\ water, u_f = 150kPa$

$\sigma_{3f}' = \sigma_{cell} - u_f = 200 - 150 = 50kPa$

$\sigma_{1f}' = \sigma_{3f}' + (\sigma_1' - \sigma_3')_f = 50 + 100 = 150kPa$

$\phi' = \sin^{-1}\left(\frac{\sigma_{3f}' - \sigma_{1f}'}{\sigma_{3f}' + \sigma_{1f}'}\right) = \sin^{-1}\left(\frac{150-50}{150+50}\right) = 30°, c_u = \frac{150-50}{2} = 50kPa$

(ii)



(iii) From the graph, shear stress is 43.3kPa and effective normal stress is 75kPa.

Otherwise, using geometry,

$x = 60\cos 60° = 25$

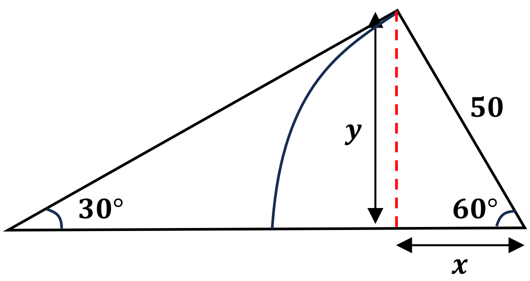
$y = 60\sin 60° = 43.301$

$center\ of\ Mohr\ circle\ (\sigma, \tau) = (100, 0)$

At failure plane:

$shear\ stress = 0 + 43.301 = 43.301kPa$

$effective\ normal\ stress = 100 - 25 = 75kPa$



(b)(i) $(\sigma_1 - \sigma_3)_1 = 86kPa, c_{u,1} = \frac{(\sigma_1-\sigma_3)_1}{2} = \frac{86}{2} = 43kPa$

$(\sigma_1 - \sigma_3)_2 = 86kPa, c_{u,2} = \frac{(\sigma_1-\sigma_3)_2}{2} = \frac{84}{2} = 42kPa$

$average\ c_u = \frac{43+42}{2} = 42.5kPa$

(ii) For UU test, since there is no consolidation, σ_3' is independent of σ_3. The failure deviator stress $(\sigma_1 - \sigma_3)_f$ is independent of σ_3. This would mean the total stress Mohr circle would have the same diameter and failure envelope would be horizontal. As such, the peak deviator stress obtained in both UU tests would be similar, if not, the same.

Q2.

(a)(i) $K_A = \frac{1-\sin 30}{1+\sin 30} = \frac{1}{3}$

$\sigma_o' = K_A \sigma_z' = \frac{1}{3}(4) = 1.33kPa$

$\sigma_1' = K_A \sigma_z' = \frac{1}{3}(4+18) = 7.33kPa$

$\sigma_2' = K_A \sigma_z' = \frac{1}{3}(4+18+(20-9.8)) = 10.73kPa$

$\sigma_2 = \sigma_z - 2c_u = (4+18+20) - 2(17) = 8kPa$

$\sigma_{2,w} = \gamma_w h_w = 9.8(1) = 9.8kPa$

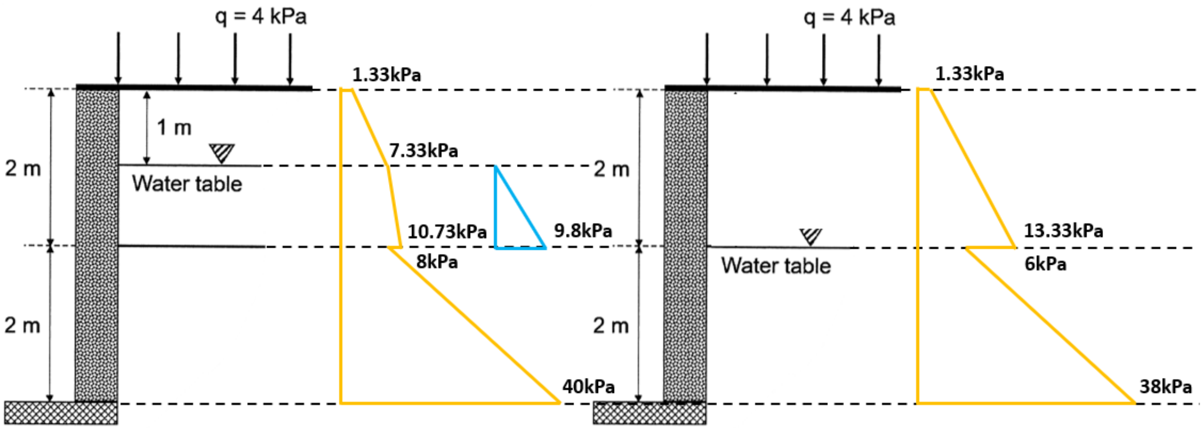
$\sigma_4 = \sigma_z - 2c_u = (4+18+20+2(16)) - 2(17) = 40kPa$

(ii) $\sigma_o' = K_A \sigma_z' = \frac{1}{3}(4) = 1.33kPa$

$\sigma_2' = K_A \sigma_z' = \frac{1}{3}(4+18(2)) = 13.33kPa$

$\sigma_2 = \sigma_z - 2c_u = (4+18(2)) - 2(17) = 6kPa$

$\sigma_4 = \sigma_z - 2c_u = (4+18(2)+2(16)) - 2(17) = 38kPa$



$Using\ trapezium\ formula, thrust = \frac{1}{2}(length)(\sigma_b - \sigma_a)$:

$thrust_{1m} = \frac{1}{2}[(1)(1.33+7.33) + (1)(7.33+10.73) + (2)(8+40) + (1)(9.8)$

$thrust_{1m} = 66.245kPa$

$thrust_{2m} = \frac{1}{2}[(2)(1.33+13.33) + (2)(6+38)] = 58.66kPa$

$\Delta thrust = thrust_{1m} - thrust_{2m} = 66.245 - 58.66 = 7.585kPa$

(b) $\Delta\sigma_z = \sum \frac{2qz^3}{\pi(x^2+z^2)^2} = \frac{2*25*2^3}{\pi(1^2+2^2)^2} + \frac{2*15*2^3}{\pi(4^2+2^2)^2} = 5.2839kPa$

Q3.

(i) Taking one unit slice,

$$W = \{(z - mz)\gamma + mz\gamma_{sat}\}1 = \{(1-m)\gamma + m\gamma_{sat}\}z$$

$$\sigma = \frac{W\cos\beta}{1/\cos\beta} = \frac{\{(1-m)\gamma + m\gamma_{sat}\}z\cos\beta}{1/\cos\beta}$$

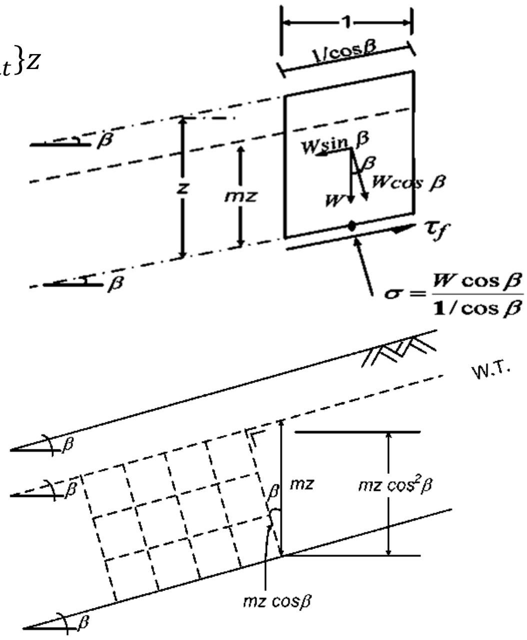
$$\sigma = \{(1-m)\gamma + m\gamma_{sat}\}z\cos^2\beta$$

$$\tau_{mob} = \frac{W\sin\beta}{1/\cos\beta} = \frac{\{(1-m)\gamma + m\gamma_{sat}\}z\sin\beta}{1/\cos\beta}$$

$$\tau_{mob} = \{(1-m)\gamma + m\gamma_{sat}\}z\sin\beta\cos\beta$$

$$h_w = mz\cos^2\beta$$

$$u = \gamma_w h_w = m\gamma_w z\cos^2\beta$$



Factor of Safety (drained):

$$F = \frac{\tau_f}{\tau_{mob}} = \frac{c' + (\sigma - u)\tan\phi'}{\tau_{mob}}$$

$$F = \frac{c' + \left[\{(1-m)\gamma + m\gamma_{sat}\}z\cos^2\beta - mz\gamma_w\cos^2\beta\right]\tan\phi'}{\{(1-m)\gamma + m\gamma_{sat}\}z\sin\beta\cos\beta}$$

(shown)

(ii) Factor of Safety (undrained):

$$F = \frac{\tau_f}{\tau_{mob}} = \frac{c_u}{\tau_{mob}}$$

$$F = \frac{c_u}{\{(1-m)\gamma + m\gamma_{sat}\}z\sin\beta\cos\beta}$$

(iii) Factor of Safety (short-term loading, undrained):

For water table at slope surface, m = 1,

$$F = \frac{c_u}{\{(1-m)\gamma + m\gamma_{sat}\}z\sin\beta\cos\beta} = \frac{c_u}{(m\gamma_{sat})z\sin\beta\cos\beta} = \frac{40}{(1)(18)(4)\sin 25^\circ\cos 25^\circ} = 1.4505 \approx 1.45$$

(iv) Factor of Safety (long-term loading, drained):

For water table at 2m from failure plane, mz = 2 → m = 2/4 = 0.5,

$$F = \frac{c' + \left[\{(1-m)\gamma + m\gamma_{sat}\}z\cos^2\beta - mz\gamma_w\cos^2\beta\right]\tan\phi'}{\{(1-m)\gamma + m\gamma_{sat}\}z\sin\beta\cos\beta}$$

$$F = \frac{20 + \left[\{(1-0.5)(17) + 0.5(18)\}(4)\cos^2 25^\circ - 0.5(4)(9.8)\cos^2 25^\circ\right]\tan 22^\circ}{\{(1-0.5)(17) + 0.5(18)\}(4)\sin 25^\circ\cos 25^\circ} = 1.3698 \approx 1.37$$

Q4.

(a) The main difference in the improvement of loose sand as compared to that of soft clay is the methods and techniques used to enhance their engineering properties. The key difference is that loose sand would employ compaction as a form of soil improvement, which helps to reduce air voids between grains, making the sand more stable. Whereas for soft clays, consolidation would be used as soil improvement, which helps to expel water and reduce settlement.

Generally speaking, for loose sand, compaction, in-situ densification, vibro-flotation, grouting, and soil reinforcement is used. For soft clays, precompression, vertical drains, admixtures are used.

(b) Grouting is the injection of special liquid or slurry materials, called grout, into the ground for the purpose of improving the soil or rock. Two main kinds of grouting:
(a) Cementitious grout made of Portland Cement, hydrates after injection
(b) Chemical grout, solidify once they are injected into the ground.

Stabilization with admixtures is when soil is mixed with admixtures, which provides artificial cementation thus increasing strength and reducing both compressibility and hydraulic conductivity. It also reduces the expansion potential in clays.

The main difference is that grouting forms a separate entity from surrounding soil or rock, whereas stabilization with admixtures forms a soil-admixture compound.

(c) The benefits of compaction in improving soil conditions includes:

(a) Increased shear strength, which reduces the potential for slope stability problems and enhances the fill's capacity for supporting loads,
(b) Decreased compressibility, which reduces the potential for excessive settlement.
(c) Decreased hydraulic conductivity, which inhibits the flow of water through the soil.
(d) Decreased void ratio reduces the amount of water in the soil and helps maintain the desirable strength properties.
(e) Increased erosion resistance, which helps maintain the ground surface in a serviceable condition.

One difference between compaction and consolidation is that compaction expels air, while consolidation expels water. Another difference is that compaction is a man-made and fast process, while consolidation is a natural and relatively slower process.

(d) Vibro-flotation (vibro-compaction) should be used. Treatment depths range from 3m to 15m, and silt content should be less than 12 to 15 percent. Dynamic compaction should not be used as the sand deposit is near a residential area.

A specially constructed probe that contains vibrators and water jets is lowered into the ground using a crane. The vibrator near the tip induces vibrations in the ground, and the water jets assist in the insertion and extraction of the probe. This would densifying the adjacent soils.

$$\rho_{relative} = \frac{e_{max}-e}{e_{max}-e_{min}} \rightarrow 0.8 = \frac{0.9-e}{0.9-0.25} \rightarrow e = 0.38$$

---END---

NOTE:

Do reach out to me at KEAL0001@e.ntu.edu.sg if you have any queries regarding any of my submitted workings. Feel free to leave an email to ask any questions covered in the curriculum, will be glad to help!

DISCLAIMER:

You are advised to take my solutions as a **guide**, rather than an absolute answer to the questions.