CV2014 – GEOTECHNICAL ENGINEERING AY22/23 SOLUTION

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Q1.

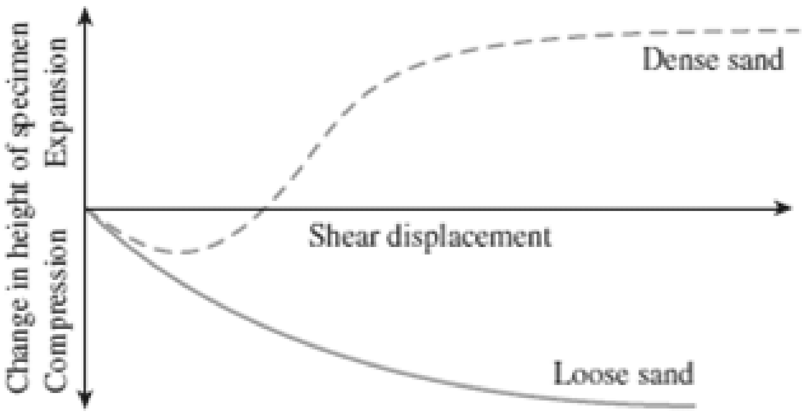
(a)(i) $\phi_{peak} = \tan^{-1}\left(\frac{98}{150}\right) = 33.158° \approx 33.2°$

$\phi_{ult} = \tan^{-1}\left(\frac{75}{150}\right) = 26.565° \approx 26.6°$

(ii) The anticipated friction angle is the same as ϕ_{ult} of 26.6°.

As the direct shear test is performed on both loose and dense sand, the grains reorient themselves and rearrange during shearing. In the case of loose sand, the initial voids between grains allow them to reorganize more easily, resulting in an increase in interlocking and friction between particles. On the other hand, dense sand already has a significant degree of interlocking due to its denser packing, so the additional shearing during the test may not cause a significant change in friction angle. This would result in the peak friction angle of loose sand being the same as the ultimate friction angle of dense sand.

(iii)



(b)(i) $peak\ deviator\ stress, (\sigma_1' - \sigma_3')_f = 120kPa$

$peak\ pore\ water, u_f = 120kPa$

$\sigma_{3f}' = \sigma_{cell} - u_f = 300 - 120 = 180kPa$

$\sigma_{1f}' = \sigma_{3f}' + (\sigma_1' - \sigma_3')_f = 180 + 120 = 300kPa$

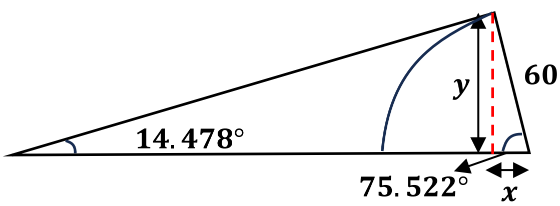
$\phi' = \sin^{-1}\left(\frac{\sigma_{3f}' - \sigma_{1f}'}{\sigma_{3f}' + \sigma_{1f}'}\right) = \sin^{-1}\left(\frac{300-180}{300+180}\right) = 14.478° \approx 14.5°, c_u = \frac{300-180}{2} = 60kPa$

(ii) using geometry,

$x = 60\cos 75.522° = 15$

$y = 60\sin 75.522° = 58.095$

$center\ of\ Mohr\ circle\ (\sigma, \tau) = (240, 0)$



At failure plane:

$shear\ stress = 0 + 58.095 = 58.095kPa$

$effective\ normal\ stress = 240 - 15 = 225kPa$

(iii) Void ratio decreases at the end of the CU test, as compared to the void ratio after consolidation occurs. During the CU test, the clay sample would first undergo isotropic consolidation and while being prevented from draining any excess pore water, the sample would experience a reduction in voids.

Progressively, a deviator stress would be applied onto the clay sample, leading to further decrease in void ratio due to the collapse of void spaces as the clay particles reorient and rearrange under the applied stress conditions. This would mean a decrease of void ratio at the end of the CU test, as compared to the void ratio after consolidation occurs.

Q2.

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

$\sigma_o' = K_A\sigma_z' = \frac{1}{3}(8) = 2.67kPa$

$\sigma_2' = K_A\sigma_z' = \frac{1}{3}(8+20(2)) = 16kPa$

$\sigma_2 = \sigma_z - 2c_u = (8+20(2)) - 2(18) = 12kPa$

$\sigma_4 = \sigma_z - 2c_u = (8+20(2)+2(16)) - 2(18) = 44kPa$

(b) Given that total unit weight does not change, $\gamma_{sand} = 20kN/m^3$ above and below GWT.

$\sigma_o' = K_A\sigma_z' = \frac{1}{3}(8) = 2.67kPa$

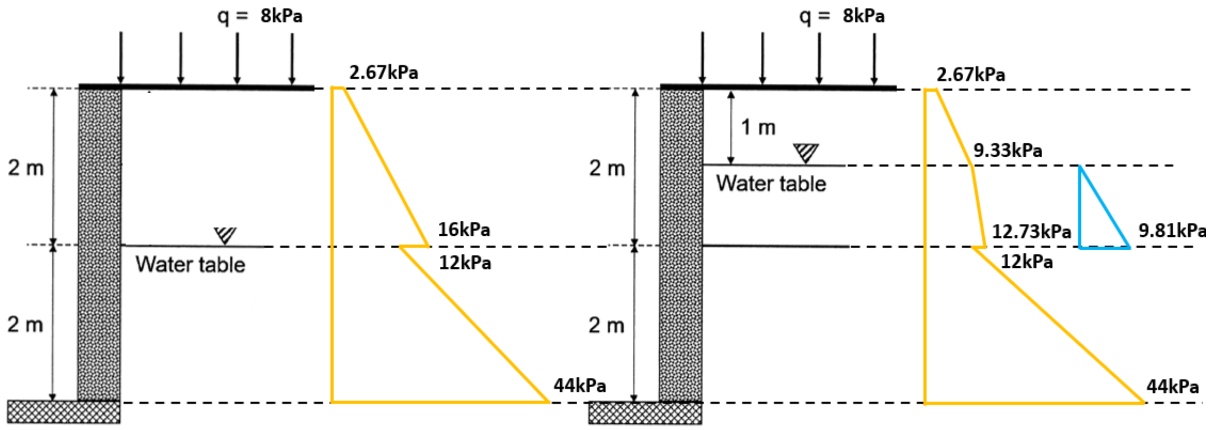
$\sigma_1' = K_A\sigma_z' = \frac{1}{3}(8+20(1)) = 9.33kPa$

$\sigma_2' = K_A\sigma_z' = \frac{1}{3}(8+20(1)+(20-9.81)(1)) = 12.73kPa$

$\sigma_2 = \sigma_z - 2c_u = (8+20(2)) - 2(18) = 12kPa$

$\sigma_{2,w} = \gamma_w h_w = 9.81(1) = 9.81kPa$

$\sigma_4 = \sigma_z - 2c_u = (8+20(2)+2(16)) - 2(18) = 44kPa$



$thrust_{new} = \frac{1}{2}[(2.67+9.33)(1) + (9.33+12.73)(1) + (12+44)(2)] + \frac{1}{2}(9.81)(1)$

$thrust_{new} = 77.935kPa$

$thrust_{old} = \frac{1}{2}[(2.67+16)(2) + (12+44)(2)] = 74.67kPa$

$\Delta thrust = 77.935 - 74.67 = 3.265kPa$

NOTE: Can't get the exact numerical solution but I believe my solution is correct.

(c)

Rankine's earth pressure theory	Coulomb's earth pressure theory
1. Wall is vertical	1. Wall can be inclined
2. Wall is perfectly smooth	2. Wall can be rough
3. Resultant force acts parallel to ground	3. Resultant force acts at an angle to the wall

Q3.

(a)(i) $F = \frac{c_u L_a r}{Wd + P(1+d)}$

$1 = \frac{(37)(18.9)(12.1)}{(70)(18)(4.5)+P(1+4.5)} \rightarrow P = 507.551kN/m$

(ii) For water layer of 3m height at slope surface,

$u = \gamma_w h_w = 10(3) = 30kPa$

$thrust = \frac{1}{2}(30)(3) = 45kN/m$

$F = \frac{c_u L_a r + thrust(d_{thrust})}{Wd + P(1+d)} \rightarrow 1.5 = \frac{c_u(18.9)(12.1)+(45)(3.5+8-1)}{(70)(18)(4.5)+(100)(1+4.5)} \rightarrow c_u = 38.73kPa$

(b) Information required:

- Unit weight of soil
- Groundwater table level
- Geometry of slope
- Friction angle of slope

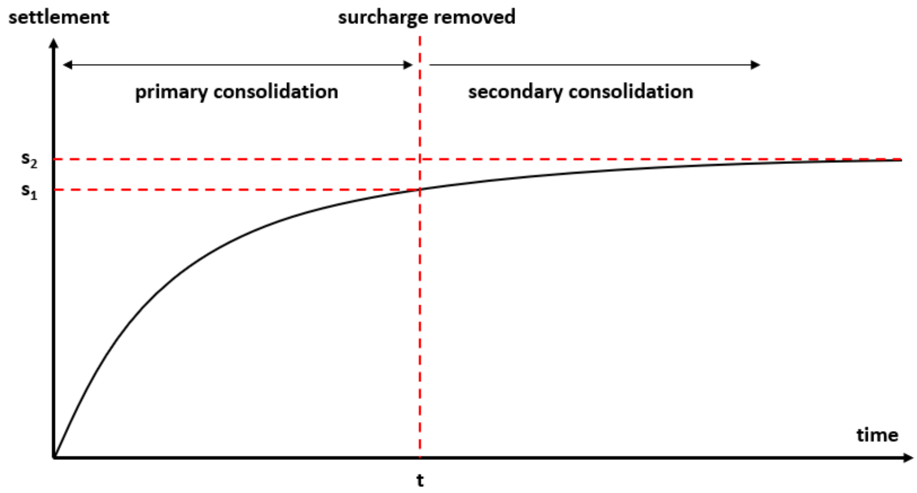
Site investigation works and laboratory tests:

- Triaxial tests
- Sand cone test
- Proctor Compaction test
- Installation of piezometers

(c) Inclinometer is used to measure horizontal movements in the ground as a function of depth. A vertical boring is drilled to a depth well below the potential zone of movement and a special plastic casing is inserted. The annular zone around the casing is then backfilled to hold it firmly in place. Thus, as the ground moves horizontally, the casing deforms with it. The readings taken would illustrate the horizontal displacement along the span of the inclinometer.

By installing various inclinometers along potential slip planes, individuals can determine variation in the ground movement and high readings can help to deduce location of incipient failure surface.

Q4.
(a)



At the beginning of surcharge loading, the soil would experience large amount of settlement, e.g. s_1, in a short period of time. This initial settlement experienced is due to primary consolidation from the loading of surcharge.

After a specific amount of settlement or certain desired properties are achieved at time t, the surcharge is removed, and the soil would undergo secondary consolidation without the additional surcharge. The settlement experienced would be ($s_2 - s_1$), which is much lower than that of the settlement experienced during primary consolidation.

Thus, by imposing a surcharge on the existing soil, it would reduce compressibility as a large part of consolidation occurs during precompression and minimize settlement after precompression.

(b) $effective\ stress, \sigma' = total\ stress, \sigma - pore\ water\ pressure, u$

Initially, when clay undergoes precompression, it would be subjected to higher total stress. The excess stress would be transferred to pore water pressure as excess pore water pressure. Gradually, the clay would consolidate, and excess pore water pressure would be dissipated. This decrease in pore water pressure would mean an increase in effective stress as total stress does not change due to constant loading of the surcharge.

The increase in effective stress would lead to improved bonds between clay particles and the clay would experience an increase in shear strength.

(c) The objective of earthwork construction is to change the ground surface from some initial configuration, typically described by a topographic map, to some final configuration, as described on a new topographic map known as a grading plan.

The five stages of conventional earthworks are:

1. Cleaning above and below ground from undesirable materials
2. Excavation to remove soil or rock
3. Transportation of soil/fill
4. Placement of soil/fill
5. Compaction to increase engineering properties

(d) $993cm^3 = 0.000993m^3$

$$\gamma_d = \frac{W_d}{V_s} = \frac{M_s g}{V_s} = \frac{(1.845)(9.81)}{0.000993} = 18.227kN/m^3$$

$$relative\ compaction = \frac{18.227}{18.5} = 98.5\% > 95\% \rightarrow OK!$$

$$w = \frac{1945-1845}{1845} = 5.42\%, don't\ fall\ in\ (12.5 \pm 2.5)\% \rightarrow not\ OK!$$

$$G_s = \frac{\rho_s}{\rho_w} \rightarrow \ \rho_s = 2.7$$

$$V_s = \frac{M_s}{\rho_s} = \frac{\gamma_d}{G_s g} = \frac{18.227}{(2.7)(9.81)} = 0.688$$

$$w = S_r \left[\frac{\gamma_w}{\gamma_d} - \frac{1}{G_s}\right] \times 100$$

$$S_r = \frac{w}{\frac{\gamma_w}{\gamma_d} - \frac{1}{G_s}} = \frac{0.0542}{\frac{9.81}{18.227} - \frac{1}{2.7}} = 0.3229 = 32.29\%$$

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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.