DELFT UNIVERSITY OF TECHNOLOGY

Faculty of Civil Engineering and Geosciences

Soil Mechanics

CTB2310 / AESB2330

BSc EXAMINATION 2017

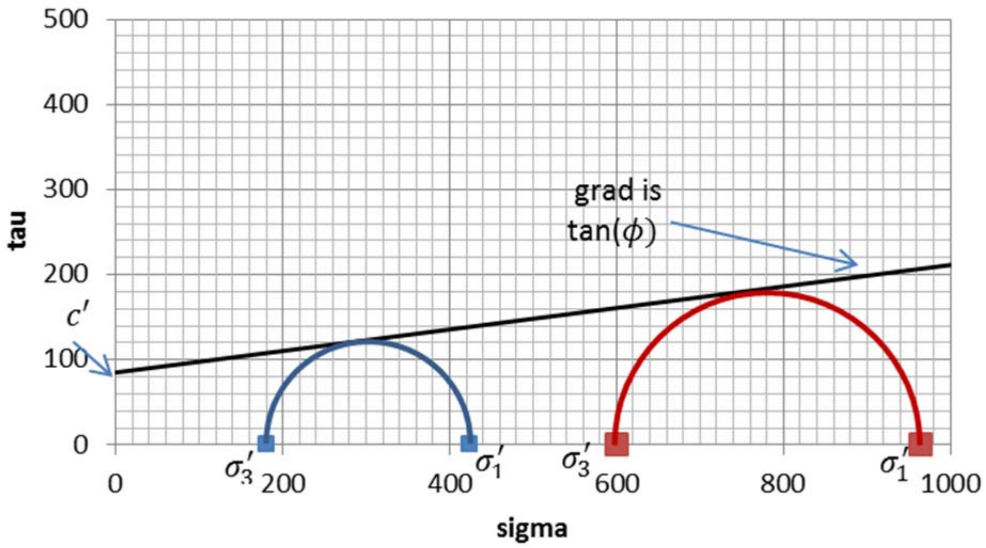
THIRD PERIOD

DATE: 18 APRIL 2017 TIME: 13.30 – 16.30

Answer ALL Questions
(Note that the questions carry unequal marks)

Other instructions
Write your name and student number on each sheet

Clearly identify the answer in the answer box

Question No.	Workings	Answer
1a	$\Delta p = B(\Delta\sigma_3 + A(\Delta\sigma_1 - \Delta\sigma_3))$ In the consolidation stage: $(\Delta\sigma_1 - \Delta\sigma_3) = 0$, therefore $\Delta p = B(\Delta\sigma_3)$ $387 - p_0 = B(400)$ $576 - p_0 = B(600)$ Solve for B: $B = \frac{576 - 387}{600 - 400} = 0.945$ For test 1 A can be determined. For test 2 A cannot be determined as pore pressures are not generated as the test is drained. From the equation at the top: $220 - 0 = 0.945(0 + A(245 - 0))$ Using the above A = 0.95	B=0.945 Test 1 A = 0.95 Test 2 A cannot be determined.
1b	Test 1: $\sigma_1' = 645 - 220 = 225\ kPa,\ \sigma_3' = 400 - 220 = 180\ kPa$ Test 2: $\sigma_1' = 965\ kPa,\ \sigma_3' = 600\ kPa$  	
1c	Can estimate from figure (2 points lower) or from equation for M-C parameters: $\sigma_1' = \sigma_3' tan^2\left(45 + {\phi'}/{2}\right) + 2c' tan\left(45 + {\phi'}/{2}\right)$ Solve simultaneously with subtraction: $965 - 425 = (600 - 180)tan^2\left(45 + {\phi'}/{2}\right)$ $\phi' = 7.2°$ Back substitute for c'	$c' = 85.4\ kPa$ $\phi' = 7.2°$

1d	Using the elastic equations (Hooke's Law): $$\Delta\varepsilon_1 = \frac{1}{E}[\Delta\sigma_1 - v(\Delta\sigma_2 + \Delta\sigma_3)]$$ $$\Delta\varepsilon_3 = \frac{1}{E}[\Delta\sigma_3 - v(\Delta\sigma_1 + \Delta\sigma_2)]$$ For a drained triaxial: $$\Delta\sigma_3 = \Delta\sigma_2 = 0$$ $$\Delta\varepsilon_1 = \frac{1}{E}[\Delta\sigma_1]$$ $$\Delta\varepsilon_3 = -\frac{1}{E}[v\Delta\sigma_1]$$	$E \approx 1280\ kPa$ $v \approx 0.36$

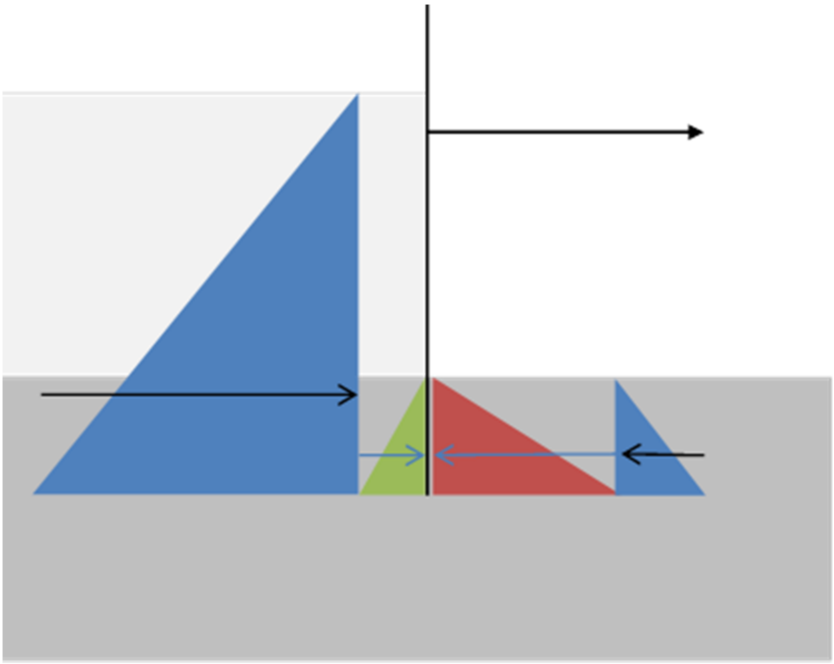
Axial stress, σ_1 (kPa)	Axial strain, ε_1 (-)	Radial strain, ε_r (-)	E (kPa)	v (-)
600	0	0		
675	0.0583	-0.02	1286.45	0.34
750	0.1163	-0.041	1293.10	0.36
825	0.175	-0.063	1277.68	0.37
900	0.267	-0.105	815.22	0.46
965	0.376	-0.171	596.33	0.61

Elastic part is the first part so:

$$E \approx 1280\ kPa$$
$$v \approx 0.36$$

Question No.	Workings	Answer
2a	The volumetric weight, $\gamma = W/V$ Initially: $$W = \frac{2175 \times 10}{1000 \times 1000} = 0.02175kN$$ $$V = 0.15 \times \frac{0.1^2 \times \pi}{4} = 1.18 \times 10^6 mm^3 = 0.00118m^3$$ $$\gamma = 18.46\ kN/m^3$$	$\gamma = 18.46\ kN/m^3$
2b	The porosity, $n = V_p/V_t$ The sample is not saturated so the volume of voids cannot be calculated from the water content. It can be calculated from the volume of solids: Mass of solids: $$M_s = 230 + 1030 + 460 = 1720g$$ Volume of solids: $$V_s = \frac{M_s}{\rho_s} = \frac{1720}{1000 \times 2665} = 0.000645m^3$$ Volume of voids: $$V_p = V_t - V_s = 0.00118 - 0.000645 = 0.000533m^3$$ $$n = \frac{V_p}{V_t} = \frac{0.000533}{0.00118} = 0.45$$	0.45
2c	Degree of saturation, $S_r = V_w/V_p$ Mass of water initially: $$M_w = 2175 - 1720 = 455g$$ Volume of water: $$V_w = \frac{455}{1000 \times 1000} = 0.000455m^3$$ Degree of saturation: $$S_r = \frac{0.000455}{0.000533} = 0.85$$	0.85
2d	Degree of saturation, $S_r = V_w/V_p$ Mass of water after 10 days: $$M_w = 2132 - 1720 = 412g$$ Volume of water:	0.77

	$$V_w = \frac{412}{1000 \times 1000} = 0.000412 m^3$$ Degree of saturation: $$S_r = \frac{0.000412}{0.000533} = 0.77$$	
2e	Dry volumetric weight, $\gamma_d = W_d/V$ Initially: $$W = \frac{1720 \times 10}{1000 \times 1000} = 0.01720 kN$$ $$V = 0.15 \times \frac{0.1^2 \times \pi}{4} = 1.18 \times 10^6 mm^3 = 0.00118 m^3$$ $$\gamma = 14.60\ kN/m^3$$	$\gamma = 14.60\ kN/m^3$
2f	Sand	Sand

Question No.	Workings	Answer
3a	The worst case is either high or low tide when the before generation. The difference is the direction of the force in the prop.  Green = active, Red = passive and Blue = neutral (from water pressure, K=1) Note that is assumed that there is no flow and all water pressures are hydrostatic.	
3b	Assuming no friction on the wall. $$K_a = \frac{1-\sin(\phi)}{1+\sin(\phi)} = 0.41$$ $$K_p = 2.46$$ $$Q_a = \frac{1}{2}K_a\gamma' d^2 = \frac{1}{2} \times 0.41 \times (19-10) \times d^2 = 1.83d^2\ kN/m$$ $$Q_p = \frac{1}{2}K_p\gamma' d^2 = \frac{1}{2} \times 2.46 \times (19-10) \times d^2 = 11.1d^2\ kN/m$$ $$Q_{w1} = \frac{1}{2}\gamma_w {h_{Qw1}}^2 = \frac{1}{2} \times 10 \times (4+d)^2 = 80 + 40d + 5d^2\ kN/m$$ $$Q_{w2} = \frac{1}{2}\gamma_w {h_{Qw2}}^2 = \frac{1}{2} \times 10 \times d^2 = 5d^2\ kN/m$$ To determine d, take moments around fixed point, i.e. tension anchor.	d=9.14 m $T = -381.1kN/m$

	Locations of action (from tension anchor): $$d_a = d_p = d_w = \frac{2}{3}d + 3.5$$ $$d_{w1} = \frac{2}{3}(4 + d) - 0.5 = 2.17 + \frac{2}{3}d$$ Moments (note the 1.5 is to give the FoS=1.5): $$1.5\left[(1.83d^2)\left(\frac{2}{3}d + 3.5\right) + (80 + 40d + 5d^2)\left(\frac{2}{3}d + 2.17\right)\right] = (11.1d^2)\left(\frac{2}{3}d + 3.5\right) + (5d^2)\left(\frac{2}{3}d + 3.5\right)$$ $$260 + 210d + 9.5d^2 - 3.90d^3 = 0$$ $d = 9.14$ m Horizontal force equilibrium shows that prop must withstand: $$T = 152.6 + 926.3 - 863.3 - 417.7 = -328.1kN / m$$	
3c	If there is soil on the inside, then the worst case scenario is now when the inside has the water and the soil acts as an active force. The difference is then in: $$Q_a = \frac{1}{2}K_a\gamma' d^2 = \frac{1}{2} \times 0.41 \times (19 - 10) \times (d + 1)^2 = 187.8\ kN/m$$ The rotational equilibrium can then be written: $$FOS\left[187.8 \times \left(\frac{2}{3}(d + 1) + 2.5\right) + (926.3)(9.59)\right] = (863.3)(8.26) + (417.7)(9.59)$$ Then solving: $$FOS = 1.45$$	$FOS = 1.45$

Question No.	Workings	Answer
4a	Use the Brinch Hansen method. Load is not inclined and foundation is long, so no shape factors. $$p_c = cN_c + qN_q + \frac{1}{2}\gamma' B N_\gamma$$ Calculate N factors: $$N_q = \frac{1+\sin\phi}{1-\sin\phi}\exp(\pi \tan\phi) = 18.4$$ $$N_c = (N_q - 1)\cot\phi = 30.1$$ $$N_\gamma = 2(N_q - 1)\tan\phi = 20.1$$ Calculate overburden: $$q = 1(18-10) = 8\ kN/m^2$$ Allowable bearing capacity: $$p_c = 981\ kN/m^2$$ Total load from the factory onto the foundation is: $$p_a = \frac{50 \times 50 \times 50}{(50 \times 4) \times 1} = 625\ kN/m^2$$ Can either add the water pressure onto the capacity or take off from the applied stress: FOS is either: $$FOS = \frac{p_c}{p_a} = \frac{981+10}{625} = 1.59$$ Or: $$FOS = \frac{p_c}{p_a} = \frac{981}{625-10} = 1.60$$	1.59 or 1.60
4b	Calculate overburden: $$q = 2(18-10) = 16\ kN/m^2$$ Calculate shape factors (B/L=1) $$s_c = 1.2, s_q = 1.5, s_\gamma = 0.7$$ Allowable bearing capacity: $$p_c = 1458\ kN/m^2$$ Total load from the factory onto the foundation is:	0.94 or 0.95

	$$p_a = \frac{50 \times 50 \times 50}{(4) \times 20} = 1562.5\ kN/m^2$$ FOS: $$FOS = \frac{p_c}{p_a} = \frac{1458 + 20}{1563} = 0.95$$ Or: $$FOS = \frac{p_c}{p_a} = \frac{1458}{1563 - 20} = 0.94$$	
4c	Split clay into 2 layers Effective stress at the beginning at the centre of the two layers: $$at - 2m\ \sigma_v' = 8 \times 2 = 16.0\ kPa$$ $$at - 6m\ \sigma_v' = 8 \times 6 = 48.0\ kPa$$ Use Flamant line load, as a strip foundation is similar to a line load. Can also use the strip foundation formula, which will result in similar values. $$\Delta\sigma_v' = \frac{2F}{\pi d}$$ $$F = 625kN/m$$ $$at - 2m\ \Delta\sigma_v' = \frac{2F}{\pi d} = 199.0kPa$$ $$at - 6m\ \Delta\sigma_v' = \frac{2F}{\pi d} = 66.3kPa$$ Strain: $\varepsilon = \frac{1}{C_{10}} \log\left(\frac{\sigma'}{\sigma'_1}\right)$ Therefore strain at one side is: $$at - 2m\ \varepsilon = \frac{1}{30} \log\left(\frac{199 + 16}{16}\right) = 0.0376$$ $$at - 6m\ \varepsilon = \frac{1}{30} \ln\left(\frac{66.3 + 48}{48}\right) = 0.0126$$ Deformation, $u = 4 \times (\varepsilon_1 + \varepsilon_2)$ $$= 4 \times (0.0376 + 0.0126) = 0.201\ m$$ Strain at other side is: $$at - 2m\ \varepsilon = \frac{1}{50} \log\left(\frac{199 + 16}{16}\right) = 0.0226$$ $$at - 6m\ \varepsilon = \frac{1}{50} \ln\left(\frac{66.3 + 48}{48}\right) = 0.0075$$ Deformation, $u = 4 \times (\varepsilon_1 + \varepsilon_2)$ $$= 4 \times (0.0226 + 0.00756) = 0.120\ m$$ Differential settlement is 0.201-0.120 = 0.080m or 8cm	8cm