DELFT UNIVERSITY OF TECHNOLOGY

Faculty of Civil Engineering and Geosciences

Soil Mechanics

CTB2310 / AESB2330

BSc EXAMINATION 2019

FOURTH PERIOD

DATE: 2 JULY 2019 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	Density = mass / volume Mass = 450g = 0.45kg Volume = $(\pi * 50^2 / 4) \times 200 \times 10^{-9} = 0.00039m^3$ Density, $\rho = 0.45 / 0.00039 = 1154kg/m^3$	$1154\ kg/m^3$
1b	$\gamma = W/V$ $= \rho * g$ $=1154*10 = 11540N/m^3 = 11.5kN/m^3$	$11.5\ kN/m^3$
1c	Soil is very light. Probably peat.	Peat
1d	$\gamma = W/V$ W = 0.383*10 = 3.83N $V = (\pi * 50^2 / 4) * 173 * 10^{-9} = 0.00034m^3$ $\gamma = 3.83 / 0.00034 = 11264$ N/m3 $= 11.3kN/m^3$	$11.3\ kN/m^3$
1e	Water content, $w = W_w/W_p$ (weight water / weight particles) W_w=450 – 383 = 67g W_p= 383g w = (67 / 383) * 100 = 17.5%	17.5%
1f	Original Void ratio, e_o $e = V_v / V_s$ $V_s = M_s * g / \gamma_s$ = 0.383(kg) * 10 / 15000(N/m3) = $0.255x10^{-3}m^3$ $V_v = V_t – V_s = 0.00039 – 0.000255 = 0.135x10^{-3}m^3$ (or could calculate from weight of water) e_o = 0.135 / 0.255 = 0.53 (dimensionless) New Void ratio, e_n $V_s = 0.255x10^{-3}m^3$ $V_v = V_t – V_s = 0.00034 – 0.000255 = 0.085x10^{-3}m^3$ (or could calculate from weight of water) e_n = 0.085 / 0.255 = 0.33 (dimensionless)	0.53 (dimensionless) 0.33 (dimensionless)

Question No.	Workings	Answer
2a	Using the Brinch Hansen method: $p_c' = c'N_c i_c s_c + q'N_q i_q s_q + \frac{1}{2}\gamma' B N_\gamma i_\gamma s_\gamma$ No inclination factors or shape factors. Therefore, only the N factors needed. $N_q = \frac{1+sin\ \phi}{1-sin\ \phi}\exp(\pi\ tan\ \phi) = \frac{1+sin\ 15}{1-sin\ 15}\exp(\pi\ tan\ 25) = 3.94$ $N_c = (N_q - 1)cot\ \phi = 10.98$ $N_\gamma = 2(N_q - 1)tan\ \phi = 1.58$ As no inclination or shape factors: $p_c' = c'N_c + q'N_q + \frac{1}{2}\gamma' B N_\gamma$ $q' = \gamma' d = (18-10)\times 1.5 = 12\ kPa$ $p_c' = c'N_c + q'N_q + \frac{1}{2}\gamma' B N_\gamma = 25\cdot 10.98 + 12\cdot 3.94 + \frac{1}{2}\cdot 8\cdot 0.75\cdot 1.58 = 326 kPa$ $p_a = \frac{100}{0.75} = 133\ kPa$ In the FoS: $FOS = \frac{p_c + 15}{p_a} = 2.56$ Will also accept FoS calculated in effective capacities: $FOS = \frac{p_c}{p_a - 15} = 2.76$	2.56
2b	Initial effective stresses: $\sigma'_{1m} = d\gamma' = 2.5\times 8 = 20 kPa$ $\sigma'_{4m} = d\gamma' = 5.5\times 8 = 44 kPa$ Use Flamant's technique, either a strip or a line load answers are almost identical: $\sigma_{zz} = \frac{2p}{\pi}\left(\tan^{-1}\left(\frac{a}{z}\right) + \frac{az}{a^2+z^2}\right)$ $\sigma_{zz} = \frac{2F}{\pi}\frac{z^3}{r^4}$ Calculate p or F including soil that has been removed $p = \frac{100}{0.75} - 1.5\times 8 = 121\ kPa, F = 100 - 0.75(1.5\times 8) = 91\ kN$ $\Delta\sigma'_{1m} = \frac{2\times 121}{\pi}\left(\tan^{-1}\left(\frac{0.375}{1}\right) + \frac{0.375}{0.375^2 + 1^2}\right) = 22.83\ kPa$ $\Delta\sigma'_{1m} = \frac{2\times 121}{\pi}\left(\tan^{-1}\left(\frac{0.375}{4}\right) + \frac{0.375}{0.375^2 + 4^2}\right) = 10.50\ kPa$	Initial $\sigma'_{1m} = 20\ kPa$ $\sigma'_{4m} = 44\ kPa$ Final $\sigma'_{1m} = 42.8\ kPa$ $\sigma'_{4m} = 54.50\ kPa$

$$\sigma'_{1m} = 20 + 22.83 = 42.8\ kPa$$
$$\sigma'_{4m} = 44 + 10.50 = 54.50\ kPa$$

2c

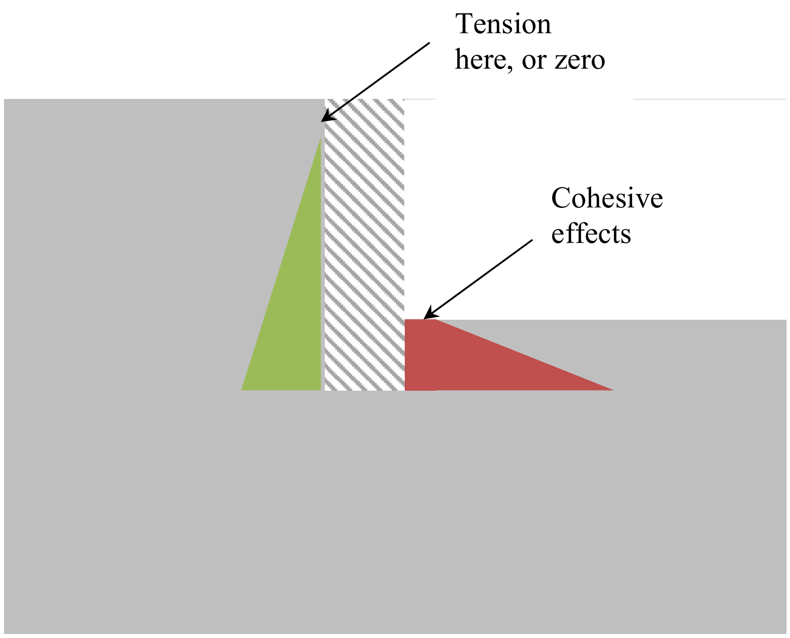
- Split clay into 2 layers
- Calculate effective stress before construction at the centre of the layers
- Strain: $\varepsilon = \frac{1}{C_p}\ln\left(\frac{\sigma'}{\sigma'_1}\right)$ and displacement is then $disp = \sum \varepsilon d$, where d is the sub-layer thickness.

layer centre depth (m)	$\sigma_v'_1$ (kPa)	Strip (kPa)	Line (kPa)	Strain (-)	Layer thickness (m)	Deform. (m)
1	20	22.8	23.2	0.051	2	0.10
4	44	10.5	10.5	0.014	4	0.06
				Displacement (m)		**0.16**

0.16m

Question No.	Workings	Answer
3a	Pore pressure equation is: $$\Delta p = B(\Delta\sigma_3 + A(\Delta\sigma_1 - \Delta\sigma_3))$$ In the consolidation stage, set up equations for each test: $$80 - p_0 = B\big(100 + A(0)\big)$$ $$250 - p_0 = B\big(300 + A(0)\big)$$ $$B = \frac{250 - 80}{300 - 100} = 0.85$$ $$p_0 = -5\ kPa$$	$B = 0.85$ p_0 $= -5\ kPa$
3b	Pore pressure equation is: $$\Delta p = 0.85(\Delta\sigma_3 + A(\Delta\sigma_1 - \Delta\sigma_3))$$ For test 1: $$21 - 0 = 0.85(0 + A(245 - 0))$$ $$A = 0.10$$ For test 2: $$116 - 0 = 0.85(0 + A(332 - 0))$$ $$A = 0.411$$	Test 1 $A = 0.10$ Test 2 $A = 0.41$
3c	Calculate principle effective stresses at failure: Test 1 $$\sigma_1' = \sigma_1 - p = 345 - 21 = 324\ kPa$$ $$\sigma_3' = \sigma_3 - p = 100 - 21 = 79\ kPa$$ Test 2 $$\sigma_1' = \sigma_1 - p = 632 - 116 = 516\ kPa$$ $$\sigma_3' = \sigma_3 - p = 300 - 116 = 184\ kPa$$ Solve from principle stresses at failure, using (for example): $$\sigma_1' = \sigma_3' tan^2\left(45 + {\phi'}/{2}\right) + 2c' tan\left(45 + {\phi'}/{2}\right)$$ Solve by simultaneous equations: $$tan^2\left(45 + {\phi'}/{2}\right) = \frac{516 - 324}{184 - 79} = 1.83$$ $$\phi' = 17.0°$$ Fill is equation for either test: $$c' = 66.4\ kPa$$	$\phi' = 17.0°$ c' $= 66.4\ kPa$

Question	Workings	Answer

No.		
4a	Using the Prandtl/Brinch Hansen formula: $q = \gamma d = 20 \times 2 = 40\ kPa$ $N_q = 1, N_c = 5.14$ $p_c = 5.14 s_u + q = 5.14 \times 75 + 40 \times 1 = 425.5\ kPa$ Applied load $p_a = \gamma_c h = 24 \times 8 = 192\ kPa$ $FoS = \frac{425.5}{192} = 2.22$	2.22
4b	 Green = active, Red = passive, no water loads Minus 3 points if cohesive effects are not shown.	
4c	Determine the active and passive lateral earth pressure coefficients. Note that the wall has friction and the soil has cohesion. Using the tables on the formula sheet, where α=90°, β=0°, δ=10° and ϕ=20°. $K_p = 2.635$ $K_a = 0.447$ Calculate the horizontal forces: For the passive side: $Q_p = \frac{1}{2} K_p \gamma h^2 + 2ch\sqrt{K_p}$	$Q_a = 179\ kN/m$ $Q_p = 235\ kN/m$

	$$Q_p = \frac{1}{2} \times 2.635 \times 20 \times 2^2 + 2 \times 20 \times 2 \times \sqrt{2.635}$$ $$= 235\ kN\ /\ m$$ For the active side the height that is not in tension must be calculated (only lose 1 point if use full height): $$h_r\ = h - \frac{2c}{\gamma\sqrt{K_a}} = 5.00m$$ $$Q_a = \frac{1}{2} K_a \gamma h_r^2 = 179\ kN/m$$	
4d	Convert from total to horizontal force: Multiply forces by: $\sin(\alpha - \delta)$ where $\delta = 10°$ active, and $\delta = -10°$ passive $$Q_{ahor} = 179 \sin(90 - 10) = 176\ kN/m$$ $$Q_{pho}\ = 235 \sin(90 + 10) = 232\ kN\ /\ m$$ Friction from wall: $$R = W tan\delta = 8 \times 2.5 \times \gamma_{conc} \times tan10$$ $$= 84.6\ kN/m$$ $$Q_{slide} = 176\ kN/m$$ $$Q_{resist} = 232 + 85 = 316\ kN/m$$ $$Q_{resist} = Q_{slide} FOS$$ $$FOS = 1.79$$	$FOS = 1.79$