DELFT UNIVERSITY OF TECHNOLOGY

Faculty of Civil Engineering and Geosciences

Soil Mechanics

CTB2310 / AESB2330

BSc EXAMINATION 2016

FOURTH PERIOD

DATE: 28 JUNE 2016 TIME: 13.30 – 16.30

Answer ALL Questions

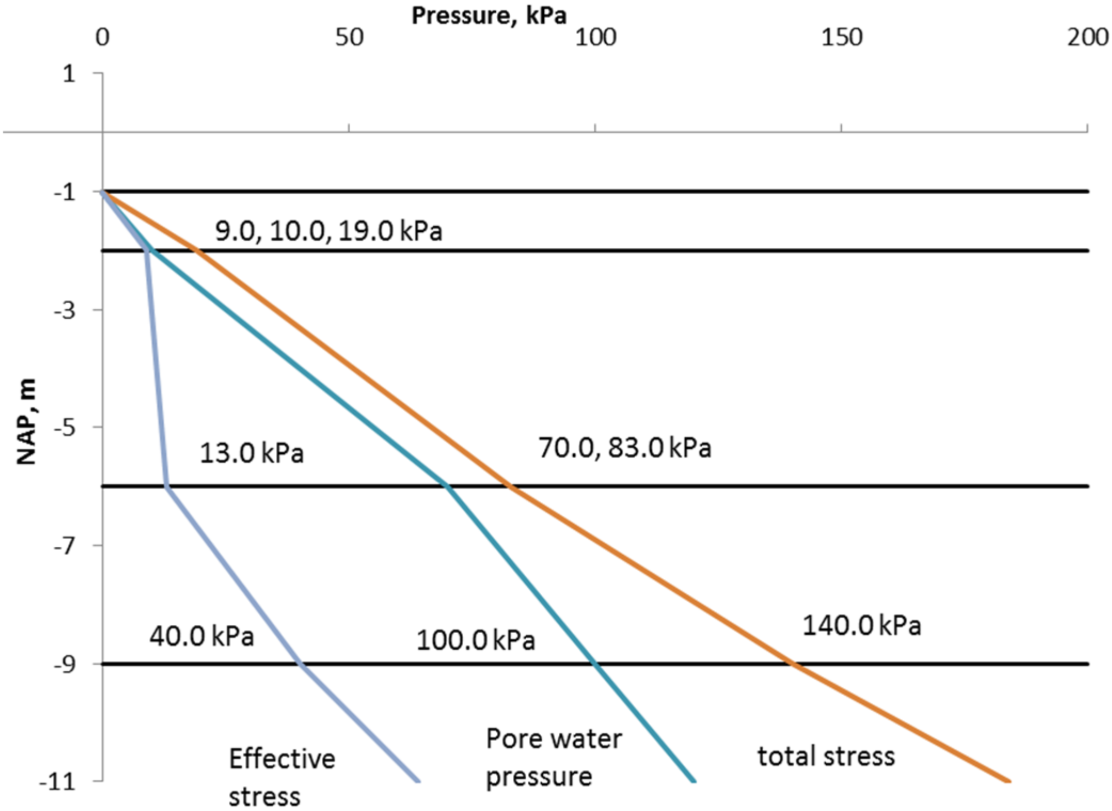
Other instructions

Write your name and student number on each sheet

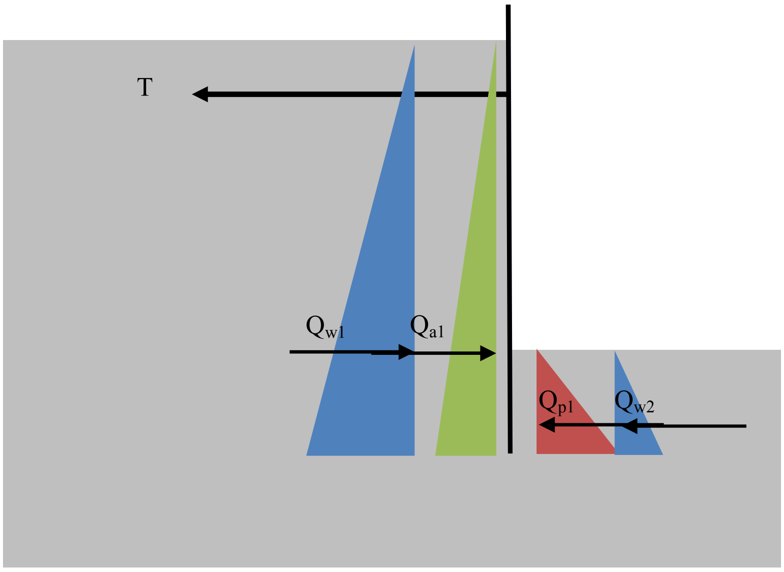
Clearly identify the answer in the answer box

Question No.	Workings	Answer
1a	Use Brinch Hansen: $$p_c = cN_c i_c s_c + qN_q i_q s_q + \frac{1}{2}\gamma' B N_\gamma i_\gamma s_\gamma$$ No inclination factors (no wind loads) Calculate N factors: $$N_q = \frac{1+sin\,\phi}{1-sin\,\phi}\exp(\pi\,tan\,\phi)$$ $$= \frac{1+sin\,15}{1-sin\,15}\exp(\pi\,tan\,15) = 3.94$$ $$N_c = (N_q - 1)cot\,\phi = 10.98$$ $$N_\gamma = 2(N_q - 1)tan\,\phi = 1.58$$ Calculate shape factors: $$s_c = 1 + 0.2\frac{B}{L} = 1.20$$ $$s_q = 1 + \frac{B}{L}sin\,\phi = 1.26$$ $$s_\gamma = 1 - 0.3\frac{B}{L} = 0.70$$ Overburden, q: $$q = \gamma h = 19 \times 1 = 19\,kPa$$ Total allowable, p_c: $$p_c = 20 \times 10.98 \times 1.20 + 19 \times 3.94 \times 1.26 + \frac{1}{2} \times 19 \times 10 \times 1.58 \times 0.70$$ $$p_c = 462.5\,kPa$$ Applied load, p: Load from water $15 \times 10 = 150\,kPa$ FoS = 462.5/150.0 = 3.08	FoS = 3.08
1b	Now need inclination factors: Horizontal stress, t: $$t = \frac{F}{A} = \frac{17.5 \times 10 \times 17}{10 \times 10} = 29.75\,kPa$$ $$i_c = 1 - \frac{t}{c + p\,tan\,\phi} = 0.56$$ (p = 10x15 + 1x25 = 175 kPa)	FoS = 1.29

	$$i_q = {i_c}^2 = 0.31$$ $$i_\gamma = {i_c}^3 = 0.17$$ $$p_c = cN_c i_c s_c + qN_q i_q s_q + \frac{1}{2}\gamma' B N_\gamma i_\gamma s_\gamma$$ $$p_c = 193.3\ kPa$$ FoS = 193.3/150.0 = 1.29	
1c	From Brinch Hansen, the shape factors change and q is the variable we must solve. Calculate shape factors: $$s_c = 1 + 0.2\frac{B}{L} = 1.10$$ $$s_q = 1 + \frac{B}{L} sin\ \phi = 1.13$$ $$s_\gamma = 1 - 0.3\frac{B}{L} = 0.85$$ To keep the FoS the same p_c should be the same: $$p_c = 193.3 = cN_c i_c s_c + qN_q i_q s_q + \frac{1}{2}\gamma' B N_\gamma i_\gamma s_\gamma$$ $$\frac{193.3 - cN_c i_c s_c - \frac{1}{2}\gamma' B N_\gamma i_\gamma s_\gamma}{N_q i_q s_q} = q = 27.26\ kPa$$ $$q = \gamma h$$ $$\frac{27.26}{19} = 1.29m$$ Therefore 29cm deeper.	29 cm

<table>
<tr><th>Question No.</th><th>Workings</th><th>Answer</th></tr>
<tr><td>2a</td><td>
</td><td></td></tr>
<tr><td>2b</td><td>Confined aquifer:
$h_0 - h = -\frac{Q_0}{2\pi kH}\ln\left(\frac{r}{R}\right)$
$h_0 - h = 70$ kPa
$Q_0 = -(h_0 - h)\frac{2\pi kH}{\ln\left(\frac{r}{R}\right)}$
$= -7\frac{2\pi \times 5.10^{-5} \times 3}{\ln\left(\frac{0.1}{10000}\right)} = 0.000573 m^3/s$
= 0.573 l/s</td><td>0.573 l/s</td></tr>
<tr><td>2c</td><td>Split clay into 2 layers
Effective stress at the beginning at the centre of the two layers:
$$at - 3m\ \sigma_v' = 9 + \frac{(13-9)}{4} \times 1 = 10.0\ kPa$$
$$at - 5m\ \sigma_v' = 9 + \frac{(13-9)}{4} \times 3 = 12.0\ kPa$$</td><td>27 cm</td></tr>
</table>

	Strain: $\varepsilon = \frac{1}{C_p} \ln\left(\frac{\sigma'}{\sigma'_1}\right)$ Pore water pressure at the base of the clay (top of the sand layer) will equal zero. Therefore effective stress at base of clay will equal 83 kPa. In the centre of the two layers: $at - 3m\ \sigma'_v = 9 + \frac{(83-9)}{4} \times 1 = 27.5\ kPa$ $at - 5m\ \sigma'_v = 9 + \frac{(83-9)}{4} \times 3 = 64.5\ kPa$ Therefore strain is: $at - 3m\ \varepsilon = \frac{1}{20} \ln\left(\frac{27.5}{10}\right) = 0.0506$ $at - 5m\ \varepsilon = \frac{1}{20} \ln\left(\frac{64.5}{12}\right) = 0.0841$ Deformation, $u = 2 \times (\varepsilon_1 + \varepsilon_2)$ $= 2 \times (0.0506 + 0.0841) = 0.27\ m$	

Question No.	Workings	Answer
3a	Worst case scenario for stability is just after the tide has gone out: full water pressure on the active side, no water on the passive side.  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 frcition on the wall. $$K_a = 0.33, K_p = 3$$ $$Q_{a1} = \frac{1}{2}K_a\gamma'_d {h_{Qa1}}^2 = \frac{1}{2}\times 0.33 \times (20-10)\times(4+d)^2$$ $$= 26.7 + 13.3d + 1.67d^2 \ kN/m$$ $$Q_{p1} = \frac{1}{2}K_p\gamma'_d d^2 = \frac{1}{2}3\times 10\times d^2 = 15d^2$$ $$Q_{w1} = \frac{1}{2}\gamma_w {h_{Qw1}}^2 = \frac{1}{2}\times 10 \times (4+d)^2$$ $$= 80 + 40d + 5d^2 \ kN/m$$ $$Q_{w2} = \frac{1}{2}\gamma_w d^2 = 5d^2$$ To determine d, take moments around fixed point, i.e. tension anchor. Locations of action (from tension anchor): $$d_{a1} = d_{w1} = \frac{2}{3}(d+h) - 0.5 = \frac{2}{3}d + 2.17$$	4.21m

	$$d_{p1} = d_{w2} = \frac{2}{3}d + 3.5$$ Moments: $$(26.7 + 13.3d + 1.67d^2)\left(\frac{2}{3}d + 2.17\right) + (80 + 40d + 5d^2)\left(\frac{2}{3}d + 2.17\right)$$ $$= (15d^2)\left(\frac{2}{3}d + 3.5\right) + (5d^2)\left(\frac{2}{3}d + 3.5\right)$$ $$231.5 + 186.8d - 20.0d^2 - 8.9d^3 = 0$$ $d = 4.21$m	
3c	From horizontal force equilibrium: $$T = Q_{a1} + Q_{w1} - Q_{p1} - Q_{w2}$$ $$T = 112.3 + 337.0 - 265.9 - 88.6 = 94.9kPa$$ Calculate b, as to whether ground capacity is enough. $$T < \frac{1}{2}(K_p - K_a)\gamma_d' b^2 = \frac{1}{2}(2.67)10 \times b^2$$ $$b > 2.7m$$ Length is: l = active zone from pile + passive zone from anchor $$l = (d + h)tan\ \theta + {}^{b}/_{tan\ \theta}$$ $$\theta = 45 - \frac{\phi}{2} = 30°$$ $$l = (4.21 + 4)tan\ 30 + {}^{2.7}/_{tan\ 30} = 9.4\ m$$	9.4 m

<table>
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<tr><td>4a</td><td>$$\Delta p = B(\Delta\sigma_3 + A(\Delta\sigma_1 - \Delta\sigma_3))$$
For the initial (isotropic) consolidation phase, $(\Delta\sigma_1 - \Delta\sigma_3) = 0$, therefore we can write:
$$\Delta p = B(\Delta\sigma_3)$$
$$140 - p_0 = B(200)$$
$$235 - p_0 = B(300)$$
$B = \frac{235-140}{300-200} = 0.95$ and $p_0 = -50kPa$</td><td>$B = 0.95$
$p_0 = -50kPa$</td></tr>
<tr><td>4b</td><td>For c' and ϕ' we need to calculate $\sigma_1'$and σ_3' (effective stresses) for both tests:
Test 1:
$\sigma_1' = 323 - 137 = 186$ kPa
$\sigma_3' = 200 - 137 = 63$ kPa
Test 2:
$\sigma_1' = 525 - 180 = 345$ kPa
$\sigma_3' = 300 - 180 = 120$ kPa

Can draw Mohr's circle or solve analytically:
$$\sigma_1' = \sigma_3' tan^2\left(45 + {\phi'}/{2}\right) + 2c' tan\left(45 + {\phi'}/{2}\right)$$
$$c' = 3.07\ kPa$$
$$\phi' = 28.2°$$
Can use a graphical method, but normally less exact. (reduce mark by 2 points)</td><td>$c' = 3.07\ kPa$
$\phi' = 28.2°$</td></tr>
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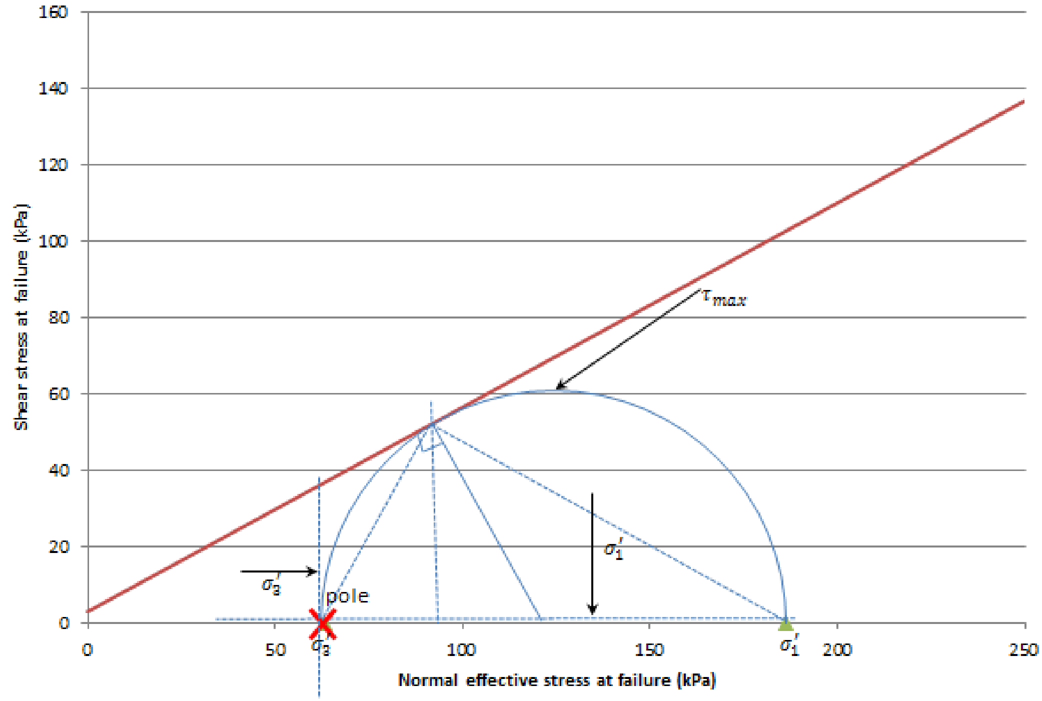
4c		
4d	Need to identify pole (see above). Using a number of trigonometric methods is possible to determine the principle stresses. Simplest is to calculate the centre and the radius of the Mohr's circle: Radius: $r = (\sigma_1 - \sigma_3)/2 = 61.5\ kPa$ Centre: $centre = \sigma_3 + r = 124.5\ kPa$ Shear stress at plane of failure: $\tau_f = r\sin(90 - \phi') = 54.2\ kPa$ Normal force: $\sigma_n = centre - \ r\cos(90 - \phi') = 95.5\ kPa$ Angle to horizontal is: $\tan^{-1} {}^{54.2}/_{(95.5 - 63)} = 59.1°$	$\tau_f = 54.2\ kPa$ 59.1° to hor.