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DELFT UNIVERSITY OF TECHNOLOGY

Faculty of Civil Engineering and Geosciences

Soil Mechanics

CTB2310 / AESB2330

BSc EXAMINATION 2018

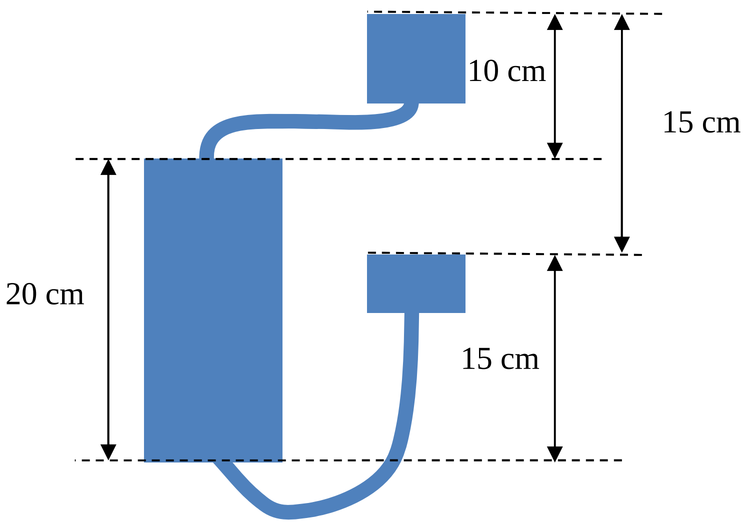
FOURTH PERIOD

DATE: 3 JULY 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

<table>
<tr><td>Question No.</td><td>Workings</td><td>Answer</td></tr>
<tr><td>1a</td><td>


Groundwater head: datum = base of sample (any datum is fine)

Groundwater head at the top of the sample: 20 + 10 = 30 cm

Groundwater head at the bottom of the sample: 0 + 15 = 15 cm

Groundwater head difference: 15-30 = -15 cm
(full marks also without negative)</td><td>-15 cm or
-0.15 m</td></tr>
<tr><td>1b</td><td>
Area of the sample: $\frac{\pi d^2}{4} = 0.00785\ m^2$

Specific discharge: $q = -k\frac{dh}{dL}$

Total discharge: $Q = qA$

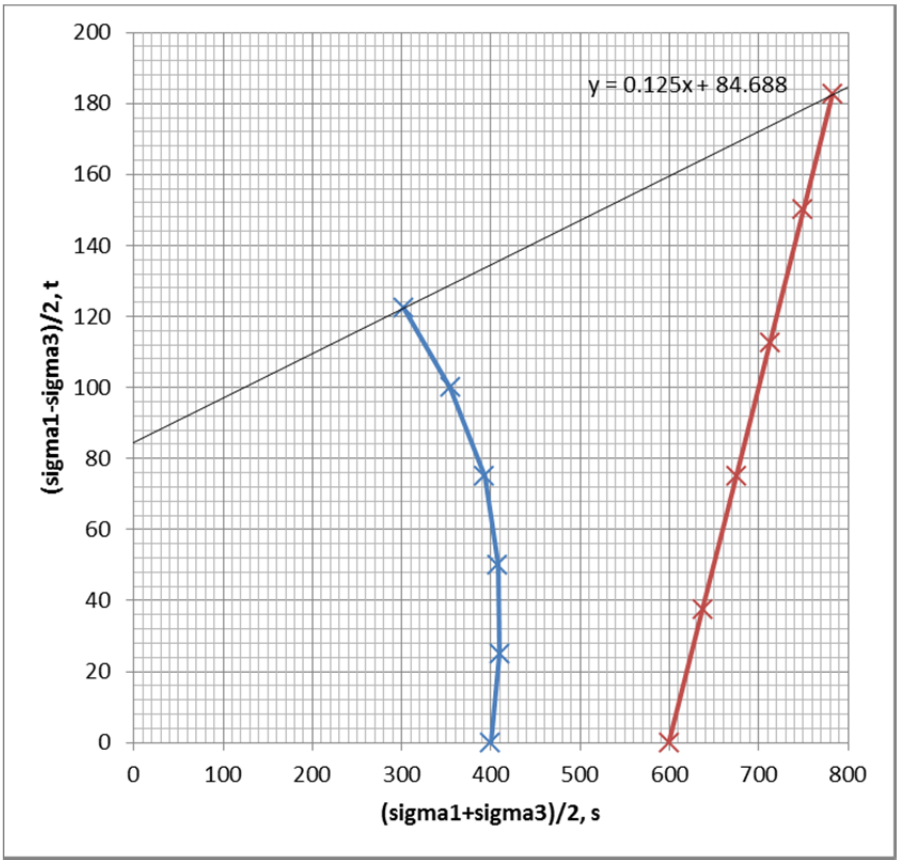
Hydraulic conductivity: $k = -\frac{Q}{A} / \left(\frac{dh}{dL}\right)$

$$\frac{dh}{dL} = \frac{-0.15}{0.2} = -0.75$$

Time, *s*	**Cum. Flow, *ml***	**dt**	**dQ, *m*^{3}**	**dQ/dt, *m*^{3}*/s***	**k, *m/s***
10	0.06	10	6×10^{-8}	6×10^{-9}	1.0×10^{-6}
100	6.9	90	6.9×10^{-6}	7.6×10^{-8}	1.3×10^{-5}
500	37.3	400	3.0×10^{-5}	7.6×10^{-8}	1.3×10^{-5}

</td><td>1.3×10^{-5} m/s</td></tr>
</table>

	Answer is average of last two results. Should ignore the first.	
1c	Datum base of sand layer. Ground water head at the excavation surface: 7 + 0 = 7m Ground water head at the base of the sand: 0 + 10 = 10m Groundwater head difference: 7 – 10 = -3 m Specific discharge: $q = -k\frac{dh}{dL} = -1.3 \times 10^{-5}\frac{(-3)}{7}$ $= 5.5 \times 10^{-6} m/s$	5.5×10^{-6} m/s

Question No.	Workings	Answer
2a		
2b	Solve either from principle stresses at failure, using: $$\sigma_1' = \sigma_3' tan^2\left(45 + {\phi'}/{2}\right) + 2c' tan\left(45 + {\phi'}/{2}\right)$$ Or from *d'* and *ψ'* parameters. From figure (final points): $$d' = 84.688\ kPa$$ $$\psi' = 7.12°$$ From definition of the failure envelope: $$sin\ \phi' = tan\ \psi'$$ $$\phi' = 7.18°$$ $$d' = c' cos\phi'$$ $$c' = 85.36\ kPa$$	$\phi' = 7.18°$ $c' = 85.36\ kPa$
2c	Using the elastic equations (Hooke's Law): $$\Delta\varepsilon_1 = \frac{1}{E}[\Delta\sigma_1 - v(\Delta\sigma_2 + \Delta\sigma_3)]$$	$E \approx 1280\ kPa$

$$\Delta\varepsilon_3 = \frac{1}{E}[\Delta\sigma_3 - v(\Delta\sigma_1 + \Delta\sigma_2)]$$

For a drained triaxial:

$$\Delta\sigma_3 = \Delta\sigma_2 = 0$$

$$\Delta\varepsilon_1 = \frac{1}{E}[\Delta\sigma_1]$$

$$\Delta\varepsilon_3 = -\frac{1}{E}[v\Delta\sigma_1]$$

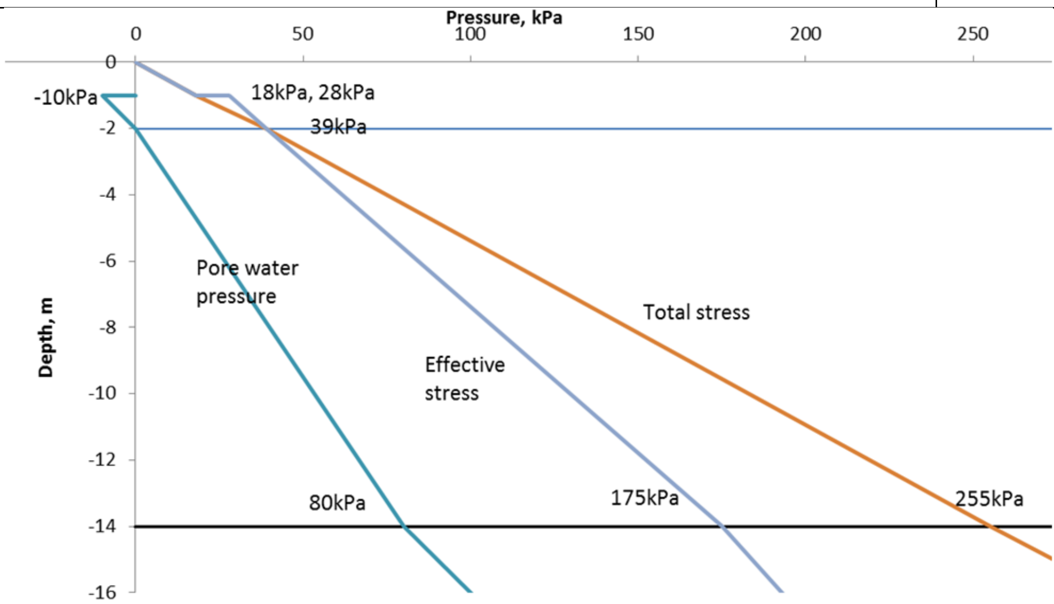
From test 2:

Axial stress, σ_1 (kPa)	**Axial strain, ε_1 (-)**	**E (kPa)**
600	0	
675	0.0583	1286.45
750	0.1163	1293.10
825	0.175	1277.68
900	0.267	815.22
965	0.376	596.33

Elastic part is the first part so:

$$E \approx 1280\ kPa$$

2d	From the pore pressures, a contraction is seen, increasing towards failure. Soil is therefore likely to be lightly overconsolidated or normally consolidated. ‘A’ value can be worked out as 0.95, which would indicate a normally consolidated soil, and high cohesion/low friction would indicate a clay	NC

Question No.	Workings	Answer
3a	 	
3b	Initial effective stresses via interpolation: $$\sigma'_{2m} = 61.7\ kPa$$ $$\sigma'_{6m} = 107.0\ kPa$$ $$\sigma'_{10m} = 152.3\ kPa$$ This is not a very wide foundation (compared to depths of interest), therefore an elastic solution is needed. Use Flamant's technique for a strip load: $$\sigma_{zz} = \frac{2p}{\pi}\left\{tan^{-1}\left(\frac{a}{z}\right) + \frac{az}{a^2+z^2}\right\}$$ At 2m depth: $$d\sigma'_{2m} = \frac{2 \times 200}{\pi}\left\{tan^{-1}\left(\frac{5}{4}\right) + \frac{5 \times 4}{5^2+4^2}\right\} = 176.2kPa$$ $$d\sigma'_{6m} = 128.4\ kPa$$ $$d\sigma'_{10m} = 95.5\ kPa$$	$\sigma'_{2m} = 62\ kPa$ $\sigma'_{6m} = 107\ kPa$ $\sigma'_{10m} = 152\ kPa$ $d\sigma'_{2m} = 176.2kPa$ $d\sigma'_{6m} = 128.4\ kPa$ $d\sigma'_{10m} = 95.5\ kPa$

<table>
<tr>
<td>3c</td>
<td>

$$\varepsilon = \frac{1}{C_p} \ln\left(\frac{\sigma}{\sigma_1}\right)$$

$$disp = \sum \varepsilon . d$$

depth	initial σ'	d	$d\sigma'$	Strain (-)	Deformation (m)
2	62	4	176.2	0.27	1.08
6	107	4	128.4	0.16	0.63
10	152	4	95.5	0.10	0.39
				total	2.10

</td>
<td>2.10 m</td>
</tr>
</table>

<table>
<tr><td>Question No.</td><td>Workings</td><td>Answer</td></tr>
<tr><td>4a</td><td>Factor of safety for an infinite slope is:
$$F = \frac{\tan\phi}{\tan\alpha} = \frac{\tan 25}{0.5} = 0.93$$</td><td>0.93</td></tr>
<tr><td>4b</td><td>Split into 5 slices, based upon 6 points given, so that each slice has a width of B=4 m

Results of calculations in table below.

1. average angles of points to get mid-slice angle

2. determine height of slice at mid-point (from slope and average y coords)

3. Calculate slice properties, sum and calculate F.
<table>
<tr><td>Slice</td><td>Angle to vertical (°)</td><td>h at mid-slice (m)</td><td>$A = \gamma h cos^2\,\alpha$</td><td>$B = c + A tan\,\phi$</td><td>$C = B/cos\,\alpha$</td><td>$D = \gamma h sin\,\alpha$</td></tr>
<tr><td>1</td><td>-5.00</td><td>1.76</td><td>31.49</td><td>14.68</td><td>14.47</td><td>-2.77</td></tr>
<tr><td>2</td><td>7.70</td><td>4.62</td><td>81.67</td><td>38.08</td><td>38.43</td><td>11.14</td></tr>
<tr><td>3</td><td>20.81</td><td>6.07</td><td>95.53</td><td>44.54</td><td>47.65</td><td>38.85</td></tr>
<tr><td>4</td><td>35.30</td><td>5.81</td><td>69.64</td><td>32.47</td><td>39.79</td><td>60.43</td></tr>
<tr><td>5</td><td>53.75</td><td>2.59</td><td>16.31</td><td>7.61</td><td>12.86</td><td>37.63</td></tr>
<tr><td></td><td></td><td></td><td></td><td>$\Sigma C =$</td><td>153.5</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td>$\Sigma D =$</td><td>145.28</td></tr>
</table>
$$F = \frac{\Sigma C}{\Sigma D} = 1.05$$</td><td>1.05</td></tr>
<tr><td>4c</td><td>• Lower FOS is closer to critical value.
or
• 1 is the critical FoS, therefore closest to 1 is correct.</td><td></td></tr>
</table>