

Name: P Vardon Student number: 001 CTB2310

DELFT UNIVERSITY OF TECHNOLOGY
Faculty of Civil Engineering and Geosciences

Soil Mechanics

CTB2310

BSc EXAMINATION 2014

THIRD PERIOD

DATE: 2 JULY 2014

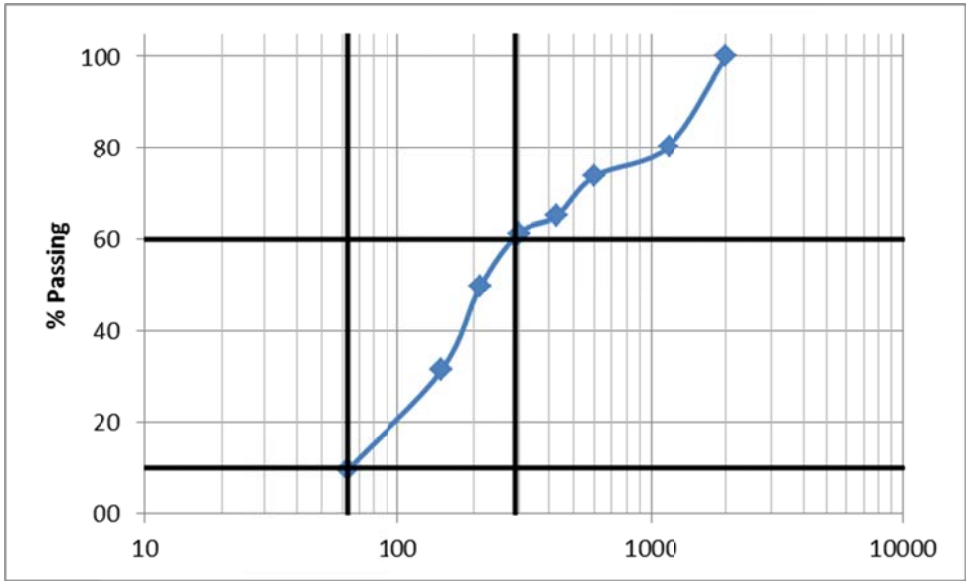
TIME: 14.00 – 17.00

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	<p>Form data into an appropriate table and calculate the cumulative % passing.</p> <table border="1" data-bbox="379 443 1366 813"> <thead> <tr> <th>Sieve size, μm</th> <th>Mass, g</th> <th>Cum. mass passing, g</th> <th>%</th> </tr> </thead> <tbody> <tr><td>Tray</td><td>13</td><td>0</td><td>0</td></tr> <tr><td>63</td><td>30</td><td>13</td><td>9.5</td></tr> <tr><td>150</td><td>25</td><td>43</td><td>31.4</td></tr> <tr><td>212</td><td>16</td><td>68</td><td>49.6</td></tr> <tr><td>300</td><td>5</td><td>84</td><td>61.3</td></tr> <tr><td>425</td><td>12</td><td>89</td><td>65.0</td></tr> <tr><td>600</td><td>9</td><td>101</td><td>73.7</td></tr> <tr><td>1180</td><td>27</td><td>110</td><td>80.3</td></tr> <tr><td>2000</td><td>0</td><td>137</td><td>100</td></tr> </tbody> </table> 	Sieve size, μm	Mass, g	Cum. mass passing, g	%	Tray	13	0	0	63	30	13	9.5	150	25	43	31.4	212	16	68	49.6	300	5	84	61.3	425	12	89	65.0	600	9	101	73.7	1180	27	110	80.3	2000	0	137	100	
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2000	0	137	100																																							
1b	<p>D_{60} and D_{10} are marked on the figure above.</p> <p>$D_{10} = 63 \mu\text{m}$</p> <p>$D_{60} = 290 \mu\text{m}$</p> <p>Uniformity coeff = $D_{60} / D_{10} = 290 / 63 = 4.6$</p>	4.6																																								
1c	<p>Almost all the material is sand ($63 \mu\text{m}$ to 2mm) and soil is well graded (uniformity coeff $\gg 1$), therefore soil is SW.</p>	SW																																								

1d	<table border="1" data-bbox="416 280 831 539"> <thead> <tr> <th>Type of soil</th> <th>k (m/s)</th> </tr> </thead> <tbody> <tr> <td>gravel</td> <td>$10^{-3} - 10^{-1}$</td> </tr> <tr> <td>sand</td> <td>$10^{-6} - 10^{-3}$</td> </tr> <tr> <td>silt</td> <td>$10^{-8} - 10^{-6}$</td> </tr> <tr> <td>clay</td> <td>$10^{-10} - 10^{-8}$</td> </tr> </tbody> </table> <p data-bbox="381 566 863 600">Table 7.1: Hydraulic conductivity k.</p> <p data-bbox="331 627 1007 663">Answers in the range of 10^{-6} to 10^{-3} m/s for 2 marks.</p> <p data-bbox="331 701 1230 736">A narrower range is also acceptable given that the soil is well graded.</p> <p data-bbox="331 775 887 810">Incorrect or missing units – reduce 1 mark.</p>	Type of soil	k (m/s)	gravel	$10^{-3} - 10^{-1}$	sand	$10^{-6} - 10^{-3}$	silt	$10^{-8} - 10^{-6}$	clay	$10^{-10} - 10^{-8}$	10^{-6} to 10^{-3} m/s
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1e	<p data-bbox="331 884 1230 920">Approximately 16 kN/m^3 (answers up to 18 kN/m^3 may be accepted).</p> <p data-bbox="331 958 1230 1030">Marks reduced for incorrect units and answers $\sim 20 \text{ kN/m}^3$ indicating saturation.</p>	16 to 18 kN/m^3										

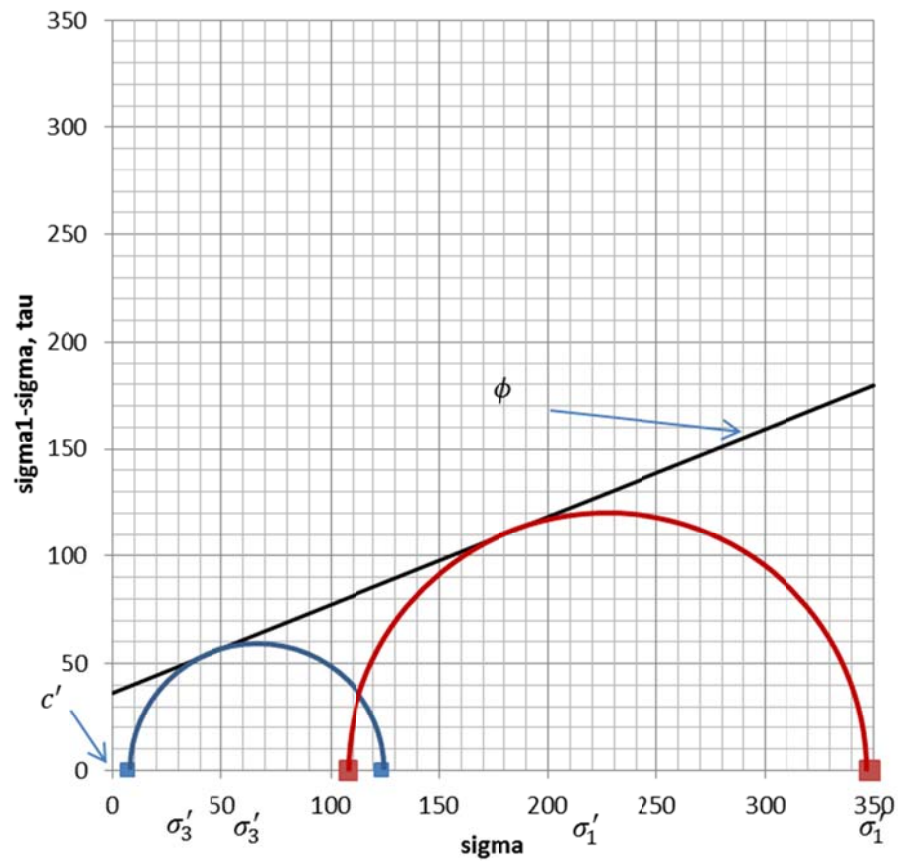
Question No.	Workings	Answer
2a	<p>Use the Brinch Hansen method.</p> $p_c = cN_c i_c s_c + qN_q i_q s_q + \frac{1}{2} \gamma' B N_\gamma i_\gamma s_\gamma$ <p>No inclination so i factors are 1 No overburden so q = 0</p> <p>Calculate N factors (use very small ϕ):</p> $N_q = \frac{1 + \sin \phi}{1 - \sin \phi} \exp(\pi \tan \phi) = 1.0 \text{ (only need later)}$ $N_c = (N_q - 1) \cot \phi = 5.14$ $N_\gamma = 2(N_q - 1) \tan \phi = 0$ $p_c = cN_c s_c$ <p>Shape factors (B=L):</p> $s_c = 1 + 0.2 \frac{B}{L} = 1.2$ $s_q = 1 + \frac{B}{L} \sin \phi = 1.0$ $s_\gamma = 1 - 0.3 \frac{B}{L} = 0.7$ <p>Total allowable, p_c:</p> $p_c = 15 \times 5.14 \times 1.2 = 92.6 \text{ kPa}$ <p>Applied load, p:</p> $p = \gamma_{oil} \times h = 9 \times 10 = 90 \text{ kPa}$ <p>Could also update for 100% of load (90.9 kPa).</p> <p>FoS = 92.52/90 = 1.03</p>	1.03
2b	<p>Overburden is now 2 m:</p> $q = \gamma' \times h = 8 \times 2 = 16 \text{ kPa}$ $p_c = cN_c s_c + qN_q s_q$ $p_c = 92.6 + 16 \times 1 \times 1 = 108.6 \text{ kPa}$ <p>FoS = 108.6/90 = 1.21 (worse case)</p> <p>Will also accept for adjusting loading for pore pressure: FoS = 108.6/(90-20) = 1.55 or, as water table is not specified, increasing q to 36 kPa.</p>	1.21

2c	<p>Need to calculate inclination factors:</p> <p>Horizontal stress, t:</p> $t = \frac{F}{found\ area} = \frac{3000}{10^2\pi} = 9.6\ kPa$ $i_c = 1 - \frac{t}{c + p \tan \phi}$ $= 1 - \frac{9.6}{15} = 0.36$ $i_q = i_c^2 = 0.13$ $i_\gamma = i_c^3 = 0.05$ $p_c = cN_c i_c s_c + qN_q i_q s_q$ $p_c = 92.6 \times 0.36 + 16 \times 0.13 = 35.7\ kPa$ <p>FoS = 35.7/90 = 0.40</p>	0.40
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Question No.	Workings	Answer																																																																								
3a																																																																										
3b	<p>$\sigma = \text{load}/\text{area}$</p> <p>$\text{area} = 0.05 * 0.05 * \frac{\pi}{4} = 0.00196m^2$</p> <p>$\epsilon = \text{disp}/\text{height}$</p> <p>$C_{10} = \frac{1}{\epsilon} \log\left(\frac{\sigma}{\sigma_1}\right)$</p> <p>Select first initial loading part and calculate:</p> <table border="1" data-bbox="320 1312 1249 1615"> <thead> <tr> <th>Load, N</th> <th>Vertical displacement, mm</th> <th>Total load, N</th> <th>Stress, kPa</th> <th>strain</th> <th>C10</th> </tr> </thead> <tbody> <tr><td>0</td><td>0</td><td>50</td><td>25.5</td><td>0</td><td>-</td></tr> <tr><td>50</td><td>1.3</td><td>100</td><td>50.9</td><td>0.052</td><td>5.8</td></tr> <tr><td>100</td><td>2</td><td>150</td><td>76.4</td><td>0.08</td><td>6.0</td></tr> <tr><td>150</td><td>2.6</td><td>200</td><td>101.9</td><td>0.104</td><td>5.8</td></tr> <tr><td>200</td><td>3.1</td><td>250</td><td>127.3</td><td>0.124</td><td>5.6</td></tr> <tr><td>250</td><td>3.5</td><td>300</td><td>152.8</td><td>0.14</td><td>5.6</td></tr> </tbody> </table> <p>Secondly pick unloading (or reloading part): Note: must start strain from initial stress datum, i.e. 250 N here.</p> <table border="1" data-bbox="320 1760 1249 1995"> <thead> <tr> <th>Load, N</th> <th>Vertical displacement, mm</th> <th>Total load, N</th> <th>Stress, kPa</th> <th>Strain</th> <th>C10</th> </tr> </thead> <tbody> <tr><td>250</td><td>3.5</td><td>300</td><td>152.8</td><td>0</td><td>-</td></tr> <tr><td>200</td><td>3.4</td><td>250</td><td>127.3</td><td>-0.00465</td><td>17.0</td></tr> <tr><td>150</td><td>3.3</td><td>200</td><td>101.9</td><td>-0.0093</td><td>18.9</td></tr> <tr><td>100</td><td>3.1</td><td>150</td><td>76.4</td><td>-0.0186</td><td>16.2</td></tr> </tbody> </table>	Load, N	Vertical displacement, mm	Total load, N	Stress, kPa	strain	C10	0	0	50	25.5	0	-	50	1.3	100	50.9	0.052	5.8	100	2	150	76.4	0.08	6.0	150	2.6	200	101.9	0.104	5.8	200	3.1	250	127.3	0.124	5.6	250	3.5	300	152.8	0.14	5.6	Load, N	Vertical displacement, mm	Total load, N	Stress, kPa	Strain	C10	250	3.5	300	152.8	0	-	200	3.4	250	127.3	-0.00465	17.0	150	3.3	200	101.9	-0.0093	18.9	100	3.1	150	76.4	-0.0186	16.2	<p>Initial loading: $C_{10}=5.5$ to 6.0</p> <p>Unloading / reloading: $C_{10}=16.0$ to 19.0</p>
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3c	Change in effective stress = 66 kPa (can read from figure in 2a)						0.270 m (uplift) (0.24 – 0.29) accepted	
	$\varepsilon = \frac{1}{C_{10}} \log\left(\frac{\sigma}{\sigma_1}\right)$							
	Layer centre, m	Thick-ness, m	Initial eff stress, kPa	Final eff stress, kPa	C10 chosen	Strain		Disp, m
	-5.25	2.5	74.75	8.75	17	-0.055		-0.14
	-7.75	2.5	92.25	26.25	17	-0.032		-0.08
	-10.25	2.5	109.75	43.75	34	-0.012		-0.03
-14.27	2.5	127.25	61.25	34	-0.009	-0.02		
[C10 choice of 5.5 to 6.0 is incorrect, but only lose 1 mark.]								
Total displacement is: 0.14+0.08+0.03+0.02 = 0.270 m (uplift)								

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4a	<p style="text-align: center;">$\Delta p = B(\Delta\sigma_3 + A(\Delta\sigma_1 - \Delta\sigma_3))$</p> <p>If B=1.0 and $\Delta\sigma_3=0$ then:</p> $A = \frac{\Delta p}{\Delta\sigma_1}$ $A_{test\ 1} = \frac{192}{(540 - 300)} = 0.8$ $A_{test\ 2} = \frac{143}{(267 - 150)} = 1.22$	$A_{test\ 1} = 0.8$ $A_{test\ 2} = 1.22$																																																																																																		
4b	<p>Test 1</p> <table border="1" data-bbox="416 707 1393 1008"> <thead> <tr> <th>Axial stress, σ_1 (kPa)</th> <th>Pore pressure, p (kPa)</th> <th>Deviator stress, kPa</th> <th>σ'_1, kPa</th> <th>σ'_3, kPa</th> <th>s, kPa</th> <th>t, kPa</th> </tr> </thead> <tbody> <tr><td>300.0</td><td>0.0</td><td>0</td><td>300</td><td>300</td><td>300</td><td>0</td></tr> <tr><td>350.0</td><td>30.0</td><td>50</td><td>320</td><td>270</td><td>295</td><td>25</td></tr> <tr><td>400.0</td><td>70.0</td><td>100</td><td>330</td><td>230</td><td>280</td><td>50</td></tr> <tr><td>450.0</td><td>110.0</td><td>150</td><td>340</td><td>190</td><td>265</td><td>75</td></tr> <tr><td>500.0</td><td>155.0</td><td>200</td><td>345</td><td>145</td><td>245</td><td>100</td></tr> <tr><td>540.0</td><td>192.0</td><td>240</td><td>348</td><td>108</td><td>228</td><td>120</td></tr> </tbody> </table> <p>Test 2</p> <table border="1" data-bbox="416 1120 1393 1420"> <thead> <tr> <th>Axial stress, σ_1 (kPa)</th> <th>Pore pressure, p (kPa)</th> <th>Deviator stress, kPa</th> <th>σ'_1, kPa</th> <th>σ'_3, kPa</th> <th>s, kPa</th> <th>t, kPa</th> </tr> </thead> <tbody> <tr><td>150.0</td><td>0</td><td>0</td><td>150</td><td>150</td><td>150</td><td>0</td></tr> <tr><td>175.0</td><td>10.0</td><td>25</td><td>165</td><td>140</td><td>152.5</td><td>12.5</td></tr> <tr><td>200.0</td><td>30.0</td><td>50</td><td>170</td><td>120</td><td>145</td><td>25</td></tr> <tr><td>225.0</td><td>60.0</td><td>75</td><td>165</td><td>90</td><td>127.5</td><td>37.5</td></tr> <tr><td>250.0</td><td>105.0</td><td>100</td><td>145</td><td>45</td><td>95</td><td>50</td></tr> <tr><td>267.0</td><td>143.0</td><td>117</td><td>124</td><td>7</td><td>65.5</td><td>58.5</td></tr> </tbody> </table>	Axial stress, σ_1 (kPa)	Pore pressure, p (kPa)	Deviator stress, kPa	σ'_1 , kPa	σ'_3 , kPa	s, kPa	t, kPa	300.0	0.0	0	300	300	300	0	350.0	30.0	50	320	270	295	25	400.0	70.0	100	330	230	280	50	450.0	110.0	150	340	190	265	75	500.0	155.0	200	345	145	245	100	540.0	192.0	240	348	108	228	120	Axial stress, σ_1 (kPa)	Pore pressure, p (kPa)	Deviator stress, kPa	σ'_1 , kPa	σ'_3 , kPa	s, kPa	t, kPa	150.0	0	0	150	150	150	0	175.0	10.0	25	165	140	152.5	12.5	200.0	30.0	50	170	120	145	25	225.0	60.0	75	165	90	127.5	37.5	250.0	105.0	100	145	45	95	50	267.0	143.0	117	124	7	65.5	58.5	
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4c

Two methods: i) from d and ψ , or ii) from equation for M-C parameters:

i)

$$\tan \psi = \sin \phi'$$

$$\phi' = 22.2^\circ$$

$$d = c' \cos \phi'$$

$$c' = 36.4 \text{ kPa}$$

ii)

$$\sigma'_1 = \sigma'_3 \tan^2 \left(45 + \frac{\phi'}{2} \right) + 2c' \tan \left(45 + \frac{\phi'}{2} \right)$$

Solve simultaneously with subtraction:

$$348 - 124 = (108 - 7) \tan^2 \left(45 + \frac{\phi'}{2} \right)$$

$$\phi' = 22.2^\circ$$

Back substitute for c'

$$\phi' = 22.2^\circ$$

$$c' = 36.4 \text{ kPa}$$

4d		
4e	<p>From figure in 1c or from 2 failure points, make straight line and find equation:</p> $t = 0.3785s + 33.7$ <p>Therefore:</p> $d = 33.7kPa$ $\psi = \tan^{-1}(0.3785) = 20.7^\circ$	$d = 33.7kPa$ $\psi = 20.7^\circ$

Question No.	Workings	Answer
4a	<p>Use the Brinch Hansen method.</p> $p_c = cN_c i_c s_c + qN_q i_q s_q + \frac{1}{2} \gamma' B N_\gamma i_\gamma s_\gamma$ <p>No inclination, long structure (i and s factors are 1):</p> $p_c = cN_c + qN_q + \frac{1}{2} \gamma' B N_\gamma$ <p>Calculate N factors:</p> $N_q = \frac{1 + \sin \phi}{1 - \sin \phi} \exp(\pi \tan \phi) = 6.4$ $N_c = (N_q - 1) \cot \phi = 14.8$ $N_\gamma = 2(N_q - 1) \tan \phi = 3.93$ <p>No effective overburden.</p> <p>Total allowable, p_c:</p> $p_c = 15 \times 14.83 + 0.5 \times 8 \times 12 \times 3.93 = 411 \text{ kPa}$ <p>Applied load, p:</p> <p>Effective weight of concrete $((25 - 10) \times 0.25 \times 2) \times (12 \times 20 + 20 \times 5 + 5 \times 12) = 3000 \text{ kN}$ (can be slightly less for more accurate determination)</p> <p>Effective weight of fill $(5 - 0.5) \times (12 - 0.5) \times (20 - 0.5) \times (17.5 - 10) = 7568 \text{ kN}$</p> <p>Total load = 10568 kN</p> <p>Total / area = 10568 / (12x20) = 44 kPa</p> <p>FoS = 411/44 = 9.3</p>	FoS = 9.3

<p>4b</p>	<p>Need to consider the shape of the caisson:</p> $p_c = cN_c s_c + qN_q s_q + \frac{1}{2} \gamma' B N_\gamma s_\gamma$ <p>Calculate shape factors:</p> $s_c = 1 + 0.2 \frac{B}{L} = 1.12$ $s_q = 1 + \frac{B}{L} \sin \phi = 1.21$ $s_\gamma = 1 - 0.3 \frac{B}{L} = 0.82$ $p_c = cN_c s_c + qN_q s_q + \frac{1}{2} \gamma' B N_\gamma s_\gamma$ $p_c = 15 \times 14.83 \times 1.12 + 0.5 \times 8 \times 12 \times 3.93 \times 0.82$ $= 404 \text{ kPa}$ <p>Weight of concrete $((25) \times 0.25 \times 2) \times (12 \times 20 + 20 \times 5 + 5 \times 12) = 5000 \text{ kN}$ (can be slightly less for more accurate determination)</p> <p>Weight of fill $(5 - 0.5) \times (12 - 0.5) \times (20 - 0.5) \times (17.5) = 17660 \text{ kN}$ Total load = 22660 kN Total / area = 22660 / (12x20) = 94 kPa</p> <p>FoS = 404/94 = 4.3</p>	<p>FoS = 4.3</p>
<p>4c</p>	<p>Use the Brinch Hansen method.</p> $p_c = cN_c i_c s_c + qN_q i_q s_q + \frac{1}{2} \gamma' B N_\gamma i_\gamma s_\gamma$ <p>In this case need the inclinations factors and no shape factors.</p> <p>Horizontal stress, t:</p> $t = \frac{F \text{ per } m}{\text{width}} = \frac{100}{12} = 8.3 \text{ kPa}$ $i_c = 1 - \frac{t}{c + p \tan \phi}$ $= 1 - \frac{8.3}{c + 44 \tan 20^\circ} = 0.73$	<p>FoS = 5.4</p>

	$i_q = i_c^2 = 0.53$ $i_\gamma = i_c^3 = 0.39$ $p_c = cN_c i_c + \frac{1}{2} \gamma' B N_\gamma i_\gamma$ $p_c = 15 \times 14.83 \times 0.73 + 0.5 \times 8 \times 12 \times 3.93 \times 0.39$ $p_c = 237 \text{ kPa}$ <p>FoS = 237/44 = 5.4</p>	
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