DELFT UNIVERSITY OF TECHNOLOGY

Faculty of Civil Engineering and Geosciences

Soil Mechanics

CTB2310

BSc EXAMINATION 2014

THIRD PERIOD

DATE: 14 APRIL 2014 TIME: 14.00 – 17.00

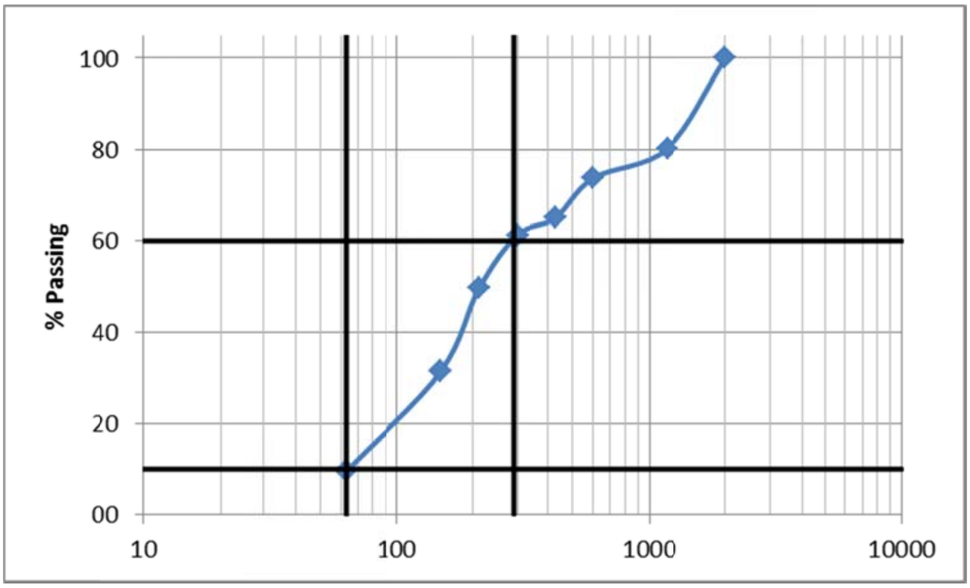
Answer ALL Questions
(Note that the questions carry unequal marks)

Other instructions
Write your name and student number on each sheet

Clearly identify the answer in the answer box

<table>
<tr><td>Question No.</td><td>Workings</td><td>Answer</td></tr>
<tr><td>1a</td><td>Form data into an appropriate table and calculate the cumulative % passing.

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


</td><td></td></tr>
<tr><td>1b</td><td>D_{60} and D_{10} are marked on the figure above.

$D_{10} = 63$ µm

$D_{60} = 290$ µm

Uniformity coeff = $D_{60} / D_{10} = 290 / 63 = 4.6$</td><td>4.6</td></tr>
<tr><td>1c</td><td>Almost all the material is sand (63 µm to 2 mm) and soil is well graded (uniformity coeff >>1), therefore soil is SW.</td><td>SW</td></tr>
</table>

<table>
<tr><td></td><td></td><td></td></tr>
<tr><td>1d</td><td>
<table>
<tr><th>Type of soil</th><th>k (m/s)</th></tr>
<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>
</table>
Table 7.1: Hydraulic conductivity k.

Answers in the range of 10^{-6} to 10^{-3} m/s for 2 marks.

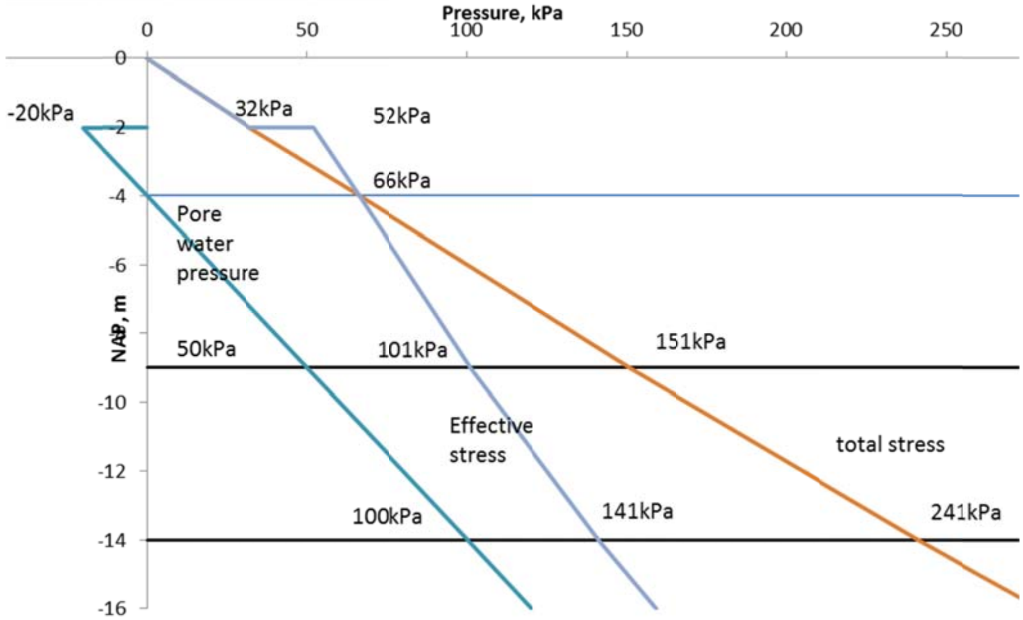
A narrower range is also acceptable given that the soil is well graded.

Incorrect or missing units – reduce 1 mark.
</td><td>10^{-6} to 10^{-3} m/s</td></tr>
<tr><td>1e</td><td>Approximately 16 kN/m^3 (answers up to 18 kN/m^3 may be accepted).

Marks reduced for incorrect units and answers ~ 20 kN/m^3 indicating saturation.</td><td>16 to 18 kN/m^3</td></tr>
</table>

Question No.	Workings	Answer
2a	Use the Brinch Hansen method. $$p_c = cN_c i_c s_c + qN_q i_q s_q + \frac{1}{2}\gamma' B N_\gamma i_\gamma s_\gamma$$ No inclination so i factors are 1 No overburden so q = 0 Calculate N factors (use very small ϕ): $N_q = \frac{1+sin\ \phi}{1-sin\ \phi}\exp(\pi\ tan\ \phi) = 1.0$ (only need later) $$N_c = (N_q - 1)cot\ \phi = 5.14$$ $$N_\gamma = 2(N_q - 1)tan\ \phi = 0$$ $$p_c = cN_c s_c$$ Shape factors (B=L): $$s_c = 1 + 0.2\frac{B}{L} = 1.2$$ $$s_q = 1 + \frac{B}{L}sin\ \phi = 1.0$$ $$s_\gamma = 1 - 0.3\frac{B}{L} = 0.7$$ Total allowable, p_c: $$p_c = 15 \times 5.14 \times 1.2 = 92.6\ kPa$$ Applied load, p: $$p = \gamma_{oil} \times h = 9 \times 10 = 90\ kPa$$ Could also update for 100% of load (90.9 kPa). FoS = 92.52/90 = 1.03	1.03
2b	Overburden is now 2 m: $$q = \gamma' \times h = 8 \times 2 = 16\ kPa$$ $$p_c = cN_c s_c + qN_q s_q$$ $$p_c = 92.6 + 16 \times 1 \times 1 = 108.6\ kPa$$ FoS = 108.6/90 = 1.21 (worse case) 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.	1.21

2c	Need to calculate inclination factors: Horizontal stress, t: $$t = \frac{F}{found\ area} = \frac{3000}{10^2\pi} = 9.6\ kPa$$ $$i_c = 1 - \frac{t}{c + p\ tan\ \phi}$$ $$= 1 - \frac{9.6}{15} = 0.36$$ $$i_q = {i_c}^2 = 0.13$$ $$i_\gamma = {i_c}^3 = 0.05$$ $$p_c = cN_c i_c s_c + qN_q i_q s_q$$ $$p_c = 92.6 \times 0.36 + 16 \times 0.13 = 35.7\ kPa$$ FoS = 35.7/90 = 0.40	0.40

Question No.	Workings	Answer
3a		

3b

Workings:

$\sigma = load/area$

$area = 0.05 * 0.05 * \frac{\pi}{4} = 0.00196 m^2$

$\varepsilon = disp/height$

$C_{10} = \frac{1}{\varepsilon}\log\left(\frac{\sigma}{\sigma_1}\right)$

Select first initial loading part and calculate:

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

Secondly pick unloading (or reloading part):
Note: must start strain from initial stress datum, i.e. 250 N here.

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

Answer:

Initial loading:

C_{10}=5.5 to 6.0

Unloading / reloading:

C_{10}=16.0 to 19.0

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

Change in effective stress = 66 kPa (can read from figure in 2a)

$$\varepsilon = \frac{1}{C_{10}} \log\left(\frac{\sigma}{\sigma_1}\right)$$

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)

</td><td>0.270 m (uplift)

(0.24 – 0.29) accepted</td></tr>
</table>

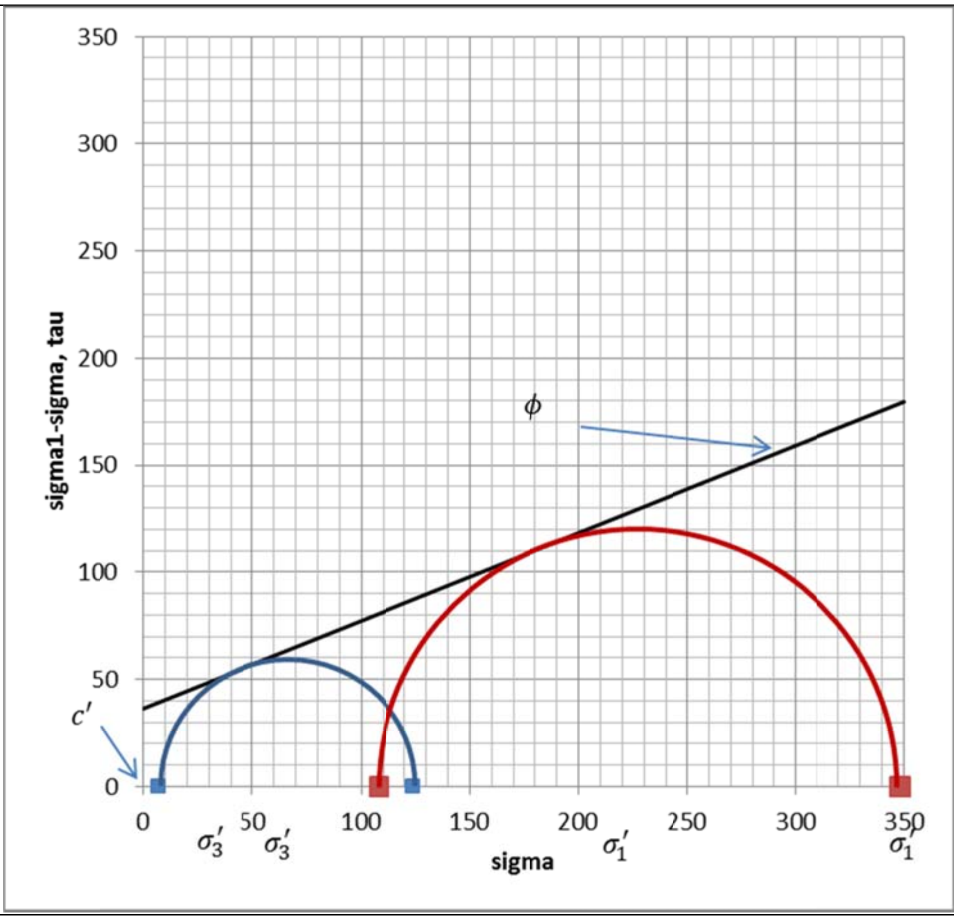
Question No.	Workings	Answer
4a	$\Delta p = B(\Delta\sigma_3 + A(\Delta\sigma_1 - \Delta\sigma_3))$ If B=1.0 and $\Delta\sigma_3$=0 then: $A = \frac{\Delta p}{\Delta\sigma_1}$ $A_{test\ 1} = \frac{192}{(540-300)} = 0.8$ $A_{test\ 2} = \frac{143}{(267-150)} = 1.22$	$A_{test\ 1} = 0.8$ $A_{test\ 2} = 1.22$
4b	Test 1 (table below) Test 2 (table below)	

Test 1

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

Test 2

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



4c

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

i)

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

$$\phi' = 22.2°$$
$$d = c'\,cos\phi'$$
$$c' = 36.4kPa$$

ii)

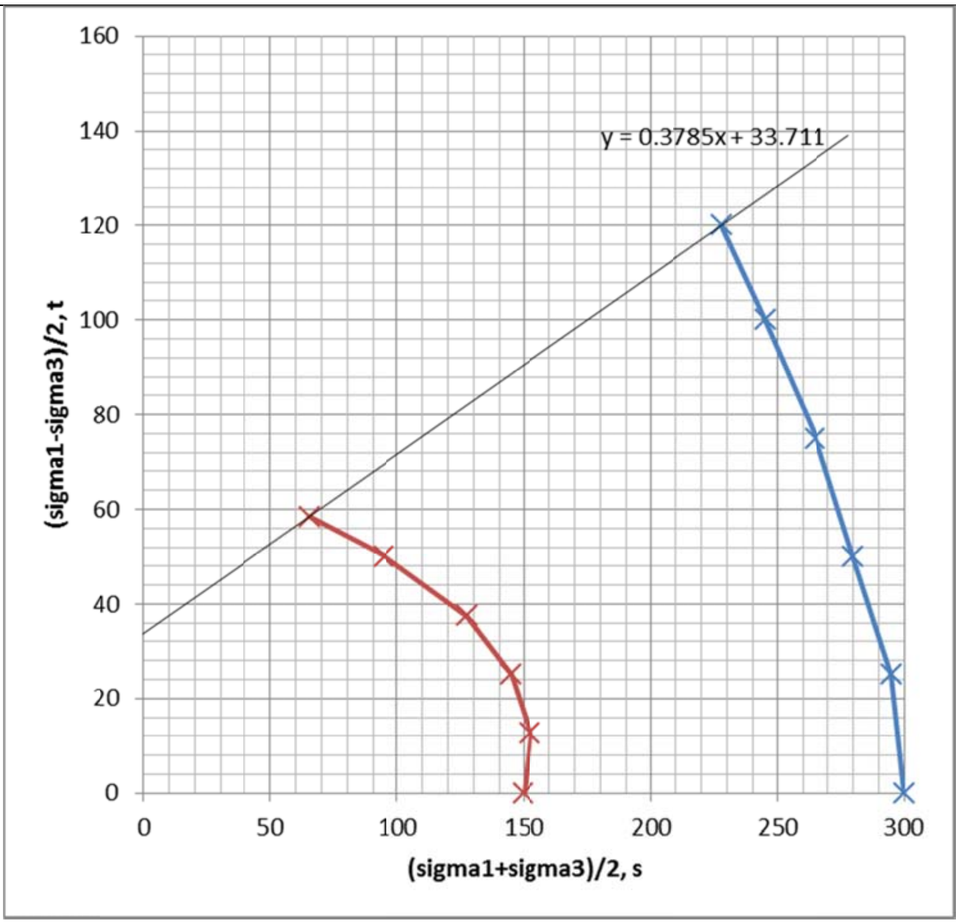
$$\sigma_1' = \sigma_3' tan^2\left(45 + {\phi'}/{2}\right) + 2c' tan\left(45 + {\phi'}/{2}\right)$$

Solve simultaneously with subtraction:

$$348 - 124 = (108 - 7)tan^2\left(45 + {\phi'}/{2}\right)$$
$$\phi' = 22.2°$$

Back substitute for c'

$\phi' = 22.2°$
$c' = 36.4kPa$

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

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

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

	$i_q = {i_c}^2 = 0.53$ $i_\gamma = {i_c}^3 = 0.39$ $p_c = cN_ci_c + \frac{1}{2}\gamma' BN_\gamma i_\gamma$ $p_c = 15 \times 14.83 \times 0.73 + 0.5 \times 8 \times 12 \times 3.93 \times 0.39$ $p_c = 237\ kPa$ FoS = 237/44 = 5.4	