DELFT UNIVERSITY OF TECHNOLOGY

Faculty of Civil Engineering and Geosciences

Soil Mechanics

CT2091

BSc EXAMINATION 2015

THIRD PERIOD

DATE: 14 APRIL 2015 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><th>Question No.</th><th>Workings</th><th>Answer</th></tr>
<tr><td>1a</td><td>$\Delta p = B(\Delta\sigma_3 + A(\Delta\sigma_1 - \Delta\sigma_3))$
Initially: $(\Delta\sigma_1 - \Delta\sigma_3) = 0$, therefore $\Delta p = B(\Delta\sigma_3)$
$$50 - 0 = B(150 - 0)$$ $$85 - 0 = B(250 - 0)$$ $$120 - 0 = B(350 - 0)$$
Use any of the above eq to determine B=0.33 to 0.34

Use any of the tests to determine A for the second part:
$$-47 - 0 = 0.33(0 + A(410 - 0))$$ $$-70 - 0 = 0.34(0 + A(597 - 0))$$ $$-90 - 0 = 0.34(0 + A(780 - 0))$$
Using the above A = -0.34</td><td>B=0.33 to 0.34

A = -0.34</td></tr>
<tr><td>1b</td><td>Two options: i) draw Mohr’s circle or ii) use the expression:
$$\sigma_1' = \sigma_3' tan^2\left(45 + {}^{\phi'}/_{2}\right) + 2c' tan\left(45 + {}^{\phi'}/_{2}\right)$$
Using any two of the tests, e.g. 1 and 3
<table><tr><th>σ_1 (kPa)</th><th>σ_3 (kPa)</th></tr><tr><td>150 + -47 + 410 = 607</td><td>150 + -47 = 197</td></tr><tr><td>350 + -90 + 780 = 1220</td><td>350 + -90 = 440</td></tr></table>
Therefore $\phi' = 25.6°$, $c' = 35$ kPa</td><td>$\phi' = 25.6°$,
$c' = 35$ kPa</td></tr>
<tr><td>1c</td><td>Various options. Easiest is:
$(\sigma_1 - \sigma_3)/2 = (1220 - 440) / 2 = 390$ kPa

Orientation from Mohr’s circle is 45° from both σ_1 and σ_3 and therefore 45° from horizontal and virtical</td><td>390 kPa

45° from horizontal</td></tr>
<tr><td>1d</td><td>Dilates. Negative pore pressure mean soil skeleton is expanding causing negative pore pressures.</td><td>Dilates.</td></tr>
</table>

Question No.	Workings	Answer
2a	Use the Brinch Hansen method. $p_c = cN_c i_c s_c + qN_q i_q s_q + \frac{1}{2}\gamma' BN_\gamma i_\gamma s_\gamma$ No inclination, long structure (i and s factors are likely to be 1 or very close): $p_c = cN_c + qN_q + \frac{1}{2}\gamma' BN_\gamma$ Calculate N factors: $N_q = \frac{1 + sin\,\phi}{1 - sin\,\phi}\exp(\pi\,tan\,\phi) = 6.4$ $N_c = (N_q - 1)cot\,\phi = 14.8$ $N_\gamma = 2(N_q - 1)tan\,\phi = 3.93$ Overburden $q = \gamma' d = 5.5$ Total allowable, p_c: $p_c = 257.7 + 21.6BkPa$ Applied load, p_a: $p_a = \frac{350}{B}kPa$ FOS: $FOS = \frac{p_c}{p_a} = 2$ Solve for B: $257.7B + 21.6B^2 = 2 \times 350$ $B = 2.28m$	B = 2.28 m
2b	Against use the Brinch Hansen method. Calculate N factors: $N_q = \frac{1 + sin\,\phi}{1 - sin\,\phi}\exp(\pi\,tan\,\phi) = 18.4$ $N_c = (N_q - 1)cot\,\phi = 30.1$ $N_\gamma = 2(N_q - 1)tan\,\phi = 20.1$ Overburden $q = \gamma' d = 16.5$ Total allowable, p_c: $p_c = 1358.5 + 110.5BkPa$ Applied load, p_a: $p_a = \frac{350}{B}kPa$ FOS:	B = 0.495 m

	$FOS = \frac{p_c}{p_a} = 2$ Solve for B: $1358.5B + 110.5B^2 = 2 \times 350$ $B = 0.495m$	
2c	Use the Brinch Hansen method. For undrained loading, only c_u is used. $p_c = c_u N_c i_c s_c$ $N_c = 5.14$ Calculate σ_1' and σ_3' recognising that they coincide with vertical and horizontal stresses: $\sigma_1' = z\gamma' = 1.5 \times 11 = 16.5\ kPa$ $K_0 \approx 1 - \sin\phi^{'} = 0.5$ $\sigma_3' = K_0\sigma_1' = 8.25\ kPa$ Undrained shear strength: $c_u = c' + (\sigma_1' - \sigma_3')\tan\phi'$ $c_u = 40\ kPa$ Bearing capacity: $p_c = 40 \times 5.14 = 204.4\ kPa$ Load: $p_c = \frac{350}{B} = \frac{350}{0.495} = 707.1\ kPa$ FOS = 204.4 / 707.1 = 0.29	FoS = 0.29
2d	In this case need the inclination factors are needed and again no shape factors. $p_c = cN_c i_c + qN_q i_q + \frac{1}{2}\gamma' B N_\gamma i_\gamma$ $FOS = \frac{p_c}{p_a} = 1.5$ Therefore p_c is required to be: $p_c = 1.5 \times \frac{350}{0.495} = 1060.6\ kPa$ Express bearing capacity in terms of i_c ($i_q = {i_c}^2$ and $i_\gamma = {i_c}^3$): $p_c = cN_c i_c + qN_q {i_c}^2 + \frac{1}{2}\gamma' B N_\gamma {i_c}^3$ $1060.6 = 1054.9 i_c + 303.6 {i_c}^2 + 54.7 {i_c}^3$ $i_c = 0.8$ Horizontal stress, t: $i_c = 1 - \frac{t}{c + p\ tan\ \phi}$ $0.8 = 1 - \frac{t}{35 + (\frac{350}{0.495})\ tan\ 30°}$ Solving for t: $t = 88.6\ kPa$ $F\ per\ m = t \times B = 88.6 \times 0.495 = 43.8kN/m$	$43.8kN/m$

Question No.	Workings	Answer
3a	Lateral stress: Use of tables to calculate KK_a and K_p. Use $\delta = 0, \beta = 0^\circ$ and $\alpha = 80^\circ$: $K_a = 0.375$ $K_p = 2.768$ The horizontal forces (per metre) is: $Q_{a1} = \frac{1}{2}K_a\gamma h^2 = \frac{1}{2} \times 0.375 \times 19 \times 7^2 = 174.56\ kN$ $Q_{a2} = K_a\gamma hd = 0.375 \times 19 \times 7 \times 1.5 = 74.8\ kN$ $Q_{a3} = \frac{1}{2}K_a\gamma' d^2 = \frac{1}{2} \times 0.375 \times (19 - 10) \times 1.5^2 = 3.8\ kN$ $Q_p = \frac{1}{2}K_p\gamma' d^2 = \frac{1}{2} \times 3.295 \times (19 - 10) \times 1.5^2 = 28.0\ kN$ Recognising that water pressures are equal and opposite. $Q = 174.56 + 74.8 + 3.8 - 28.0 = 225.14\ kN$ Resistance is: $F = W\ tan\ \delta$ $W = 24 \times 9 \times \left(1.8 + \frac{8.5}{\tan(80)}\right) = 673.0\ kN$ $F = 305.0$ $FOS = \frac{305.0}{225.14} = 1.35$ Alternative method for FOS, grouping all forces sliding against all resisting $Q_w = \frac{1}{2}\gamma_w d^2 = \frac{1}{2} \times 10 \times 1.5^2 = 11.25\ kN$ $FOS = \frac{305.0 + 11.25 + 28.0}{174.56 + 74.8 + 3.8 + 11.25} = 1.30$	$FOS = 1.35$
3b	Lateral stress: Use of tables to calculate K_a and K_p. Use $\delta = 24.4$, and $\alpha = 80^\circ$. $\beta = 0^\circ$ for passive and $\beta = 20^\circ$ for active: $K_a = 0.497$ $K_p = 6.118$ The Q forces (per metre) is (note not horizontal): $Q_{a1} = \frac{1}{2}K_a\gamma h^2 = \frac{1}{2} \times 0.497 \times 19 \times 7^2 = 231.35\ kN$ $Q_{a2} = K_a\gamma hd = 0.497 \times 19 \times 7 \times 1.5 = 99.2\ kN$ $Q_{a3} = \frac{1}{2}K_a\gamma' d^2 = \frac{1}{2} \times 0.497 \times (19 - 10) \times 1.5^2 = 5.0\ kN$	$FOS = 1.8$

	$Q_p = \frac{1}{2}K_p\gamma' d^2 = \frac{1}{2}\times 6.118\times(19-10)\times 1.5^2 = 61.9\ kN$ Resolve all in horizontal directions and sum: $Q_h = Q\sin(\alpha-\delta)$ $Q_{ah} = (231.35+99.2+5.0)\sin(80-24.4) = 276.9\ kN$ $Q_{ph} = (61.9)\sin(80--24.4) = 60.0\ kN$ $Q = 276.9-60.0 = 216.9\ kN$ Resistance is: $F = (W+Q_{av}+Q_{pv})\ tan\ \delta$ *Only reduce by 1 mark if use W, not* Q_v. $W = 24\times 9\times\left(1.8+\frac{8.5}{\tan(80)}\right) = 673.0\ kN$ $Q_{pv=}(61.9)\cos(80--24.4) = -\ 15.4\ kN$ $Q_{av} = (231.35+99.2+5.0)\cos(80-24.4) = 189.4\ kN$ $F = 383.8\ kN$ $FOS = \frac{383.8}{216.9} = 1.8$ Alternative method gives: $FOS = 1.57$	
3c	As before $K_a = 0.375$ $K_p = 2.768$ The horizontal forces (per metre) is: $Q_{a1} = \frac{1}{2}K_a\gamma' h^2 = \frac{1}{2}\times 0.375\times(19-10)\times 8.5^2 = 121.9\ kN$ $Q_{wa} = \frac{1}{2}\gamma_w h^2 = \frac{1}{2}\times 10\times 8.5^2 = 361.3\ kN$ $Q_p = \frac{1}{2}K_p\gamma' d^2 = \frac{1}{2}\times 3.295\times(19-10)\times 1.5^2 = 28.0\ kN$ $Q_{wp} = \frac{1}{2}\gamma_w d^2 = \frac{1}{2}\times 10\times 1.5^2 = 11.25\ kN$ $Q = 443.9\ kN$ Resistance is: $F = 305.0$ $FOS = \frac{305.0}{443.9} = 0.69$ Alternative method for FOS, grouping all forces sliding against all resisting $FOS = 0.71$	$FOS = 0.69$

<table>
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<tr><td>4a</td><td>

Test 1

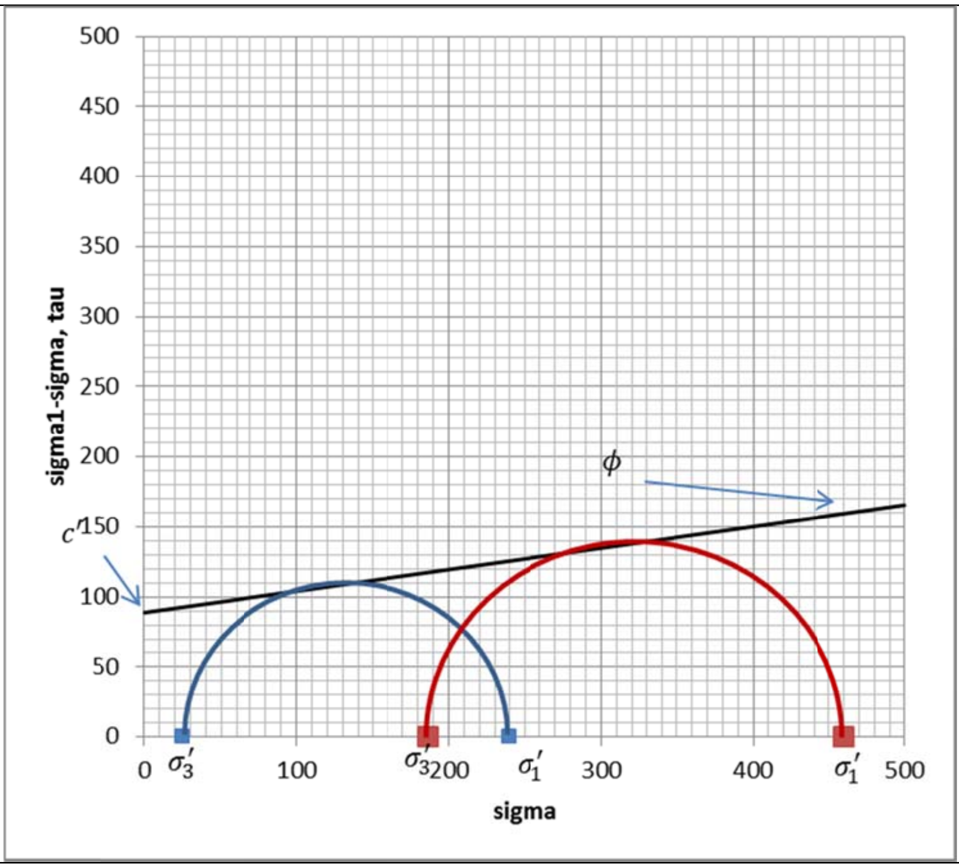
Axial stress, σ_1 (kPa)	Pore pressure, p (kPa)	Deviator stress, kPa	σ'_{1,} kPa	σ'_{3,} kPa	s, kPa	t, kPa
450	0	0	450	450	450	0
500	30	50	470	420	445	25
550	70	100	480	380	430	50
600	110	150	490	340	415	75
650	155	200	495	295	395	100
723	263	273	460	187	323.5	136.5

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	150	150	150	0
200	10	50	190	140	165	25
250	30	100	220	120	170	50
300	60	150	240	90	165	75
350	105	200	245	45	145	100
365	125	215	240	25	132.5	107.5

</td><td>Test 1
$\sigma'_1 = 460$ kPa
$\sigma'_3 = 187$ kPa

Test 2
$\sigma'_1 = 240$ kPa
$\sigma'_3 = 25$ kPa</td></tr>
<tr><td>4b</td><td>



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<td>4c</td>
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Can estimate from figure or from equation for M-C parameters:

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

Solve simultaneously with subtraction:

$$460 - 240 = (187 - 25) tan^2\left(45 + {\phi'}/_{2}\right)$$

$$\phi' = 8.6°$$

Back substitute for c’

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$\phi' = 8.6°$

c’ = 88.4 kPa

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<tr>
<td>4d</td>
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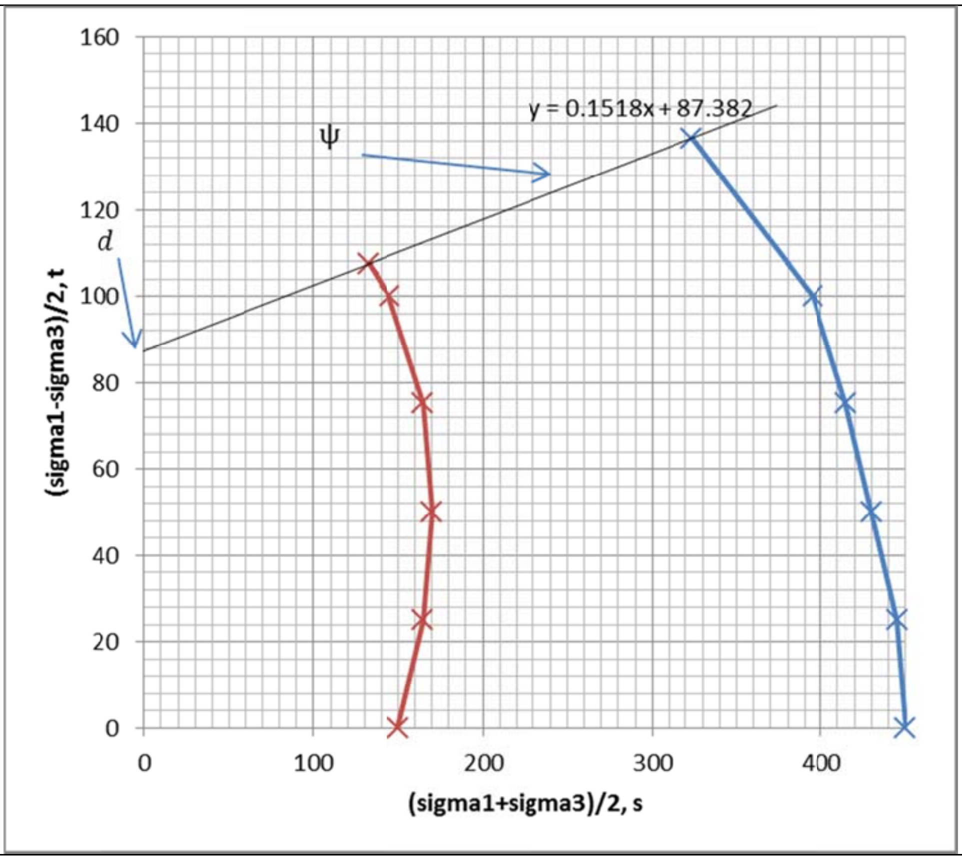

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