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DELFT UNIVERSITY OF TECHNOLOGY

Faculty of Civil Engineering and Geosciences

Soil Mechanics II

CT2091

BSc EXAMINATION 2012

ANSWER BOOK

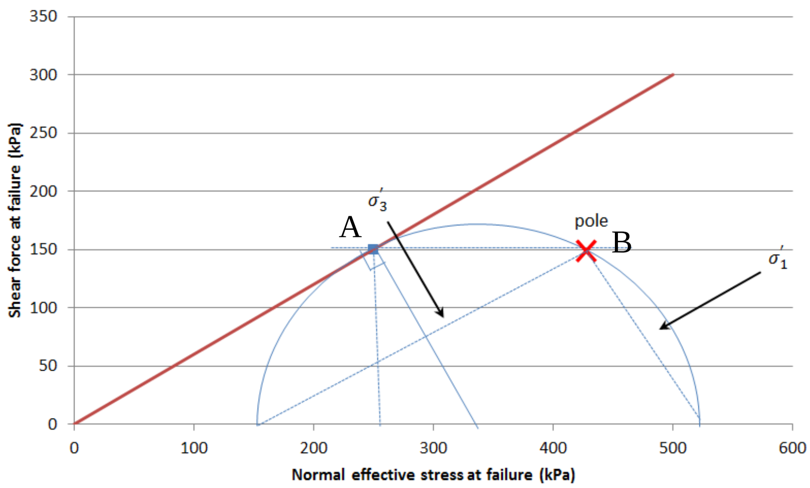
FIRST PERIOD

DATE: 2 November 2012 TIME: 09.00 – 12.00

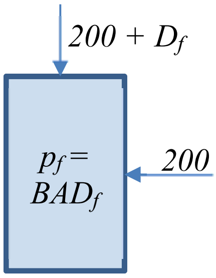
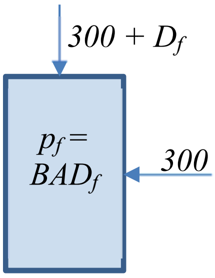
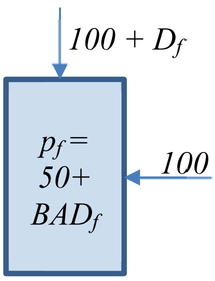
Answer ALL Questions
(Note that the questions carry unequal marks)

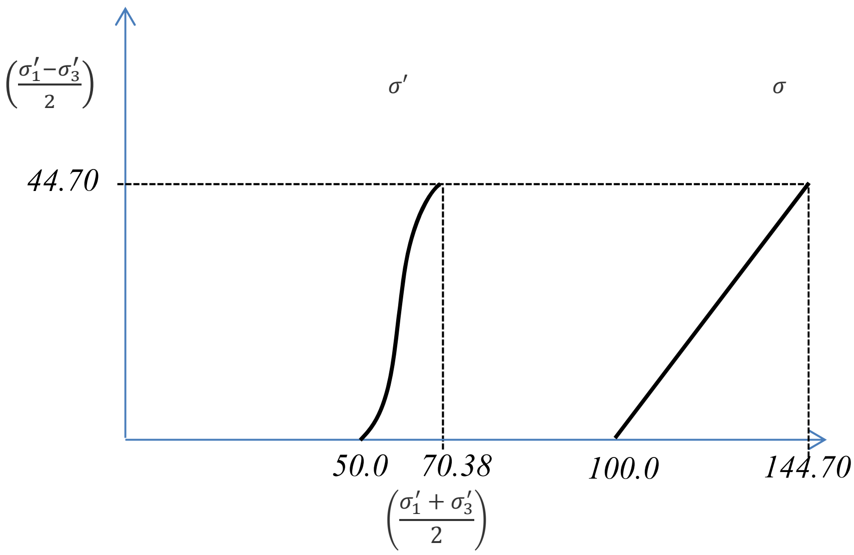
Other instructions
Write your name and student number on each sheet

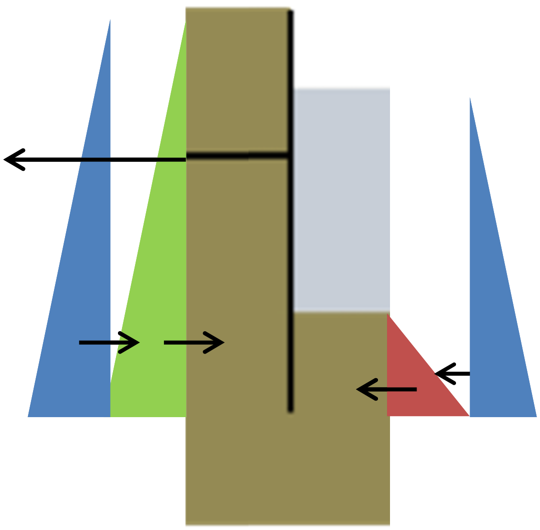
Clearly identify the answer in the answer box

Question No.	Workings	Answer
1a	Dry, clean sand therefore c=0 Also no moisture therefore $\sigma = \sigma'$ $\sigma'_v = \sigma'_n = 250kPa$ $\tau = 150kPa$ So $\phi' = tan^{-1}(150/250) = 31°$ By using right angle triangles: $$cos\ \phi' = \frac{\sqrt{(150^2 + 250^2)}}{\sigma'_{n,centre}}$$ $$\sigma'_{n,centre} = 340.2\ kPa$$ Radius of circle (from pythagorus): $$\sqrt{340.2^2 - (150^2 + 250^2)} = 174.9\ kPa$$  	$\phi' = 31°$
1b	Pole is found from a straight line from A to B (as we know the plane on which the stress A is acting). The Pole is point B. Coordinates of the pole = 340.2 + (340.2-250), 150 kPa =430.4, 150 kPa	430.4, 150 kPa

1c	$$\sigma_1' = 340.2 + 174.9 = 515.1\ kPa$$ $$\sigma_3' = 340.2 - 174.9 = 165.3\ kPa$$ Directions defined by Mohr's circle and Pole. $$\theta_1 = tan^{-1}\left(\frac{515.1 - 430.4}{150}\right) = 29.5°$$ σ_1' acts at 29.5° to horizontal σ_3' acts at 60.5° to horizontal	

Question No.	Workings	Answer
2a	Test 1  Test 2  *Test 1* $D_f = 253$ kPa $p_f = 0.85 \times 0.32 \times 253 = 68.8$ kPa $\sigma'_1 = 200+253-68.8 = 384.2$ kPa $\sigma'_3 = 200-68.8 = 131.2$ kPa *Test 2* $D_f = 362$ kPa $p_f = 0.85 \times 0.32 \times 362 = 98.5$ kPa $\sigma'_1 = 300+362-98.5 = 563.5$ kPa $\sigma'_3 = 300-98.5 = 201.5$ kPa $\sigma'_1 = \sigma'_3 \frac{1+\sin\phi'}{1-\sin\phi'} + 2c'\sqrt{\frac{1+\sin\phi'}{1-\sin\phi'}}$ $x = \sqrt{\frac{1+\sin\phi'}{1-\sin\phi'}}$, therefore $\sigma'_1 = \sigma'_3 x^2 + 2c'x$ Test 1: $384.2 = 131.2x^2 + 2c'x$ Test 2: $563.5 = 201.5x^2 + 2c'x$ Then, $179.3 = 70.3x^2$ and $x = 1.5970$ By substitution: c'=15.5 kPa and ϕ'=25.9°	c'=15.5 kPa ϕ'=25.9°
2b	Test 3  *Test 3* $p_f = 50+0.85 \times 0.32 \times D_f$ $= 50+0.272\, D_f$ $\sigma'_1 = 100+ D_f -50-0.272\, D_f$ $\sigma'_3 = 100-50-0.272\, D_f$	$D_f = 89.4$ kPa

	$\sigma_1' = \sigma_3' \dfrac{1 + \sin\phi'}{1 - \sin\phi'} + 2c'\sqrt{\dfrac{1 + \sin\phi'}{1 - \sin\phi'}}$ $\sigma_1' = 2.5511\sigma_3' + 49.5142$ Substituting above yields: $50 + 0.728D_f = 2.5511(50 - 0.272D_f) + 49.5142$ *D_f = 89.4 kPa*	
2c	 Note exact shape of effective stress path is not important (straight line is ok).	fig
2d		Fig above

Question No.	Workings	Answer
3a		
3b	Note no tension anchor so passive horizontal equilibrium must be satisfied by earth pressures. $$K_p' = \frac{1+sin\phi'}{1-sin\phi'} = 3$$ $$K_a' = \frac{1-sin\phi'}{1+sin\phi'} = 0.33$$ Forces: Active forces: From effective stress soil, $\frac{1}{2}K_a\gamma'(4+d)^2$ From water, $\frac{1}{2}K_0\gamma'(4+d)^2$ Passive forces: From effective stress soil, $\frac{1}{2}K_p\gamma' d^2$ From water, $\frac{1}{2}K_0\gamma'(3+d)^2$ FoS = 1.5, so must multiply active forces by 1.5. Therefore equating: $0.75 \times 0.33 \times (20-10) \times (4+d)^2 + 7.5(4+d)^2 = 15d^2 + 5(3+d)^2$ $$0 = 15d^2 + 5(3+d)^2 - 9.975(4+d)^2$$ $$0 = 10.025d^2 - 49.8d - 114.6$$ d=6.68 m (note that this is deeper than h)	d=6.68 m

3c	Horizontal equilibrium can include tension anchor, therefore rotation equilibrium is important at the tension anchor. Forces: Active forces and location of action below anchor: From effective stress soil, $\frac{1}{2}K_a\gamma'(4+3)^2 = 81.7kN$ at 2.7m From water, $\frac{1}{2}K_0\gamma'(4+3)^2 = 245\ kN$ at 2.7m Passive forces: From effective stress soil, $\frac{1}{2}K_p\gamma'3^2 = 135\ kN$ at 4.0m From water, $\frac{1}{2}K_0\gamma'(3+3)^2 = 180\ kN$ at 3.0m Moments: Overturning: $81.7 \times 2.7 + 245 \times 2.7 = 871\ kNm$ Resisting: $135 \times 4 + 180 \times 3 = 1080\ kNm$ FoS = 1080/871 = 1.24	FoS = 1.24
3d	Tension anchor via horizontal equilibrium: $T = 81.7 + 245 - 135 - 180 = 11.7\ kN$	$T = 11.7\ kN$

<table>
<tr><th>Question No.</th><th>Workings</th><th>Answer</th></tr>
<tr><td>4a</td><td>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.
Calculate N factors:
$$N_q = \frac{1+sin\,\phi}{1-sin\,\phi}\exp(\pi\,tan\,\phi) = 6.40$$
$$N_c = (N_q - 1)cot\,\phi = 14.83$$
$$N_\gamma = 2(N_q - 1)tan\,\phi = 3.93$$
Calculate shape factors:
$$s_c = 1 + 0.2\frac{B}{L} = 1.1$$
$$s_q = 1 + \frac{B}{L}sin\,\phi = 1.17$$
$$s_\gamma = 1 - 0.3\frac{B}{L} = 0.85$$
Load:
Weight of concrete, $= A\gamma d = 20 \times 10 \times 25 \times 2.5 = 12500\ kN$
Weight of soil, $= A\gamma d = 20 \times 10 \times 20 \times 2.5 = 10000\ kN$
Total $= 12500 + 10000 + 50000 = 72500\ kN$ (from applied load)
Pore pressure, p = $10 \times 5 = 50\ kPa$
Load = $\frac{W}{A} - p = \frac{72500}{200} - 50 = 312.5\ kPa$

Surcharge (note effective stress usage), q:
$$q = \gamma' d = 50\ kPa$$
$$p_c = cN_c s_c + qN_q s_q + \frac{1}{2}\gamma' BN_\gamma s_\gamma = 705\ kPa$$
FoS = 705 / 313 = 2.26</td><td>FoS = 2.26</td></tr>
<tr><td>4b</td><td>Again use the Brinch Hansen method.
$$p_c = cN_c i_c s_c + qN_q i_q s_q + \frac{1}{2}\gamma' BN_\gamma i_\gamma s_\gamma$$
In this case need the inclinations factors:</td><td>FoS = 1.16</td></tr>
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	Horizontal stress, t: $$t = \frac{F}{area} = \frac{7500}{200} = 37.5\ kPa$$ Vertical load, p: Total $= 12500 + 10000 + 30000 = 52500\ kN$ (from applied load) Pore pressure, p = $10 \times 5 = 50\ kPa$ [**don't penalise for omitting pore pressure in load**] Load $= \frac{W}{A} - p = \frac{52500}{200} - 50 = 212.5\ kPa$ $$i_c = 1 - \frac{t}{c + p\ tan\ \phi} = 0.57$$ $$i_q = {i_c}^2 = 0.33$$ $$i_\gamma = {i_c}^3 = 0.19$$ $$p_c = 246\ kPa$$ FoS = 246/213 = 1.16	
4c	FoS reduces as shape factors, N_c and N_q reduce (B/L) gets smaller.	reduces