DELFT UNIVERSITY OF TECHNOLOGY

Faculty of Civil Engineering and Geosciences

Soil Mechanics II

CT2091

BSc EXAMINATION 2013 - RESIT

ANSWER BOOK

SECOND PERIOD

DATE: 22 January 2013 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	Split into 5 slices, based upon 6 points given, so that each slice has a width of B=4.18 m	F = 1.37

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.

Slice	Angle to vertical at mid-height (°)	h at mid-slice (m)	$A = \gamma h cos^2 \alpha$	$B = c + A tan \phi$	$C = B / cos \alpha$	$D = \gamma h sin \alpha$
1	-8.08	1.50	26.49	27.32	27.59	-3.80
2	6.14	3.97	70.68	31.18	31.36	7.67
3	20.78	5.35	84.16	32.36	34.62	34.24
4	37.20	5.37	61.19	30.35	38.14	58.49
5	60.53	2.45	10.57	25.92	52.98	38.49
				$\Sigma C =$	184.70	
					$\Sigma D =$	135.10

$F = \frac{\Sigma C}{\Sigma D}$ =1.37

Question No.	Workings	Answer
1b	Same approach as a, but with Bishop's method. Normally need to iterate, but for exam first iteration only, F=1.	F = 1.36

Slice	Angle to vertical (°)	h at mid-slice (m)	$A = c + \gamma h tan \phi$	$B = tan \alpha \, tan \phi / F$	$C = cos \alpha (1 + B)$	$D = A / C$	$E = \gamma h sin \alpha$
1	-8.08	1.50	27.36	-0.01	0.98	27.99	-3.80
2	6.14	3.97	31.26	0.01	1.00	31.14	7.67
3	20.78	5.35	33.43	0.03	0.97	34.61	34.24
4	37.20	5.37	33.45	0.07	0.85	39.41	58.49
5	60.53	2.45	28.86	0.16	0.57	51.02	38.49
					$\Sigma D =$	184.17	
						$\Sigma E =$	135.10

$F = \frac{\Sigma C}{\Sigma D}$ =1.36

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<td>1c</td>
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Resistance moment: $c_u R^2 \theta = 25 \times 17^2 \times \left(\frac{90.2 \times \pi}{180}\right) = 11{,}374\ kN$

Can approach overturning moment by either slices or as a whole.

Slice	W=hBγ (kN)	d= -4.46 + B(slice / 0.5) (m)	Wd (kNm)
1	112.9	-2.37	-267.7
2	298.9	1.81	540.9
3	402.7	5.99	2412.0
4	403.8	10.17	4106.7
5	184.5	14.35	2647.5
		$\Sigma Wd =$	9439.5

$$F = \frac{resistive\ moment}{overturning\ moment} = \frac{11374}{9439.5} = 1.20$$

Note that all solutions have similar results. Slope is likely to be safe, but FoS is not significant.

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<td>F = 1.20</td>
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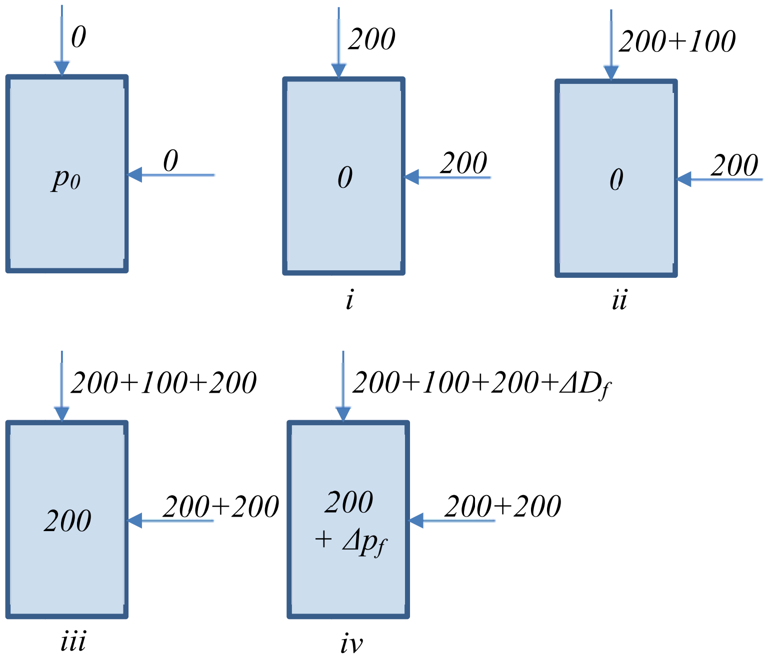
<tr><th>Question No.</th><th>Workings</th><th>Answer</th></tr>
<tr><td>2</td><td>



$$\Delta p = B(\Delta\sigma_3 + A(\Delta\sigma_1 - \Delta\sigma_3))$$
$$\Delta p = (\Delta\sigma_3 + A(\Delta\sigma_1 - \Delta\sigma_3))$$
In step iv, $\Delta p_f = \Delta p$ *and* $\Delta\sigma_3 = 0$ therefore:
$$\Delta p_f = A(\Delta\sigma_1) = 0.15\Delta D_f$$
$\sigma_1' = \sigma_1 - p$ and at failure this gives:
$$\sigma_{1f}' = 500 + \Delta D_f - (200 + \Delta p_f)$$
And substitution gives:
$$\sigma_{1f}' = 300 + 0.85\Delta D_f$$
$$\sigma_{3f}' = 400 - (200 + \Delta p_f) = 200 - 0.15\Delta D_f$$
From Mohr-Coulomb failure envelope:
$$\sigma_1' = \sigma_3' tan^2\left(45 + {\phi'}/{2}\right) + 2c' tan\left(45 + {\phi'}/{2}\right)$$
Or as $c' = 0$:
$$\sigma_1' = \sigma_3' tan^2\left(45 + {\phi'}/{2}\right)$$
$$\sigma_1' = 2.04\,\sigma_3'$$
Again via substitution:
$$300 + 0.85\Delta D_f = 2.04(200 - 0.15\Delta D_f)$$
So:
$$\Delta D_f = 93.4 \text{ kPa}$$
Including the existing 100 kPa deviator stress the compression strength is therefore, 193 kPa.

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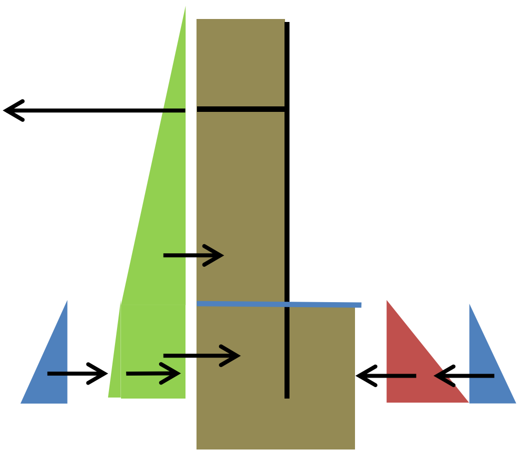
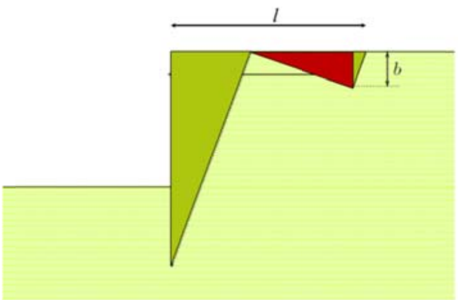
Question No.	Workings	Answer
3a		
3b	$$K_p' = \frac{1 + sin\phi'}{1 - sin\phi'} = 3$$ $$K_a' = \frac{1 - sin\phi'}{1 + sin\phi'} = 0.33$$ Forces: Active forces: From total stress soil top section, $\frac{1}{2}K_a\gamma(3.5)^2$ kN Location of action from tension anchor, (2/3)×3.5 – 1 m From total stress soil rect. section, $K_a\gamma 3.5d$ kN Location of action from tension anchor, d/2 + 2.5 m Effective stress base triangular section, $\frac{1}{2}K_a\gamma'(d)^2$ kN Location of action from tension anchor, 2d/3 + 2.5 m From water, $\frac{1}{2}K_0\gamma'(d)^2$ Passive forces: From effective stress soil, $\frac{1}{2}K_p\gamma' d^2$ Location of action from tension anchor, 2d/3 + 2.5 m From water, $\frac{1}{2}K_0\gamma'(d)^2$ Rotation around tension anchor (ignoring water as equal in both directions). Moments:	$d = 2.073$ m

	Overturning: $\frac{1}{2}K_a\gamma 3.5^2 \times [1.33] + K_a\gamma 3.5d \times \left[2.5 + \frac{d}{2}\right] + \frac{1}{2}K_a\gamma'(d)^2 \times \left[{}^2/_3\, d + 2.5\right]\ kNm$ Resisting: $\frac{1}{2}K_p\gamma' d^2 \times \left[{}^2/_3\, d + 2.5\right]\ kNm$ $overturning = resisting$ $54.39 + 58.325d - 21.7d^2 - 8.9d^3 = 0$ $d = 2.073$m	
3c	$\frac{1}{2}K_a\gamma(3.5)^2 = 40.83$ kN $K_a\gamma 3.5d = 48.37$ kN $\frac{1}{2}K_a\gamma'(d)^2 = 7.16$ kN $\frac{1}{2}K_p\gamma' d^2 = 64.46$ kN Tension anchor via horizontal equilibrium: $T = 40.83 + 48.37 + 7.16 - 64.46 = 31.91\ kN$	31.91 kN
3d	 b = 1.5m (from question) *l* = active zone from pile + passive zone from anchor $Q_p = \frac{1}{2}K_p\gamma b^2 = 67.5\ kN$ $l = (d + 3.5)\tan\theta + {}^b/_{\tan\theta}$ $\theta = 45 - \frac{\phi}{2} = 30°$ $l = (2.073 + 3.5)\tan 30 + {}^{1.5}/_{\tan 30} = 5.81\ m$	5.81 m

Question	Workings	Answer

No.		
4a	(see below)	$c' = 15\ kPa$ $\phi' = 30.2°$

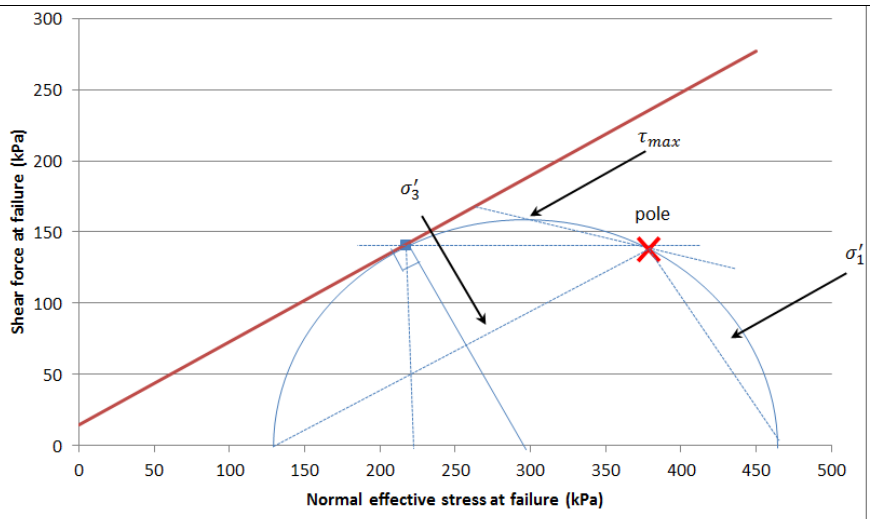
Test No.	Normal force, N	σ'_n, kPa	Shear force, N	τ, kPa
1	400	111.1	287	79.7
2	780	216.7	508	141.1
3	1100	305.6	694	192.8

Could draw Mohr's circles, but also can use simultaneous equations for any other the two test, e.g.:

$$79.7 = c' + 111.1 tan\ \phi'$$
$$192.8 = c' + 305.6 tan\ \phi'$$

$$c' = 15\ kPa$$
$$\phi' = 30.2°$$

4b i



Marks here just for the Mohr's circle and failure

4b ii

Centre of circle, *216.7 + 141.1 tan 30.2° = 298.8 kPa*
Radius of circle, 141.1 / cos 30.2° = *163.3 kPa*

$\sigma'_1 = 298.8 + 163.3 = 462.1\ kPa$
$\sigma'_3 = 298.8 - 163.3 = 135.5\ kPa$

σ'_1 acts at 45°-$\phi'/2$ = 29.9°
σ'_3 acts at 45°+$\phi'/2$ = 60.1°

Unit kPa
$\sigma'_1 = 462.1$
$\sigma'_3 = 135.5$

σ'_1 acts at 29.9°
σ'_3 acts at 60.1°
to horizontal

4c iii

$$\tau_{max} = 163.3\ kPa$$

	Angle using trig from Pole (which is known from shear failure – opposite side of circle) $tan\ \theta = \frac{163.3-141.1}{298.8-216.7} = 15.1°$ to horizontal.	$\tau_{max} = 163.3\ kPa$ 15.1° to horiz.