DELFT UNIVERSITY OF TECHNOLOGY

Faculty of Civil Engineering and Geosciences

Soil Mechanics

CTB2310 / AESB2330

BSc EXAMINATION 2017

FOURTH PERIOD

DATE: 4 JULY 2017 TIME: 13.30 – 16.30

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

Need to calculate stresses at failure.

Area is 0.05 x 0.05 = 0.0025 m^2

Normal force (N)	Shear force at failure (N)	Normal stress (kPa)	Shear stress at failure (kPa)
1200	470	480	188
1800	520	720	208

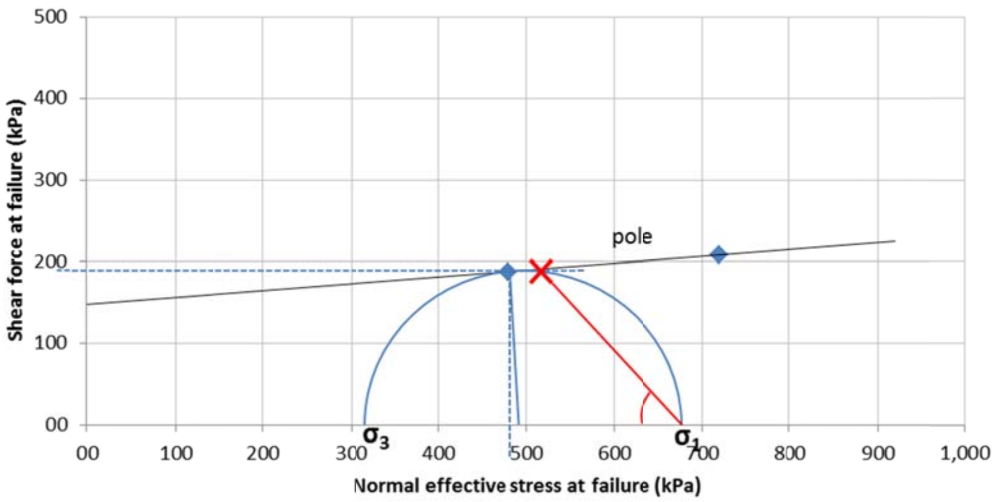
By solving $\tau = \sigma'_{nf} tan\phi' + c'$ simultaneously the parameters can be calculated:

$$c' = 148.0\ kPa$$
$$\phi' = 4.8°$$

Can use a graphical method, but normally less exact. (Reduce mark by 2 points).

Answer: $c' = 148.0\ kPa$, $\phi' = 4.8°$

1b



1c

Using a number of trigonometric methods is possible to determine the principle stresses.

Simplest is to calculate the centre and the radius of the Mohr's circle:

Radius: $r = \frac{188.0}{\cos\phi'} = 188.7\ kPa$

Centre: $480.0 + 188.0 \tan\phi' = 495.7\ kPa$

$\sigma_1 = 495.7 + 188.7 = 684.3\ kPa$
$\sigma_3 = 495.7 + 188.7 = 307.0\ kPa$

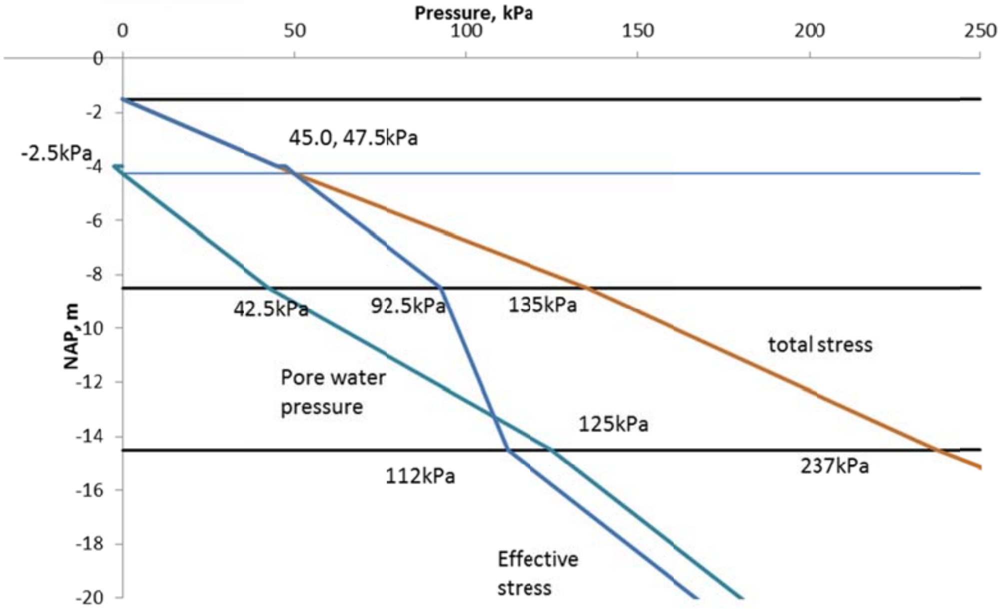
Answer: $\sigma_1 = 684.3\ kPa$ 47.4° to hor.

$\sigma_3 = 307.0\ kPa$ 42.6° to hor.

	Angle to horizontal is e.g. the angle marked above in red for σ_1. Vertical line of triangle is 188.0 kPa, horizontal edge is: $188.7 - 188.0 \tan \phi' = 173.0\ kPa$ Angle to horizontal is: $\tan^{-1} {}^{188}/_{173} = 47.4°$ For σ_3: 90-47.4 = 42.6°	

Question No.	Workings	Answer

2a



2b

Total stresses increase by 200kPa, Pore pressures remain the same, therefore effective stresses increase by 200kPa.

By interpolation:
Stress in the centre of 2 layers:

Centre layer 1: -10 m NAP

	σ (kPa)	p (kPa)	σ' (kPa)
Before	160.5	63.1	97.4
After	360.5	63.1	297.4

Centre layer 2: -13 m NAP

	σ (kPa)	p (kPa)	σ' (kPa)
Before	211.5	104.4	107.1
After	411.5	104.4	307.1

Answer: See table

2c

Primary strain: $\varepsilon = \frac{1}{C_p} \ln\left(\frac{\sigma'}{\sigma'_1}\right)$

Top layer

$$\varepsilon = \frac{1}{10} \ln\left(\frac{297.4}{97.4}\right) = 0.112$$

Bottom layer

$$\varepsilon = \frac{1}{10} \ln\left(\frac{307.1}{107.1}\right) = 0.105$$

Deformation, $u = \Sigma\, d \times \varepsilon$

Total deformation = $\Sigma\, (3 \times \varepsilon)$

$= 3x(0.112 + 0.105) = 0.65$ m

Answer: 0.65 m

2d

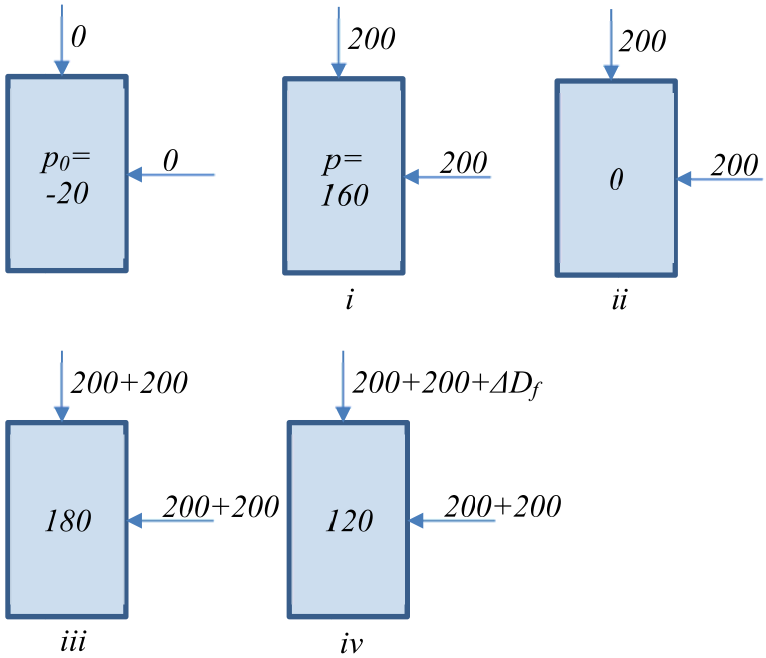
Calculate the consolidation coeff:

$$c_v = \frac{k}{\gamma_w m_v} = \frac{1.0 \times 10^{-10}}{10 \times 0.0001} = 1.0 \times 10^{-7} m^2/s$$

Answer: 2.42 years

	For 90% of consolidation to be complete: $$\frac{c_v t_{90}}{h^2} = 0.848$$ h=3m, as sand is on both sides of the clay, therefore: $$t_{90} = \frac{0.848h^2}{c_v} = 76320000\ s = 2.42 \text{ years}$$	

<table>
<tr><th>Question No.</th><th>Workings</th><th>Answer</th></tr>
<tr><td>3a</td><td>



$$\Delta p = B(\Delta\sigma_3 + A(\Delta\sigma_1 - \Delta\sigma_3))$$

In stage i:

$$180 = B(200 + A(0))$$
$$B = \frac{180}{200} = 0.9$$

</td><td>$B = 0.9$</td></tr>
<tr><td>3b</td><td>

In step iv:

$\sigma_1' = \sigma_1 - p$, so at failure this gives:

$$\sigma_{1f}' = 400 + \Delta D_f - 120$$
$$\sigma_{3f}' = 400 - 120 = 280 \text{ kPa}$$

From Mohr-Coulomb failure envelope:

$$\sigma_1' = \sigma_3' tan^2\left(45 + {}^{\phi'}/_2\right) + 2c'tan\left(45 + {}^{\phi'}/_2\right)$$

As *c'=0*:

$$\sigma_1' = \sigma_3' tan^2\left(45 + {}^{\phi'}/_2\right)$$
$$\sigma_1' = 2.04\ \sigma_3' = 571.2 \text{ kPa}$$
$$\Delta D_f = 291.2 \text{ kPa}$$

</td><td>$\Delta D_f = 291.2$ kPa</td></tr>
</table>

3c	*Δp=-60kPa* and *$\Delta\sigma_3$=0* therefore: $$\Delta p_f = AB(\Delta\sigma_1)$$ $$-60 = AB(291.2)$$ $$A = \frac{-60}{291.2} = -0.23$$	$A = -0.23$
3d	A= – 0.23, therefore the sample dilates and therefore is dense. B=0.9, therefore the sample is not fully saturated.	See text

<table>
<tr><th>Question No.</th><th>Workings</th><th>Answer</th></tr>
<tr><td>4a</td><td>Factor of safety for an infinite slope is:
$$F = \frac{\tan\phi}{\tan\alpha} = \frac{\tan 30}{\tan 25} = 1.24$$</td><td>1.24</td></tr>
<tr><td>4b</td><td>Split into 4 slices, based upon 5 points given, so that each slice has a width of B=0.98 m

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.

<table>
<tr><th>Slice</th><th>Angle to vertical (°)</th><th>h at mid-slice (m)</th><th>$A = \gamma h cos^2 \alpha$</th><th>$B = c + A tan\,\phi$</th><th>$C = B/cos\,\alpha$</th><th>$D = \gamma h sin\,\alpha$</th></tr>
<tr><td>1</td><td>61.1</td><td>0.66</td><td>2.92</td><td>11.69</td><td>24.17</td><td>10.94</td></tr>
<tr><td>2</td><td>24.7</td><td>1.31</td><td>20.58</td><td>21.88</td><td>24.09</td><td>10.42</td></tr>
<tr><td>3</td><td>0.9</td><td>1.09</td><td>20.66</td><td>21.93</td><td>21.93</td><td>0.34</td></tr>
<tr><td>4</td><td>-22.6</td><td>0.43</td><td>7.01</td><td>14.05</td><td>15.22</td><td>-3.17</td></tr>
<tr><td></td><td></td><td></td><td></td><td>$\Sigma C =$</td><td>85.41</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td>$\Sigma D =$</td><td>18.54</td></tr>
</table>
$$F = \frac{\Sigma C}{\Sigma D} = 4.61$$</td><td>4.61</td></tr>
<tr><td>4c</td><td>1. Cohesion plays an important role – is not included in 4a
2. The slip circle is not the critical one, there will be ones with a lower FoS.</td><td></td></tr>
</table>