DELFT UNIVERSITY OF TECHNOLOGY

Faculty of Civil Engineering and Geosciences

Soil Mechanics

CTB2310 / AESB2330

BSc EXAMINATION 2016

THIRD PERIOD

DATE: 12 APRIL 2016 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

<table>
<tr><th>Question No.</th><th>Workings</th><th>Answer</th></tr>
<tr><td>1a</td><td>

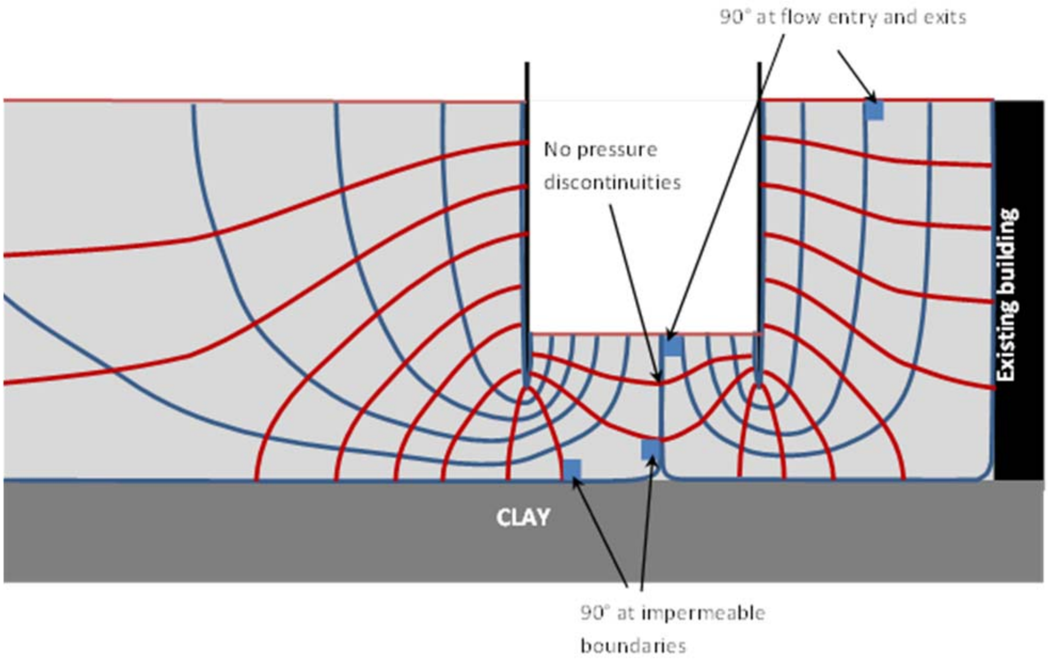
$$Q = kA\frac{\Delta h}{\Delta L}, Q = \frac{\Delta V}{\Delta t}$$

therefore $k = \frac{Q\Delta L}{A\Delta h}$ for a later time step, early timestep is not yet at steady state.

<table>
<tr><th>Time (seconds)</th><th>Cumulative water volume (ml)</th><th>$Q = \Delta V/\Delta t$ (m^3/s)</th><th>k (m/s)</th></tr>
<tr><td>0</td><td>0</td><td></td><td></td></tr>
<tr><td>10</td><td>2</td><td>2.0x10^{-7}</td><td>2.12x10^{-5}</td></tr>
<tr><td>60</td><td>40</td><td>7.6x10^{-7}</td><td>8.06x10^{-5}</td></tr>
<tr><td>120</td><td>86</td><td>7.67x10^{-7}</td><td>8.13x10^{-5}</td></tr>
<tr><td>180</td><td>131</td><td>7.5x10^{-7}</td><td>7.96x10^{-5}</td></tr>
</table>

Average of (8.13x10^{-5}, 7.96x10^{-5}, 8.06x10^{-5}) is 8.05x10^{-5} m/s. Also accept any of the last 3 in the table for full marks.

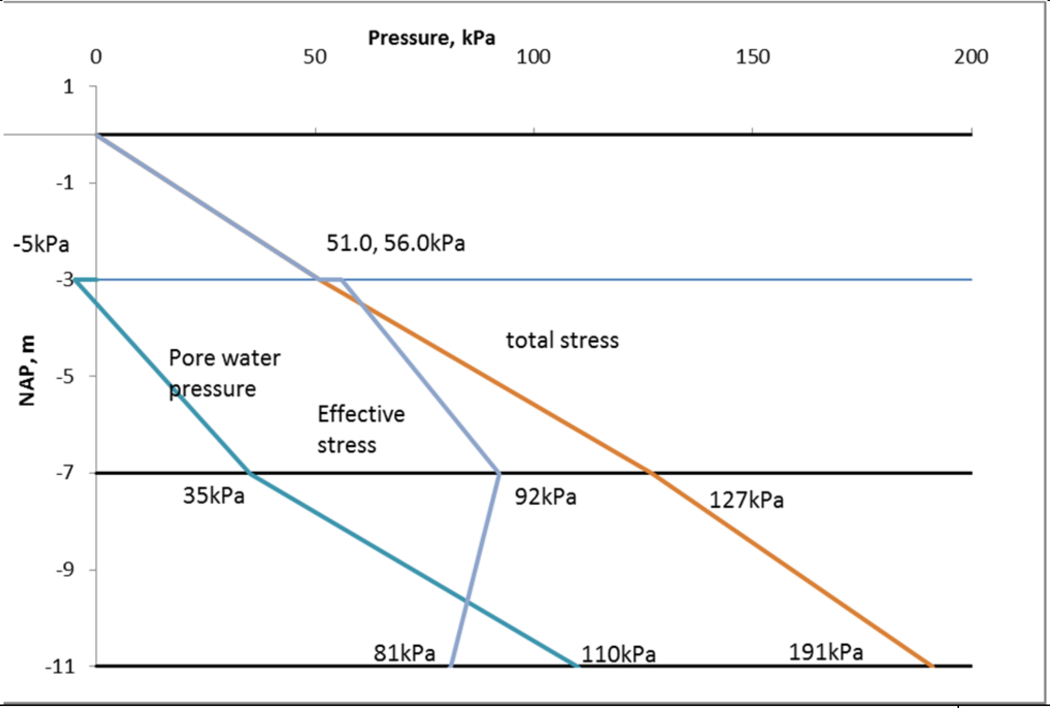
</td><td>8.05x10^{-5} m/s</td></tr>
<tr><td>1b</td><td>

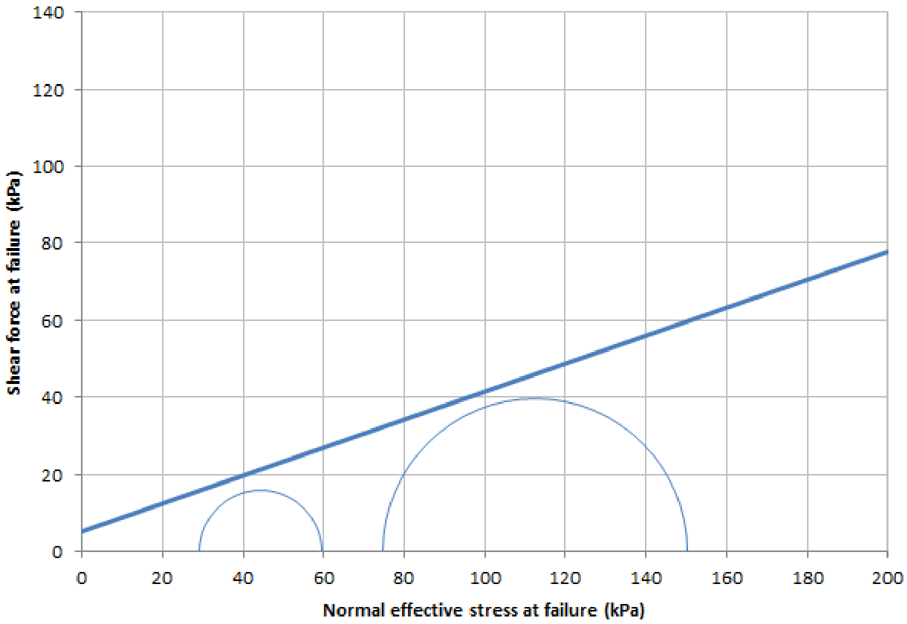


Intersections of lines are also approximately square.
No stream lines touch each other.
Sizes of intersections are approximately square.

</td><td></td></tr>
</table>

1c	No unique answer. Based on the figure above: Stream lines = 6 + 5 = 11, Stream intervals = 9 Potential lines = 12 +12 = 24, potential intervals = 11 (on both sides) Flow into the excavation can be calculated via: $Q = \frac{n_s}{n_n} k\Delta hB$ $Q = \frac{4+5}{11} 8 \times 10^{-5} \times 5 \times 1 = 0.000328 m^3/s\ \ /m$ Or 1.18 $m^3/h\ /m$	1.18 $m^3/h\ /m$
1d	No unique answer. Based on the figure above: Critical point for liquefaction is at the downstream end of the flow path, where the smallest square is. Two methods: calculate effective stress or calculate critical gradient. Critical gradient is $i_{crit} = -\frac{\gamma_s - \gamma_w}{\gamma_w} = -\frac{19-10}{10} = -0.9$ Gradient over last square is: dH = 5/11 = 0.46 m dz = -0.5 m dH/dz = -0.91 **Risk** of liquefaction Method for checking effective stress: Total stress at base of last square = 0.5 x 19 = 9.5 kPa PWP due to gravity = 0.5 x 10 = 5 kPa PWP due to flow = dHγ_w = 0.46 x 10 = 4.6 kPa Effective stress = 9.5- (5+4.6) = -0.1 kPa <0 therefore at risk.	At risk.

Question No.	Workings	Answer
2a		
2b	By interpolation from above, at the middle of the clay layer, before construction: $\sigma_v = {(127+191)}/_{2} = 159\ kPa$ $\sigma_v{}' = {(81+92)}/_{2} = 86.5\ kPa$ After construction, and after pore water pressures have dissipated both total and effective stresses will increase by the same amount, 5 x 18 = 90 kPa: $\sigma_v = 159 + 90 = 249\ kPa$ $\sigma_v' = 86.5 + 90 = 176.5\ kPa$	Before $\sigma_v = 159\ kPa$ $\sigma_v{}' = 86.5\ kPa$ After $\sigma_v = 249\ kPa$ $\sigma_v' = 176.5\ kPa$
2c	Strain: $\varepsilon = \frac{1}{C_p}\ln\left(\frac{\sigma'}{\sigma'_1}\right)$ $\varepsilon = \frac{1}{20}\ln\left(\frac{176.5}{86.5}\right) = 0.0357$ Deformation, $u=4 \times \varepsilon$ $= 4 \times 0.0357 = 0.14\ m$ Consolidation coefficient: $m_v = \frac{\Delta\varepsilon}{\Delta\sigma} = \frac{0.0357}{90} = 0.0004kPa^{-1}$	93 days

	$c_v = \frac{k}{\gamma_w m_v} = \frac{3.5 \times 10^{-9}}{10 \times 0.0004} = 8.8 \times 10^{-7} m^2/s$ h=2m as permeable sand/rock on both sides, so: $\frac{c_v t_{99}}{h^2} = 1.784, t_{99} = 1.784 \times \frac{2^2}{8.8\times10^{-7}} = 8.0 \ \times 10^6 \ s$ $= 2243 \ hours = 93 \ days$	
2d	The major (vertical) stresses are from above (by interpolation), calculate the horizontal (minor) stresses as: $\sigma_h' = K_0 \sigma_v' = (e.g.)0.5 \times 60.5 = 30.25$ Mohr's circles are:  Soil is weak. Very little shear capacity, therefore stability of slopes should be calculated carefully.	

<table>
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<tr><td>3a</td><td>Factor of safety for an infinite slope is:
$$F = \frac{\tan\phi}{\tan\alpha} = \frac{\tan 25}{0.5} = 0.93$$</td><td>0.93</td></tr>
<tr><td>3b</td><td>Split into 5 slices, based upon 6 points given, so that each slice has a width of B=4 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>-5.00</td><td>1.18</td><td>20.99</td><td>9.79</td><td>9.83</td><td>-1.84</td></tr>
<tr><td>2</td><td>7.70</td><td>3.08</td><td>54.44</td><td>25.39</td><td>25.62</td><td>7.42</td></tr>
<tr><td>3</td><td>20.81</td><td>4.05</td><td>63.68</td><td>29.70</td><td>31.77</td><td>25.90</td></tr>
<tr><td>4</td><td>35.30</td><td>3.87</td><td>46.43</td><td>21.65</td><td>26.53</td><td>40.29</td></tr>
<tr><td>5</td><td>53.75</td><td>1.73</td><td>10.87</td><td>5.07</td><td>8.58</td><td>25.09</td></tr>
<tr><td></td><td></td><td></td><td></td><td>$\Sigma C =$</td><td>102.32</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td>$\Sigma D =$</td><td>96.85</td></tr>
</table>
$$F = \frac{\Sigma C}{\Sigma D} = 1.05$$</td><td>1.05</td></tr>
<tr><td>3c</td><td>• Lower FOS is closer to critical value.
or
• 1 is the critical FoS, therefore closest to 1 is correct.</td><td></td></tr>
</table>

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

Need to calculate stresses at failure.

Area is 0.04 x 0.04 = 0.0016 m^2

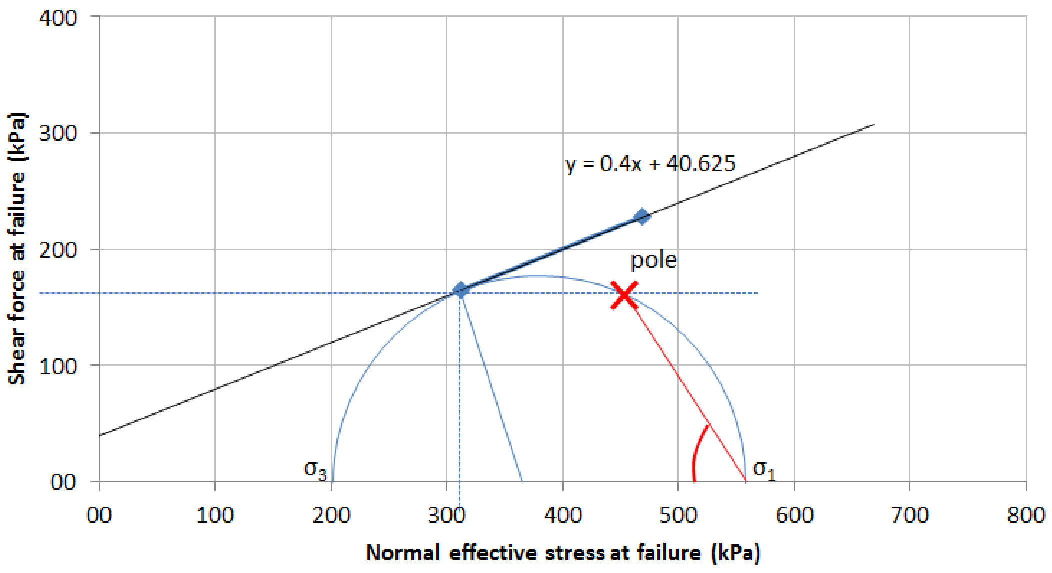
<table>
<tr><th>Normal force (N)</th><th>Shear force at failure (N)</th><th>Normal stress (kPa)</th><th>Shear stress at failure (kPa)</th></tr>
<tr><td>500</td><td>265</td><td>312.5</td><td>165.6</td></tr>
<tr><td>750</td><td>365</td><td>468.8</td><td>228.1</td></tr>
</table>

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

$$c' = 40.6\ kPa$$
$$\phi' = 21.8°$$

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

</td><td>$c' = 40.6\ kPa$
$\phi' = 21.8°$</td></tr>
<tr><td>4b</td><td colspan="2">



</td></tr>
<tr><td>4c</td><td>

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

</td><td>$\sigma_1 = 557.1\ kPa$
55.9° to hor.</td></tr>
</table>

	circle: Radius: $r = \frac{165.6}{\cos\phi'} = 178.4\ kPa$ Centre: $312.5 + 165.6\tan\phi' = 378.8\ kPa$ $\sigma_1 = 378.8 + 178.4 = 557.1\ kPa$ $\sigma_3 = 378.8 - 178.4 = 200.4\ kPa$ Angle to horizontal is e.g. the angle marked above in red for σ_1. Vertical line of triangle is 165.5 kPa, horizontal edge is: $178.4 - 165.6\tan\phi' = 112.1\ kPa$ Angle to horizontal is: $\tan^{-1} {}^{165.6}/_{112.1} = 55.9°$ For σ_3: 90-55.9 = 34.1°	$\sigma_3 = 200.4\ kPa$ 34.1° to hor.