DELFT UNIVERSITY OF TECHNOLOGY

Faculty of Civil Engineering and Geosciences

Soil Mechanics

CTB2310 / AESB2330

BSc EXAMINATION 2018

THIRD PERIOD

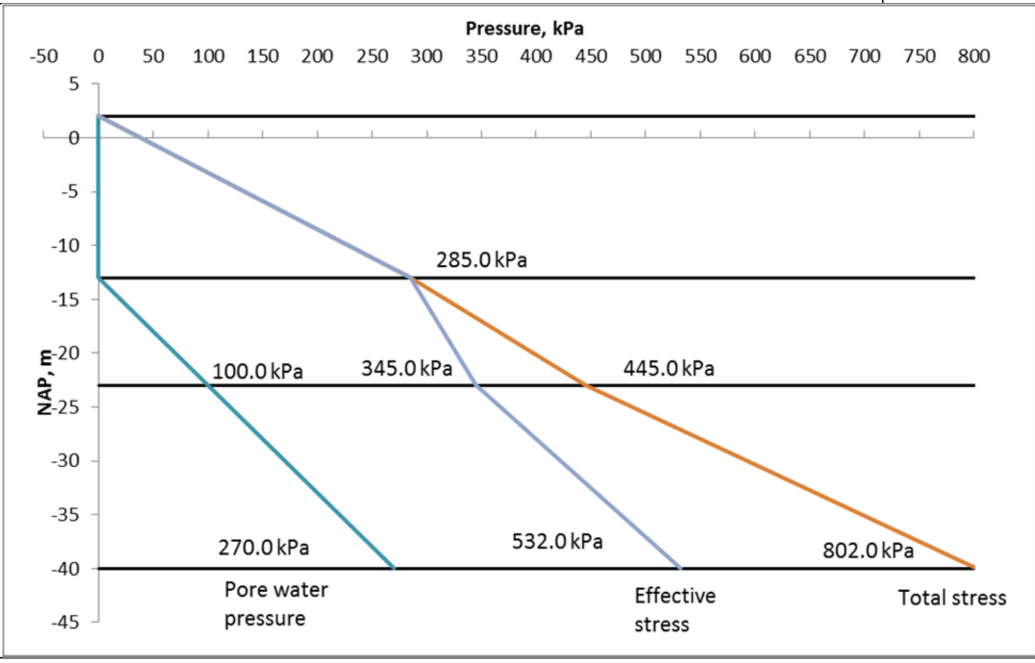
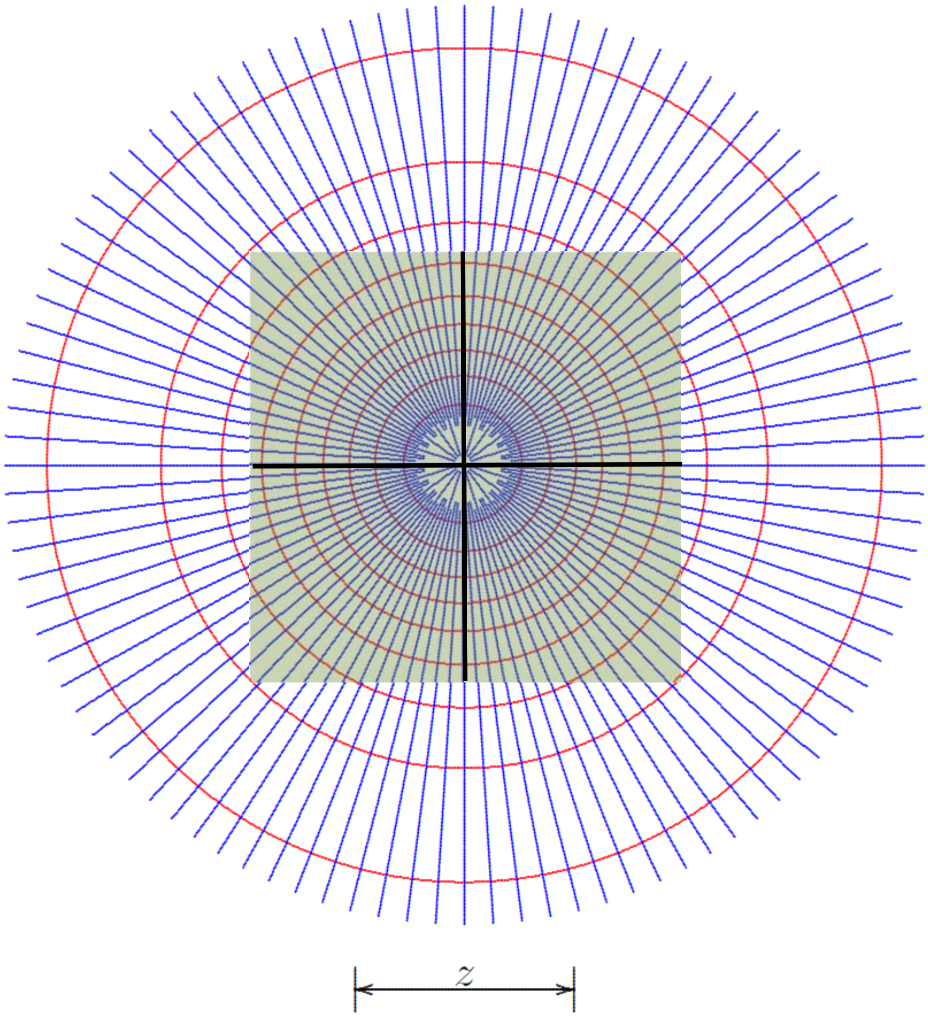
DATE: 16 APRIL 2018 TIME: 13.30 – 16.30

Answer ALL Questions

Other instructions

Write your name and student number on each sheet

Clearly identify the answer in the answer box

Question No.	Workings	Answer
1a		
1b		

1b	Effective stress at the centre, via interpolation: $$\sigma' = 285 + \frac{345-285}{2} = 315\ kPa$$ Change in stress is at 10m below the final surface. Therefore the building is 2z x 2z on Newmark's chart. Number of squares is: Complete circles: 6 Squares: (6x100) + 72+ 24 = 696 (range of correct is 680 – 710) Change of effective stress at the end of the excavation: 696 x 0.001 x (-10x19) = -132 kPa Change of effective stress at the end of the construction: 696 x 0.001 x (500 – 10x19) = 216 kPa	$\sigma'_{initial} = 315\ kPa$ $\Delta\sigma'_{exca} = -132\ kPa$ $\Delta\sigma'_{const} = 216\ kPa$
1c	Strain, at the end of the excavation, is: $\varepsilon = \frac{1}{C_p}\ln\left(\frac{\sigma}{\sigma_1}\right) = \frac{1}{20}\ln\left(\frac{315-132}{315}\right) = -0.027$ Displacement = $-0.027 \times 10 = -0.27m$ Strain, at the end of the construction, is: $\varepsilon = \frac{1}{C_p}\ln\left(\frac{\sigma}{\sigma_1}\right) = \frac{1}{20}\ln\left(\frac{216+315}{315}\right) = 0.026m$ Displacement = $0.026 \times 10 = 0.26m$	$disp_{exc} = -0.27m$ $disp_{const} = 0.26m$

<table>
<tr><th>Question No.</th><th>Workings</th><th>Answer</th></tr>
<tr><td>2a</td><td>Using the Brinch Hansen method:
$$p_c = cN_c i_c s_c + qN_q i_q s_q + \frac{1}{2}\gamma' B N_\gamma i_\gamma s_\gamma$$
No inclination factors or surcharge due to being at ground level.

Therefore, N factors and shape factors are needed. Shape factors also ok to be calculated in Q2b.
$$N_q = \frac{1+sin\,\phi}{1-sin\,\phi}\exp(\pi\,tan\,\phi) = \frac{1+sin\,15}{1-sin\,15}\exp(\pi\,tan\,15) = 3.941$$
$$N_c = (N_q - 1)cot\,\phi = 10.977$$
$$N_\gamma = 2(N_q - 1)tan\,\phi = 1.576$$</td><td>$N_q = 3.941$
$N_c = 10.977$
$N_\gamma = 1.576$</td></tr>
<tr><td>2b</td><td>As no (effective) surcharge:
$$p_c = cN_c s_c + \frac{1}{2}\gamma' B N_\gamma s_\gamma$$
$$s_c = 1 + 0.2\frac{B}{L} = 1.2$$
$$s_\gamma = 1 - 0.3\frac{B}{L} = 0.7$$
$$s_q = 1 + \frac{B}{L}\sin\phi = 1.26(unneeded)$$
$$p_a = \frac{25000}{B^2}$$
$$FOS = \frac{p_c}{p_a}$$
Therefore:
$$25000 \times FOS = cN_c s_c B^2 + \frac{1}{2}\gamma' B^3 N_\gamma s_\gamma$$
$$B \approx 3.89m$$</td><td>$B \approx 3.89m$</td></tr>
<tr><td>2c</td><td>Need to calculate the inclination factors.

Horizontal stress, t:
$$t = \frac{F}{A} = \frac{75 \times 22.5}{3.89 \times 3.89} = 111.5\,kPa$$
$$i_c = 1 - \frac{t}{c + p\,tan\,\phi} = 0.83$$
(p = 22500/3.89/3.89 = 1487 kPa)
$$i_\gamma = {i_c}^3 = 0.57$$
$$p_c = cN_c i_c s_c + \frac{1}{2}\gamma' B N_\gamma i_\gamma s_\gamma = 2736\,kPa$$
FoS = 2736/1487 = 1.84</td><td>1.84</td></tr>
</table>

<table>
<tr><th>Question No.</th><th>Workings</th><th>Answer</th></tr>
<tr><td>3a</td><td>Recognise that:
$\tau = \sigma'_{nf} tan\phi + c$
Area is 0.05x0.05 = 0.0025 m^2

Stresses are therefore:
<table>
<tr><th>Test No.</th><th>Normal force (N)</th><th>Peak shear force (N)</th><th>Normal stress (kPa)</th><th>Shear stress (kPa)</th></tr>
<tr><td>1</td><td>75</td><td>45</td><td>30</td><td>18</td></tr>
<tr><td>2</td><td>175</td><td>57</td><td>70</td><td>22.8</td></tr>
</table>
And therefore with two tests:

c'=14.4 kPa
ϕ=6.84°</td><td>c'=14.4 kPa
ϕ=6.84°</td></tr>
<tr><td>3b</td><td>Stresses are therefore:
<table>
<tr><th>Test No.</th><th>Normal force (N)</th><th>Residual shear force (N)</th><th>Normal stress (kPa)</th><th>Shear stress (kPa)</th></tr>
<tr><td>1</td><td>75</td><td>35</td><td>30</td><td>14</td></tr>
<tr><td>2</td><td>175</td><td>42</td><td>70</td><td>16.8</td></tr>
</table>
And therefore with two tests:

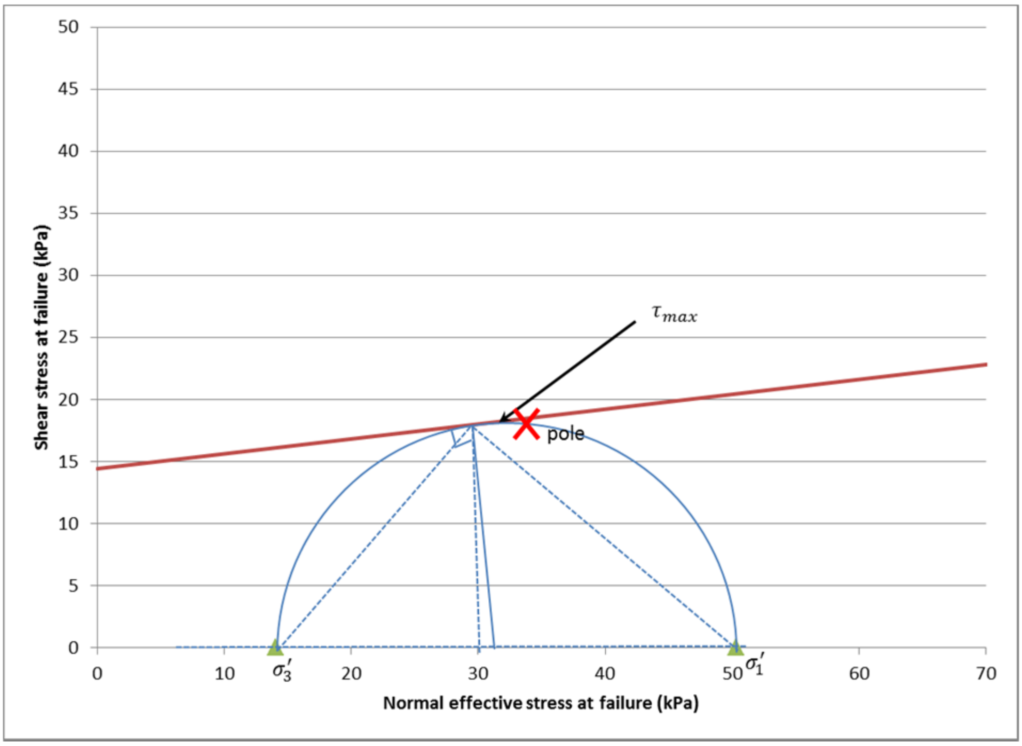
c'=11.9 kPa
ϕ=4.00°</td><td>c'=11.9 kPa
ϕ=4.00°</td></tr>
<tr><td>3c</td><td>Need to calculate σ'_1 and σ'_3. Easiest is from:

Radius = ${}^{\tau}/_{cos\phi} = {}^{18}/_{cos 6.84} = 18.1$ kPa

Centre = $30 + radius\ sin\ \phi = 30 + 18.1 \sin 6.84 = 32.1$ kPa

$\sigma_1 = centre + radius = 50.3$ kPa

$\sigma_3 = centre - radius = 14.0$ kPa</td><td></td></tr>
</table>

3c	50 45 40 35 30 25 20 15 10 5 0 Shear stress at failure (kPa) τ_{max} pole 0 10 σ_3' 20 30 40 50 σ_1' 60 70 Normal effective stress at failure (kPa)

<table>
<tr><th>Question No.</th><th>Workings</th><th>Answer</th></tr>
<tr><td>4a</td><td>Hooke's law in 3D
$$\varepsilon_{zz} = \frac{1}{E}\left[\sigma_{zz}' - v\left(\sigma_{xx}' + \sigma_{yy}'\right)\right]$$ $$\varepsilon_{xx} = \frac{1}{E}\left[\sigma_{xx}' - v\left(\sigma_{yy}' + \sigma_{zz}'\right)\right]$$ $$\varepsilon_{yy} = \frac{1}{E}\left[\sigma_{yy}' - v(\sigma_{xx}' + \sigma_{zz}')\right]$$ In confined conditions: $$\varepsilon_{yy} = \varepsilon_{xx} = 0$$ Therefore: $$\sigma_{xx}' = \sigma_{yy}' = \frac{v}{1-v}\sigma_{zz\prime}$$ As $$\sigma_{xx}' = \sigma_{yy}' = K\sigma_{zz}'$$ $$K = \frac{v}{1-v}$$ At 6 m depth: $$\sigma_{zz} = 6 \times 19 = 114\ kPa$$ $$\sigma_{zz}' = 114 - (6 \times 10) = 54\ kPa$$ $$K = \frac{0.35}{1-0.35} = 0.54$$ $$\sigma_{xx}' = 54 \times 0.54 = 29.2\ kPa$$ $$\sigma_{xx} = 29.2 + 60 = 89.2\ kPa$$</td><td>$K = \frac{v}{1-v}$
$\sigma_{zz} = 114\ kPa$
$\sigma_{zz}' = 54\ kPa$
$\sigma_{xx}' = 29.2\ kPa$
$\sigma_{xx} = 89.2\ kPa$</td></tr>
<tr><td>4b</td><td>For this wall there is friction against the wall, so need to use the full equation or the look-up table.
$$\alpha = 80°$$ For the active side: $$\beta = 10°$$ $$\delta = 20°$$ Therefore: $$K_a = 0.367$$ For the passive side: $$\beta = -10°$$ $$\delta = -20°$$ There is no table, so the formula must be used.
$$K_p = \frac{sin^2(\alpha - \varphi)}{sin^2\alpha\ sin(\alpha - \delta)\left[1 - \sqrt{\frac{sin(\varphi - \delta)sin(\varphi + \beta)}{sin(\alpha - \delta)sin(\alpha + \beta)}}\right]^2}$$ $$K_p = 3.47$$</td><td>$K_a = 0.367$
$K_p = 3.47$</td></tr>
</table>

<table>
<tr><td>4c</td><td>
Calculate the horizontal stresses:

$$Q_{a1} = \frac{1}{2}K_a\gamma_d' h_{Qa1}{}^2 = \frac{1}{2} \times 0.367 \times 17 \times 2^2 = 12.5\ kN/\ m$$
$$Q_{a2} = K_a\gamma_d' h_{Qa2} = 0.367 \times 17 \times 2 \times 4 = 49.9\ kN/\ m$$
$$Q_{a3} = \frac{1}{2}K_a\gamma_d' h_{Qa3}{}^2 = \frac{1}{2} \times 0.367 \times (19 - 10) \times 4^2 = 26.4\ kN/\ m$$
$$Q_{w1} = \frac{1}{2}\gamma_w h_{Qw1}{}^2 = \frac{1}{2} \times 10 \times 4^2 = 80\ kN/\ m$$

$$Q_{p1} = \frac{1}{2}K_p\gamma_d' d^2 = \frac{1}{2}3.47 \times 9 \times 0.5^2 = 3.9\ kN/m$$
$$Q_{w2} = \frac{1}{2}\gamma_w h_{Qw2}{}^2 = \frac{1}{2} \times 10 \times 0.5^2 = 1.25\ kN/\ m$$

Convert from total to horizontal force:

Multiply forces by: $\sin(\alpha - \delta)$
Where $\delta = 20°$ active, and $\delta = -20°$ passive

Friction from wall:
$$R = W tan\delta = 6 \times (t - 6tan10) \times \gamma_{conc} \times tan20 = 54.6t - 57.8$$

$$Q_{slide} = (15.5 + 49.9 + 26.4)\sin(60) + 80 = 169.7\ kN/m$$
$$Q_{resist} = 3.9\sin(100) + 1.25 + R = 5.1\ kN/m$$
$$R = 54.6t - 57.8 = \ kN/m$$
$$Q_{resist} = Q_{slide} FOS$$

$$t = 5.6m$$
</td><td>$t = 5.6m$</td></tr>
<tr><td>4d</td><td colspan="2">
Any two of the following:

- Embedding the wall more
- Increasing the thickness of the concrete wall
- Draining the soil
</td></tr>
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