National Exams December 2014

04-Geol-06, Soil Mechanics

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is a CLOSED BOOK EXAM. Candidates may use one of two calculators, the Casio or Sharp-approved models.

3. There are SIX (6) questions in this exam booklet. Each question is worth 20 marks. YOU MUST ANSWER five (5) out of the six (6) questions. The first five (5) questions that appear in the exam booklet will be marked.

4. Where stated in the examination, please hand in any additional pages with your exam booklet.

5. Each question is worth 20 marks. The total number of marks for the exam is 100.
Question 1. Classification
a. Plot the grain-size curves on Figure Q1 on the next page and classify soils A and B according to the Unified Soil Classification System (USCS). The USCS chart is included in the Useful Information Section at the end of the exam. Soil A has a liquid limit of 9% and a plastic limit of 7%. Soil B has a liquid limit of 70% and a plastic limit of 25%.  

<table>
<thead>
<tr>
<th>Metric Sieve Size</th>
<th>US Sieve Size</th>
<th>Percent Finer</th>
<th>Soil A</th>
<th>Soil B</th>
</tr>
</thead>
<tbody>
<tr>
<td>75 mm</td>
<td>3 in</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>50 mm</td>
<td>2 in</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>25 mm</td>
<td>1 in</td>
<td>90</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>19 mm</td>
<td>0.75 in</td>
<td>86</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>9.5 mm</td>
<td>0.375 in</td>
<td>80</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>4.76 mm</td>
<td>No. 4</td>
<td>65</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>2.38 mm</td>
<td>No. 8</td>
<td>50</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>0.84 mm</td>
<td>No. 20</td>
<td>30</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>420 μm</td>
<td>No. 40</td>
<td>15</td>
<td>95</td>
<td></td>
</tr>
<tr>
<td>250 μm</td>
<td>No. 60</td>
<td>10</td>
<td>82</td>
<td></td>
</tr>
<tr>
<td>150 μm</td>
<td>No. 100</td>
<td>9</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>75 μm</td>
<td>No. 200</td>
<td>6</td>
<td>75</td>
<td></td>
</tr>
</tbody>
</table>

20 marks
Figure Q1
Question 2.  Soil Physical Properties  
20 marks

a. A research program is investigating the influence of different pore fluids on the behaviour of a clay soil. Two different pore fluids are used. One pore fluid is distilled water (ρ_w=1.0g/cm^3) and the other is a saline pore fluid (ρ_w=1.2g/cm^3). Two samples with identical dry density and degree of saturation are to be compacted with a diameter of 50mm and height of 100mm. The samples are to have 85% saturation and a 1.65g/cm^3 dry density. The specific gravity of the soil particles is 2.65.

i. Calculate the mass of pore fluid and mass of dry soil for the sample with distilled water (ρ_w=1.0g/cm^3).

ii. Calculate the mass of pore fluid and mass of dry soil for the sample with saline pore fluid (ρ_w=1.2g/cm^3).

Question 3.  Lateral earth Pressures / Slope Stability  
10 marks

a. Explain the "at rest", "active" and "passive" earth pressure coefficients. Give an example of each type of earth pressure.

b. Describe the general approach common to all limit equilibrium methods of slope stability analysis.

10 marks
Question 4. Consolidation

20 marks

a. A building is to be constructed on a stratum of the clay 7 m thick for which consolidation test revealed that the compression index $C_c = 0.32$, recompression index $C_r = 0.065$, initial void ratio $e_0 = 0.864$, and preconsolidation stress, $\sigma'_p = 310$ kPa. The average existing effective overburden pressure on this clay stratum is 126 kPa. The average applied pressure on the clay after construction of the building is 285 kPa.

i. Estimate the decrease in thickness of the clay stratum caused by full consolidation under the building load.

ii. Estimate the decrease in thickness due to the building load if the clay had never been consolidated under a load greater than the existing overburden.

b. Assuming the settlement analysis for this proposed structure indicates that the underlying clay layer will settle 10 cm in 2 years and that ultimately the total settlement will be about 50 cm. However, this analysis is based on the clay layer being doubly drained. It is suspected that there may be no drainage at the bottom of the layer. Assuming that $C_v = 2.41 \times 10^{-4}$ cm$^2$/s.

i. How will the total settlement change from the double to the single drainage case? Show all the equations.

ii. How long will it take for 10 cm of settlement to occur if there is only single drainage?

iii. How long will it take for 10 cm of settlement to occur if there is double drainage?
**Question 5. Seepage**

Refer to the dam and the flow net shown in Figure Q5: $L = 30 \text{ m}$, $H = 20 \text{ m}$, $h_I = 10 \text{ m}$, $D = 3 \text{ m}$, $\gamma_{\text{sat}} = 21.3 \text{ kN/m}^3$, $\gamma_w = 9.81 \text{ kN/m}^3$ and points a, b, c, d and e are 7.5 m apart, find:

a. The rate of seepage volume under the dam per unit length if $k = 3 \times 10^{-3} \text{ cm/s}$.

b. Total, effective, and pore water pressure at points A, B, C, and D, assuming that $z_A = 10 \text{ m}$, $z_B = 15 \text{ m}$, $z_C = 6 \text{ m}$ and $z_D = 9 \text{ m}$.

c. Draw the pore water pressure diagram along the base of the dam between 1 and 5 based on pore water pressure values at 1, 2, 3, 4 and 5. Calculate the total uplift force between 1 and 5.

![Flow Net Diagram](Figure Q5)
Question 6. General Questions

5 marks each

a. List the equation for Darcy's law and describe its components.
b. Soil behaviour is affected by water content. Describe the change in strength and stiffness of a clay soil based on its water content and relate it to consistency (Atterberg) limits.
c. A falling head test was performed on a soil. The soil specimen was 5 cm diameter and 10 cm tall. The head in the 5 mm diameter burette fell from 1.25 m to 1.15 m in 35 minutes.
   a) Calculate the conductivity of the soil in centimeters per second.
   b) What type of soil was being tested?
d. A soil has gravimetric water content of 15%, void ratio of 0.54 and specific gravity of 2.6. Calculate the soil's dry density, volumetric water content and degree of saturation.
USEFUL INFORMATION

\[ C_u = \frac{D_{60}}{D_{10}} \]

\[ C_c = \left( \frac{D_{25}}{D_{60}} \right)^2 \]

\[ N_{corrected} = 100\% \frac{N - N_{fines}}{100 - N_{fines}} \]

\[ I_p = 0.73(w_k - 20) \]

\[ I_D = -\frac{e_{max} - e}{e_{max} - e_{min}} \]

\[ I_L = \frac{w - w_p}{w_L - w_p} \]

\[ Activity = \frac{w_L - w_p}{\%clay} \]

\[ \rho_d = \frac{\rho_i}{1 + w} \]

\[ \rho' = \rho_{sat} - \rho_w \]

\[ n = \frac{e}{1 + e} \]

\[ S_e = wG_z \]

\[ h_i = h_o + h_p = z + \frac{u}{\gamma_w} \]

\[ i = \frac{\Delta h}{L} \]

\[ v = ki \]

\[ k = \frac{\gamma_w}{\eta} \]

\[ v_s = \frac{v}{n} \]

\[ q = vA = kiA \]

\[ q = k\Delta h \frac{N_f}{N_d} \]

\[ k = \frac{aL}{\Delta t} \ln \frac{h_1}{h_2} = 2.3 \frac{aL}{A(t_2 - t_1)} \log \frac{h_1}{h_2} \]

\[ k_N = \frac{H}{\left( \frac{h_1}{k_1} + \frac{h_2}{k_2} + \frac{h_3}{k_3} \right)} \]

\[ k_p = \frac{k_1h_1 + k_2h_2 + k_3h_3}{H} \]

\[ p = \frac{\sigma_1 + \sigma_3}{2} \]

\[ q = \frac{\sigma_1 - \sigma_3}{2} \]

Force \( \rightarrow \) Newton (N) \( \rightarrow 1\) N = 1 kg m/s\(^2\)
Pressure \( \rightarrow \) Pascal (Pa) \( \rightarrow 1\) Pa = 1 N/m\(^2\)
\( \rightarrow 1\) kPa = 1 kN/m\(^2\)

\[ \Delta u = B(\Delta \sigma_3 + A(\Delta \sigma_1 - \Delta \sigma_3)) \]

\[ \tau_{rpt} = c' + \sigma' \tan \phi' \]

\[ \sigma' = \sigma - u \]

\[ \psi' = \arctan (\sin \phi') \]

\[ a = c' \cos \phi' \]

\[ T = \frac{c_{ef}}{H_{de}} \frac{c_v}{m \gamma_w} \]

\[ \Delta H = C_e \left( \frac{H_o}{1 + e_o} \right) \log \frac{\sigma'_{ef}}{\sigma'_{wo}} + C_c \left( \frac{H_o}{1 + e_o} \right) \log \frac{\sigma'_{ef}}{\sigma'_{pc}} \]

\[ T = \frac{\pi (U)}{4(100)} \]

\[ T = 1.781 - 0.933 \log (100 - U) \quad U > 60\% \]
<table>
<thead>
<tr>
<th>FIELD IDENTIFICATION PROCEDURES</th>
<th>Unified Soil Classification System</th>
<th>LABORATORY CLASSIFICATION CRITERIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excluding particles larger than 75 mm and passing fractions on estimated mass</td>
<td>Grp Syn</td>
<td>TYPICAL NAMES</td>
</tr>
<tr>
<td><strong>GRAVELS</strong></td>
<td>GW</td>
<td>WELL GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES</td>
</tr>
<tr>
<td><strong>MORE THAN HALF OF COARSE FRACTION LARGER THAN 4.75 mm</strong></td>
<td>GR</td>
<td>POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES</td>
</tr>
<tr>
<td><strong>GRAVEL WITH FINES (appreciable amount of fines)</strong></td>
<td>GM</td>
<td>SILTY GRAVELS, POORLY GRADED GRAVEL-SAND-SILT MIXTURES</td>
</tr>
<tr>
<td><strong>MORE THAN HALF OF COARSE FRACTION LARGER THAN 4.75 mm</strong></td>
<td>GC</td>
<td>CLAYEY GRAVELS, POORLY GRADED GRAVEL-SAND-CLAY MIXTURES</td>
</tr>
<tr>
<td><strong>SANDS</strong></td>
<td>SW</td>
<td>WELL GRADED SANDS, LITTLE OR NO FINES</td>
</tr>
<tr>
<td><strong>MORE THAN HALF OF COARSE FRACTION LARGER THAN 4.75 mm</strong></td>
<td>SP</td>
<td>POORLY GRADED SANDS, GRAVELY SANDS, LITTLE OR NO FINES</td>
</tr>
<tr>
<td><strong>SANDS WITH FINES (appreciable amount of fines)</strong></td>
<td>SM</td>
<td>SILTY SANDS, POORLY GRADED SAND-SILT MIXTURES</td>
</tr>
<tr>
<td><strong>MORE THAN HALF OF COARSE FRACTION LARGER THAN 4.75 mm</strong></td>
<td>SC</td>
<td>CLAYEY SANDS, POORLY GRADED SAND-CLAY MIXTURES</td>
</tr>
</tbody>
</table>

**IDENTIFICATION PROCEDURES ON FRACTION SMALLER THAN 425 µm**

<table>
<thead>
<tr>
<th>LIQUID LIMIT LESS THAN 35%</th>
<th>DRY STRENGTH (CRUSHING CHARACTERISTICS)</th>
<th>DILATANCY (REACTION TO SWING)</th>
<th>TOUGHNESS (NEAR PLASTIC LIMIT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NONE</td>
<td>QUICK</td>
<td>NONE</td>
<td>ML</td>
</tr>
<tr>
<td>MEDIUM TO HIGH</td>
<td>NONE TO VERY SLOW</td>
<td>MEDIUM</td>
<td>CL</td>
</tr>
<tr>
<td>SLIGHT TO MEDIUM</td>
<td>SLOW</td>
<td>SLOW</td>
<td>CL</td>
</tr>
<tr>
<td>SLIGHT TO MEDIUM</td>
<td>SLOW</td>
<td>SLIGHT</td>
<td>MI</td>
</tr>
<tr>
<td>HIGH</td>
<td>NONE</td>
<td>MEDIUM TO HIGH</td>
<td>CI</td>
</tr>
<tr>
<td>SLIGHT TO MEDIUM</td>
<td>VERY SLOW</td>
<td>SLIGHT</td>
<td>CI</td>
</tr>
<tr>
<td>SLIGHT TO MEDIUM</td>
<td>SLOW TO NONE</td>
<td>MEDIUM</td>
<td>MH</td>
</tr>
<tr>
<td>HIGH TO VERY HIGH</td>
<td>NONE TO HIGH</td>
<td>HIGH</td>
<td>CH</td>
</tr>
<tr>
<td>HIGH</td>
<td>NONE TO VERY SLOW</td>
<td>SLIGHT TO MEDIUM</td>
<td>CH</td>
</tr>
<tr>
<td>HIGH</td>
<td>NONE TO VERY SLOW</td>
<td>SLIGHT TO MEDIUM</td>
<td>CH</td>
</tr>
</tbody>
</table>

**LIQUID LIMIT BETWEEN 35% AND 50%**

**LIQUID LIMIT GREATER THAN 50%**

**HIGHLY ORGANIC SOILS**

**IDENTIFIED BY COLOUR, ODOUR, SPONGY FEEL & FREQUENTLY BY FIBROUS TEXTURE**