NATIONAL EXAMS – DECEMBER 2008
04-GEOL-A6 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. Only Casio or Sharp approved model calculators are permitted. A formula sheet and some charts are attached to this exam.

3. ANSWER ANY 5 OUT OF THE 6 QUESTIONS. Only the first 5 answers presented in the booklet will be marked.

4. Questions have the values shown. The total value is 75.

5. In the absence of specific parameters required in the formulation and solution of problems, the candidates are expected to exercise sound engineering judgment and to clearly state their assumptions.
1. a) Classify the following soil according to the Unified Soil Classification System. The soil has a liquid limit of 20% and a plastic limit of 7%.

<table>
<thead>
<tr>
<th>Metric Sieve Size</th>
<th>US Sieve Size</th>
<th>Percent finer</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 mm</td>
<td>1 in</td>
<td>100</td>
</tr>
<tr>
<td>19 mm</td>
<td>0.75 in</td>
<td>95</td>
</tr>
<tr>
<td>9.5 mm</td>
<td>0.375 in</td>
<td>80</td>
</tr>
<tr>
<td>4.76 mm</td>
<td>No. 4</td>
<td>50</td>
</tr>
<tr>
<td>2.38 mm</td>
<td>No. 8</td>
<td>43</td>
</tr>
<tr>
<td>0.84 mm</td>
<td>No. 20</td>
<td>38</td>
</tr>
<tr>
<td>420 μm</td>
<td>No. 40</td>
<td>30</td>
</tr>
<tr>
<td>250 μm</td>
<td>No. 60</td>
<td>21</td>
</tr>
<tr>
<td>150 μm</td>
<td>No. 100</td>
<td>16</td>
</tr>
<tr>
<td>75 μm</td>
<td>No. 200</td>
<td>10</td>
</tr>
</tbody>
</table>

b) A sample of fully saturated clay has a moisture content of 30% and the average Specific Gravity of the solids in the sample is 2.5. Calculate the void ratio of the clay.

(Value 8)

2. Fig. Q.2 below illustrates a weir under which seepage flow occurs. A flownet is drawn on the figure.

a) Identify one equipotential line and one flow line.

(Value 5)

b) Calculate the water pressure at point A along the base of the weir.

(Value 10)

3. A 4m high rigid retaining wall illustrated on figure Q.3 supports a silty sand backfill. There is no water table.

a) Using Rankine’s earth pressure theory, calculate the force exerted on the wall by the soil assuming that outward rotation of the wall is allowed.

(Value 10)

b) If wall rotation was to be completely prevented, what would be the force on the wall?

(Value 5)
4. Identify and discuss any 3 factors other than geometry, which can affect the stability of a slope.  

(Value 15)

5. A 5 m thick clay layer rests on impervious bedrock and is overlain by 5m of sandy soil. The water table is at a depth of 2m below the surface of the sand. A 3m thick layer of fill ($\gamma = 20 \text{kN/m}^3$) will be placed on the surface of the sand. The soils properties are:

Sandy soil: $\gamma_t = 21 \text{kN/m}^3$, $\gamma_{sat} = 23 \text{kN/m}^3$,  
Friction angle, $\phi' = 33^\circ$

Clay: $\gamma_{sat} = 19 \text{kN/m}^3$, $\phi' = 28^\circ$, $c' = 5 \text{kPa}$,  
Undrained shear strength, $C_u = 100 \text{kPa}$  
Initial void ratio, $e_0 = 2.055$  
Compression Index, $C_c = 0.8$  
Recompression or Swelling Index $C_{(r \text{ or } s)} = 0.03$  
Preconsolidation pressure, $\sigma'_p = 110 \text{kPa}$  
Coefficient of Consolidation, $c_v = 7.5 \times 10^{-8} \text{ m}^2/\text{sec}$

Calculate the consolidation settlement that will occur 3 years after the placement of the fill.  

(Value 15)

6. Answer any three of the following questions. Only the first three answers presented in the booklet will be marked.

a) How are clay minerals created?  

(Value 5)

b) Explain how particle size contributes to the plasticity of clays.  

(Value 5)

c) Explain how isomorphic substitutions (one cation is replaced by another of the same size within a mineral structure) contribute to the plasticity of clays.  

(Value 5)

d) What happens to the void ratio of a sand subjected to shear strain?  

(Value 5)

e) Define the “at-rest earth pressure coefficient”.  

(Value 5)

f) Describe with the help of a sketch, the distribution and evolution of pore water pressure throughout the thickness of a layer of Normally Consolidated clay undergoing one-dimensional consolidation.  

(Value 5)

g) Is the effective stress a true intergranular stress? Explain your answer.  

(Value 5)
Figure Q.2

Figure Q.3

Sand:
\( \gamma_m = 22 \text{ kN/m}^3 \)
\( \phi = 30^\circ \)

Ground surface

Impervious boundary
All charts presented here were extracted from: An Introduction to Soil Mechanics, Holtz and Kovacs
\[ \Delta u = B[\Delta \sigma_3 + A(\Delta \sigma_1 - \Delta \sigma_3)] \]

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

\[ \tau_f = c' + \sigma' \tan \phi' \]

\[ S_c = C_f \left( \frac{H_o}{1 + e_o} \right) \log \frac{\sigma' p}{\sigma' w} + C_c \left( \frac{H_o}{1 + e_o} \right) \log \frac{\sigma' v}{\sigma' p} \]

\[ T = \frac{c_f}{H_o} \]

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

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

\[ C_u = \frac{D_{50}}{D_{10}} \]

\[ C_c = \frac{(D_{30})^2}{D_{10}D_{60}} \]

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

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

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

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

\[ e = V_v / V_s \text{ (void ratio)} \]

\[ n = V_v / V_t \text{ (porosity)} \]

\[ w = M_w / M_s \text{ (moisture content)} \]

\[ S = V_w / V_v \text{ (saturation)} \]

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

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

\[ k_N = \frac{H}{(H_1 + H_2 + H_3) \frac{k_1}{k_2}} \]

\[ k_p = \frac{k_1H_1 + k_2H_2 + k_3H_3}{H} \]

\[ k = CD_{10}^2 \text{ (C=100, k = cm/s & D_{10} = cm)} \]

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

\[ \rho_w = 1000 \text{ kg/m}^3 \]

\[ \gamma_w = 9.81 \text{ kN/m}^3 \]

\[ \text{Force} \rightarrow \text{Newton (N)} \rightarrow 1 \text{ N} = 1 \text{ kg m/s}^2 \]

\[ \text{Pressure} \rightarrow \text{Pascal (Pa)} \rightarrow 1 \text{ Pa} = 1 \text{ N/m}^2 \]

\[ 1 \text{ kPa} = 1 \text{ kN/m}^2 \]

\[ N_{corr} = 100 \times \frac{N - N_{finest}}{100 - N_{finest}} \]

\[ \Delta \sigma_{v(avg)} = \frac{(\Delta \sigma_{v(top)} + 4 \Delta \sigma_{v(mid)} + \Delta \sigma_{v(bottom)})}{6} \]

\[ K_a = \frac{1 - \sin \phi'}{1 + \sin \phi'} \]

\[ K_p = \frac{1}{K_a} \]

\[ K_o \approx 1 - \sin \phi' \]

\[ \text{Air} \]

\[ \text{Water} \]

\[ \text{Solids} \]
### Soil Classification

#### Laboratory Classification Criteria

<table>
<thead>
<tr>
<th>Group Symbols</th>
<th>Typical Names</th>
<th>Major Divisions</th>
</tr>
</thead>
<tbody>
<tr>
<td>GW</td>
<td>Well-graded gravel, gravel-sand mixtures, little or no fines</td>
<td>Coarse-grained soils</td>
</tr>
<tr>
<td>GP</td>
<td>Poorly graded gravel, gravel-sand mixtures, little or no fines</td>
<td>Coarse-grained soils</td>
</tr>
<tr>
<td>GM</td>
<td>Silty gravels, gravel-sand, silts</td>
<td>Coarse-grained soils</td>
</tr>
<tr>
<td>GC</td>
<td>Clayey gravels, gravel-sand-clay mixtures</td>
<td>Coarse-grained soils</td>
</tr>
<tr>
<td>SW</td>
<td>Well-graded sands, gravelly sands, little or no fines</td>
<td>Fine-grained soils</td>
</tr>
<tr>
<td>SP</td>
<td>Poorly graded sands, gravelly sands, little or no fines</td>
<td>Fine-grained soils</td>
</tr>
<tr>
<td>SM</td>
<td>Silty sands, sand-silt mixtures</td>
<td>Fine-grained soils</td>
</tr>
<tr>
<td>SC</td>
<td>Clayey sands, sand-silt mixtures</td>
<td>Fine-grained soils</td>
</tr>
</tbody>
</table>

- **Liquid Limit Test (LL)**: Inorganic clays and very fine sands, rock flour, silty or clayey fine sands or clays with slight plasticity.
- **CL**: Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
- **ML**: Inorganic silts and organic silty clays of low plasticity.
- **OL**: Inorganic silts, micasilts at discontinuous fine sands or silts, silts, silty silt, silt clay.
- **MH**: Inorganic clays of high plasticity, lean clays.
- **CH**: Organic clays of medium to high plasticity, organic silt.
- **DO**: Organic clays, of medium to high plasticity, organic silt.

#### Plasticity Chart

For laboratory classification of fine-grained soils.

- **PLASTICITY INDEX (PI)**
- **LIQUID LIMIT (LL)**

#### Formulas and Charts

- **Comparing soils at equal liquid limit**: Toughness and dry strength increase with increasing plasticity index.

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1. Boundary classifications: soil possessing characteristics of two groups are designated by combinations of group symbols. For example, GW-SC: well-graded gravel-sand mixture with clay binder.
2. All sieves, sizes, and test methods used are U.S. Standard.