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. Questions have the values shown. The total value is 70.

4. 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. Soil properties
   a. A soil has a dry density of 2.065 Mg/m³ and a bulk density of 2.093 Mg/m³. The void ratio of the soil is 0.283. Calculate the moisture content and the Specific Gravity of the solids.

   (value 5)

   b. A fully saturated clay soil has a void ratio of 2.134. Knowing that the average Specific Gravity of the clay minerals in the soil is 2.6, calculate the bulk unit weight and the dry unit weight of the clay.

   (value 5)

   c. How are the drained and undrained shear strength parameters of a clay soil obtained?

   (value 10)

2. Soil Classification.
   Classify the soils of the table below according to the USCS.

   (value 10)

<table>
<thead>
<tr>
<th>Sieve</th>
<th>Soil A</th>
<th>Soil B</th>
</tr>
</thead>
<tbody>
<tr>
<td>No 4</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>No 10</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>No 20</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>No 40</td>
<td>72</td>
<td>1</td>
</tr>
<tr>
<td>No 60</td>
<td>82</td>
<td>5</td>
</tr>
<tr>
<td>No 100</td>
<td>86</td>
<td>10</td>
</tr>
<tr>
<td>No 200</td>
<td>90</td>
<td>14</td>
</tr>
<tr>
<td>0.01 mm</td>
<td>100</td>
<td>58</td>
</tr>
<tr>
<td>0.02 mm</td>
<td>100</td>
<td>68</td>
</tr>
</tbody>
</table>

   LL -- 55

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3. In situ Stresses / Consolidation and settlement.
   A 4m by 4m reservoir is to be placed at the surface of a sandy soil as illustrated on Figure Q3. The reservoir when filled, will weigh 1200 kN. The water table is located at a depth of 2m.

   a. Calculate the maximum consolidation settlement that is expected to take place in the clay layer.

   (value 10)

   b. How much settlement is expected after 3 years?

   (value 5)
4. Lateral earth Pressures / Slope Stability

   a. Explain the “at rest”, “active” and “passive” earth pressure coefficients.  (value 6)

   b. Describe the general approach common to all limit equilibrium methods of slope       stability analysis.  (value 4)

5. Seepage / Groundwater

The dam shown in Figure Q6 retains 10 m of water. A sheet pile wall is placed, in the          upstream section of the structure, in order to reduce the flow beneath the dam. The          sheet pile wall is embedded 3 m in a 20 m thick layer of silty sand. Beneath the silt lays an impermeable clay. The average hydraulic conductivity of the silty sand is 2 x10^-4 cm/s. We assume that the silty sand is homogeneous and isotropic.

   a. Complete the flow net in Figure Q5.  (value 3)

   b. Calculate the flow rate below the dam.  (value 3)

   c. Calculate the pore water pressure at corner A on both sides of the sheet pile wall      and at corner B beneath the dam.  (value 6)

   d. Estimate the factor of safety against piping.  (value 3)
Figure Q5

impermeable clay/argile imperméable

silty sand/ stilleux

$k = 2 \times 10^{-4}$ cm/s

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\[ \Delta u = B[\Delta \sigma_3 + A(\Delta \sigma_1 - \Delta \sigma_3)] \]
\[ \sigma' = \sigma - u \]
\[ \tau_f = c' + \sigma' \tan \phi' \]
\[ S_e = C_e \left( \frac{H_o}{1 + e_o} \right) \log \frac{\sigma'_e}{\sigma'_w} + C_c \left( \frac{H_o}{1 + e_o} \right) \log \frac{\sigma'_c}{\sigma'_p} \]
\[ T = \frac{c_t \cdot t}{H_{dr}} \]
\[ q = k \Delta h \frac{N_f}{N_d} \]
\[ h_t = h_p + z = \frac{u}{\gamma'_w} + z \]
\[ C_u = \frac{D_{60}}{D_{10}} \]
\[ C_e = \frac{(D_{30})^2}{D_{10} \cdot D_{60}} \]
\[ i = \frac{\Delta h}{l} \]
\[ \rho_d = \frac{\rho_i}{(1 + w)} \]
\[ \psi' = \arctan (\sin \phi') \quad a = c' \cos \phi' \]
\[ e = V_v / V_s \quad (\text{void ratio}) \]
\[ n = V_v / V_t \quad (\text{porosity}) \]
\[ w = M_w / M_s \quad (\text{moisture content}) \]
\[ S = V_w / V_v \quad (\text{saturation}) \]
\[ p = \frac{\sigma_1 + \sigma_3}{2} \]
\[ q = \frac{\sigma_1 - \sigma_3}{2} \]
\[ k_N = \frac{H}{\left( \frac{H_1 + H_2 + H_3}{k_1 \cdot k_2 \cdot k_3} \right)} \]
\[ k_p = k_1 H_1 + k_2 H_2 + k_3 H_3 \]
\[ k = CD_{10}^2 \quad (C=100, k = \text{cm/s} \& D_{10} = \text{cm}) \]
\[ \rho' = \rho_{sat} - \rho_w \quad \rho_w = 1000 \text{ kg/m}^3 \]
\[ \gamma'_w = 9.81 \text{ kN/m}^3 \]
\[ \text{Force} \rightarrow \text{Newton (N)} \rightarrow 1 \text{ N} = 1 \text{ kg m/s}^2 \]
\[ \text{Pressure} \rightarrow \text{Pascal (Pa)} \rightarrow 1 \text{ Pa} = 1 \text{ N/m}^2 \]
\[ 1 \text{ kPa} = 1 \text{ kN/m}^2 \]
\[ N_{corr} = 100 \times (N - N_{\text{fines}}) / (100 - N_{\text{fines}}) \]
\[ \Delta \sigma'_{v(avg)} = \frac{\left( \Delta \sigma'_{v(op)} + 4 \Delta \sigma'_{v(mid)} + \Delta \sigma'_{v(bot)} \right)}{6} \]
\[ K_s = \frac{1 - \sin \phi'}{1 + \sin \phi'} \quad K_p = 1/K_s \quad K_o \approx 1 - \sin \phi' \]
\[ \sigma'_h = \sigma'_v K_a - 2C'_v \sqrt{K_a} \quad \sigma'_h = \sigma'_v K_p + 2C'_v \sqrt{K_p} \]

\[ \begin{array}{c}
\text{Air} \\
V_a \\
V_b \\
V_t \\
Water
\end{array} \\
\begin{array}{c}
\text{Solids}
\end{array} \\
\begin{array}{c}
V_w \\
V_s \\
M_w \\
M_s
\end{array} \\
\begin{array}{c}
\text{M_t}
\end{array}
# Soil Mechanics

## Laboratory Classification Criteria

<table>
<thead>
<tr>
<th>Major Divisions</th>
<th>Group Symbols</th>
<th>Typical Names</th>
<th>Laboratory Classification Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Coarse-grained Soils</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>More than half of material is larger than No. 200 (0.075 mm)</td>
<td>GW, GP, GM, GC, SW, SP, SM, SC</td>
<td>Well-graded gravels, gravel sand mixtures, little or no fines.</td>
<td></td>
</tr>
<tr>
<td>Silt and Clay</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liquid limit less than 50</td>
<td>ML, CL, OL, MH, CH, OH</td>
<td>Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.</td>
<td></td>
</tr>
<tr>
<td>Silt and Clay</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liquid limit greater than 50</td>
<td>ML, CL, OL, MH, CH, OH</td>
<td>Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, silty clays.</td>
<td></td>
</tr>
<tr>
<td>Highly Organic Soils</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Boundary classifications: soils possessing characteristics of two groups are designated by combinations of group symbols. For example, GW-GC, well-graded gravel sand mixture with clay binder.

All sieve sizes on this chart are U.S. Standard.

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**Plasticity Chart**

For laboratory classification of fine-grained soils.

Comparing soils at equal liquid limits: toughness and dry strength increase with increasing plasticity index.

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### Formulas and Charts

**NATIONAL EXAMS – DECEMBER 2012**