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 100.

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 compacted soil sample fills a 944 cm³ mould. The dry density of the sample is 2065 kg/m³, the moisture content is 5% and the Specific Gravity of the solids is 2.6. Calculate the total mass of the sample in the mould, the void ratio, and the saturation. (Value 10)
   b. The hydraulic conductivity of a soil depends on what? (value 5)

2. Soil Classification.
   Classify the soils of figure Q.2 (Page 4) according to the Unified Soil Classification System. The fines of soil A have a liquid limit of 60% and a plastic limit of 20%, while those of soil B have a liquid limit of 30% and a plastic limit of 20%. (value 10)

3. In situ Stresses / Consolidation and settlement.
   A 4m thick sand fill is placed on a layer of Normally-Consolidated clay to pre-consolidate it, as shown on figure Q.3. The free surface (water table) is located at the top of the clay layer and is expected to stay there.
   a. Calculate the time it will take for the 4m fill to settle as much as the full consolidation settlement of a 1m fill. Or in other words, when can we remove 3m of the fill and be left with 1m of fill that will not settle anymore? (value 15)
   b. Clays are very frequently observed to be over-consolidated in the field. What causes the over-consolidation of clays? (value 10)

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Diagram: Sand fill: $\gamma_f = 20$ kN/m³
- Clay:
  - Bulk unit weight: $\gamma_i = 20$ kN/m³
  - Compression indices: $C_{L} = 0.4$, $C_{P} = 0.03$
  - Coefficient of consolidation: $c_v = 0.45$ m²/year
  - Initial void ratio: $e_0 = 1.384$
- Impervious Rock

Figure Q.3
4. Lateral earth Pressures / Slope Stability
   Figure Q.4. shows a Segmental Retaining Wall with geosynthetic reinforcement, installed to stabilize a slope.

   a. Sketch and explain conceptual diagrams of the distribution of forces (no numerical values required) acting on the back of the wall facing and the distribution of forces on the reinforced soil mass. What two theories are most commonly used to calculate the forces on retaining walls?

       (value 20)

   b. Sketch and explain two unlikely slope failure surfaces and two more likely ones.

       (value 10)

   ![Figure Q.4.]

5. Seepage / Groundwater

   a. Describe and explain any one potential benefit and any one potential detriment of lowering the water table.

       (Value 10)

   b. At the foot of an earth dam, two piezometers were installed one above the other, to record the pore pressure to monitor for potential instabilities. The lower piezometer has an intake at an elevation of 200m above sea level and the upper piezometer has an intake at 205m. The pore water pressure measured at the lower piezometer is 350kPa and the pressure at the upper one is 280kPa. With supporting calculations and assumptions, evaluate the risk of boiling at that location.

       (Value 10)
\[ \Delta u = B[\Delta \sigma_3 + A(\Delta \sigma_1 - \Delta \sigma_3)] \]

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

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

\[ S_c = C_c \left( \frac{H_o}{1+e_o} \right) \log \frac{\sigma'_p}{\sigma'_{ov}} + C_e \left( \frac{H_o}{1+e_o} \right) \log \frac{\sigma'_v}{\sigma'_p} \]

\[ T = \frac{c_f}{H_{dr}^2} \]

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

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

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

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

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

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

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

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

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

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

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

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

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

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

\[ k_N = \frac{H}{(\frac{H_1 + H_2 + H_3}{k_1 k_2 k_3})} \]

\[ k_p = \frac{k_1 H_1 + k_2 H_2 + k_3 H_3}{H} \]

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

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

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

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

**Force**: Newton (N) → 1 N = 1 kg m/s²

**Pressure**: Pascal (Pa) → 1 Pa = 1N/m² → 1 kPa = 1 kN/m²

\[ N_{corr} = 100 \times (N - N_{fines}) / (100-N_{fines}) \]

\[ \Delta \sigma_v^{avg} = \frac{(\Delta \sigma_{v(opp)} + 4\Delta \sigma_{v(mid)} + \Delta \sigma_{v(bot)})}{6} \]

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

\[ K_p = 1/K_a \]

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

\[ \sigma_h' = \sigma_c' K_a - 2C' \sqrt{K_a} \]

\[ \sigma_h' = \sigma_c' K_p + 2C' \sqrt{K_p} \]
## Soil Classification

<table>
<thead>
<tr>
<th>Major Divisions</th>
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<tr>
<td>Group Symbols (1)</td>
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<tr>
<td>Coarse-grained Soils More than half of material is larger than No. 200 (45 μm) sieve size.</td>
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### Plasticity Chart

For laboratory classification of fine-grained soils

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

### Formulas and Charts

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1. Boundary classifications: soils possessing characteristics of two groups are designated by combinations of group symbols. For example: GW-GC.
2. Well-graded gravel-sand mixture with clay binder.
3. All sieve sizes on this chart are U.S. Standard.