PROFESSIONAL ENGINEERS ONTARIO
NATIONAL EXAMINATION – MAY 2010
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. 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.

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1. The grain size distributions of two soils are illustrated on figure Q1. Soil A has a liquid limit of 25% and a plastic limit of 10% while soil B has no plasticity. Soil A will be used to construct the impervious core of a small earth dam while Soil B will be used as a filter zone placed on either side of the core.

   a. Determine the USCS classification of soil A and soil B.

   (value 8)

   b. Determine whether Soil B is appropriate as a filter for Soil A.

   (value 7)

   c. After compaction, an 8000 cm^3 sample of Soil A is extracted from a lift. The sample had a total mass of 20 kg. A 100g sub-sample had a mass of 90 g after drying. Assuming that the average Specific Gravity of the solids is 2.65, calculate the void ratio and the porosity of the compacted soil. Comment on the values you obtain.

   (value 15)

2. a. Calculate the consolidation settlement of the soil profile illustrated on figure Q.2, 1 year after the emplacement of 3m of compacted fill (γ_t = 22 kN/m^3) above the sandy soil. The water table is 1m below the original ground surface.

   (value 20)

   b. Estimate the average increase in total stress in the clay layer if a 2m by 3m footing supporting a load of 5000 kN, is placed on the sandy soil, instead of the compacted fill.

   (value 10)

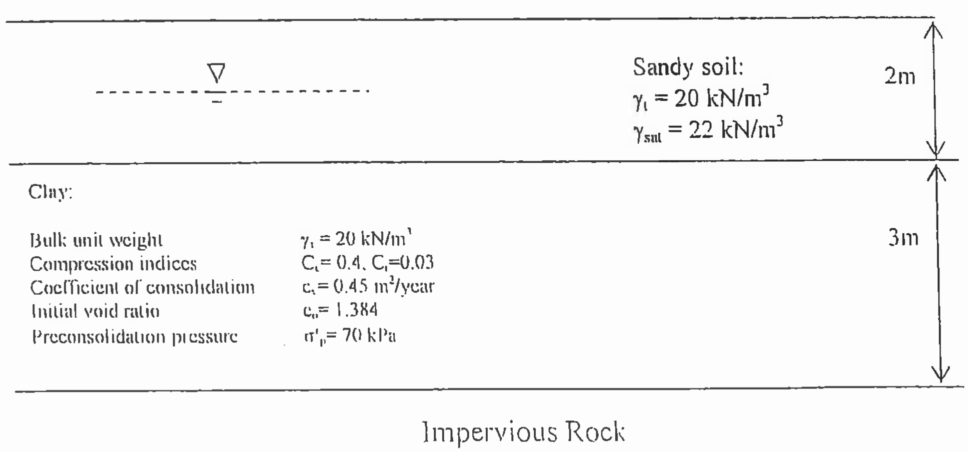


Figure Q.2

3. Answer the following True of False questions concerning retaining walls:

   a. Rankine's theory of earth pressure applies to a broader range of conditions than Coulomb's theory.
   b. An inward (towards the soil) displacement of the wall is required to mobilize active failure.
   c. The active earth pressure coefficient is always lower than the passive earth pressure coefficient.
   d. The at-rest earth pressure is always higher than the passive earth pressure
   e. The resultant active earth-pressure force acting on the soil-wall face is oriented at an angle ϕ' above the normal to the face.

(value 15)

4. Answer **only five** of the following eight questions: (value 5 each)

   a. Explain the current criteria used for the design of soil filters.
   b. Why do most natural soil deposits tend to be silica-rich?
   c. Identify and explain the two major rules to follow when drawing a Flow Net?
   d. How is the permeability of a clay soil determined in a laboratory?
   e. Sketch and explain the expected moisture content distribution in a thick sandy unsaturated soil zone above a water table.
   f. Explain why alluvial gravel is not the material of choice for the base layer in a flexible (Asphalt) road pavement system.
   g. Identify and discuss two factors responsible for the plasticity of clays.
   h. Explain the difference between the short term and long term stability of a slope in a cohesive soil.

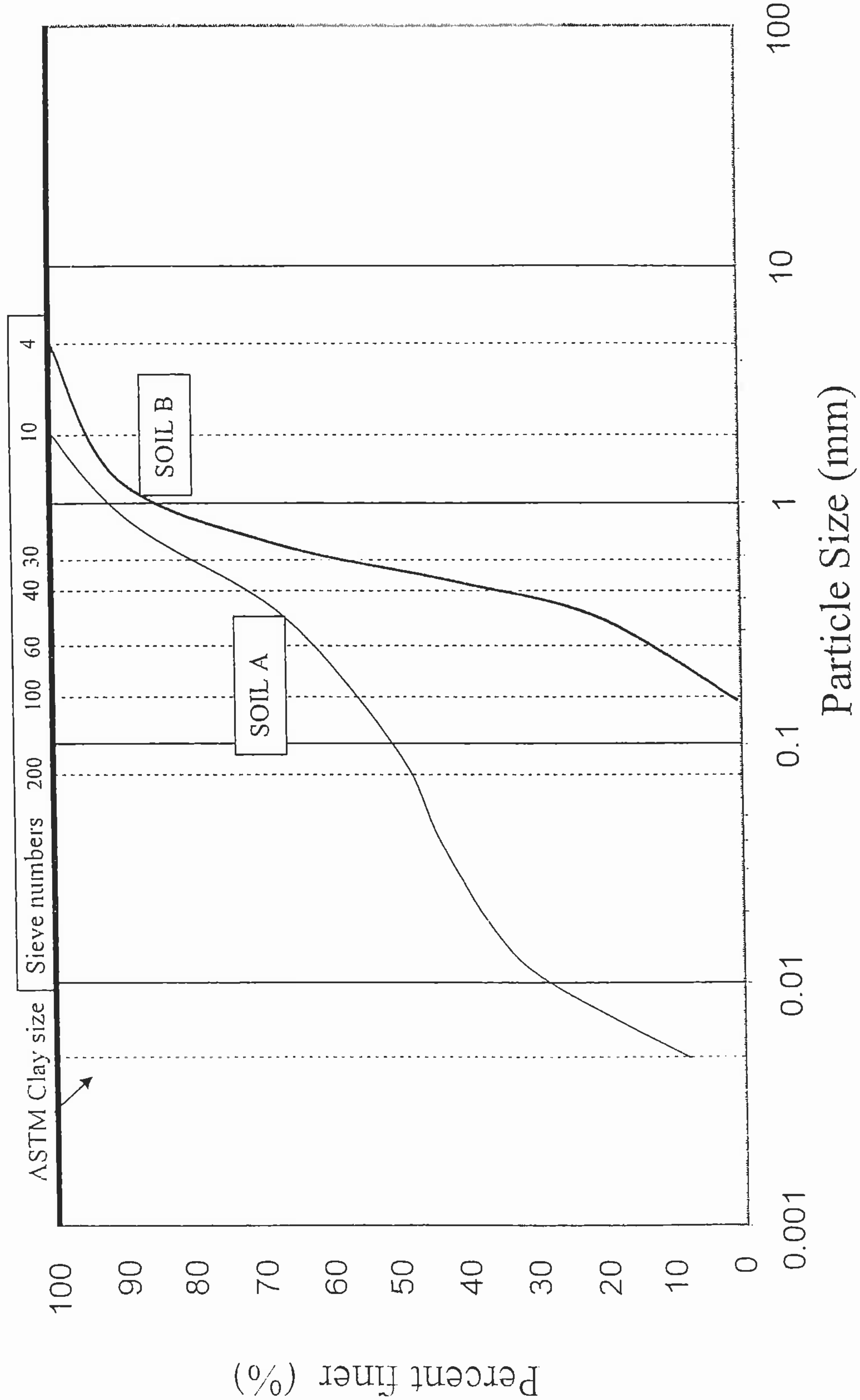
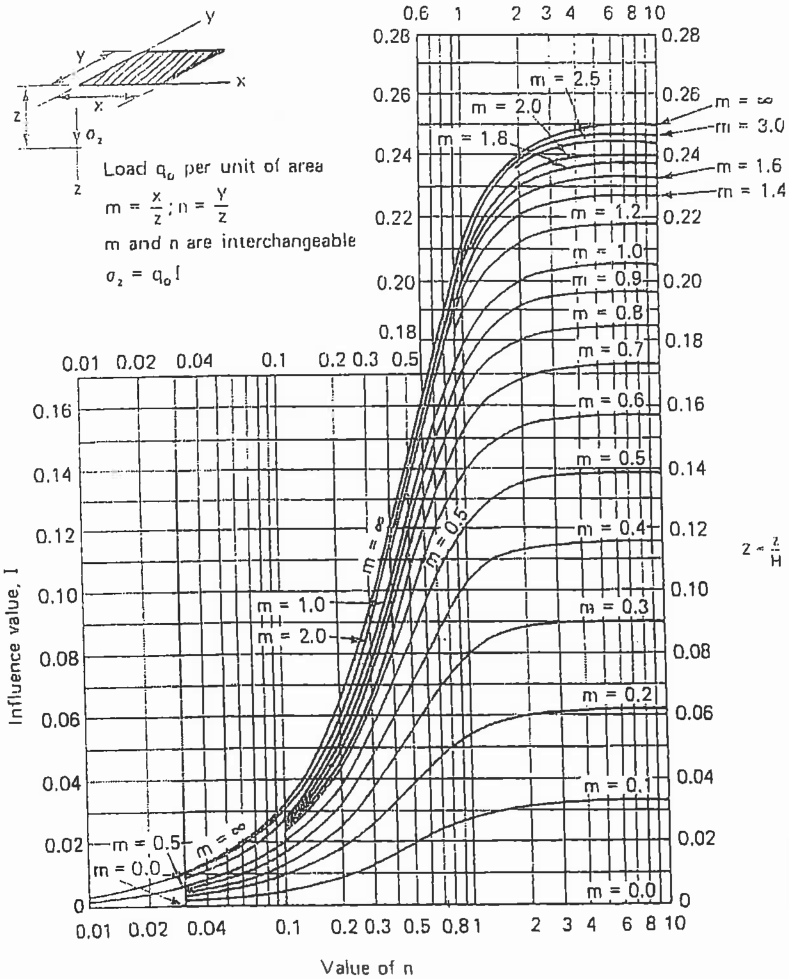
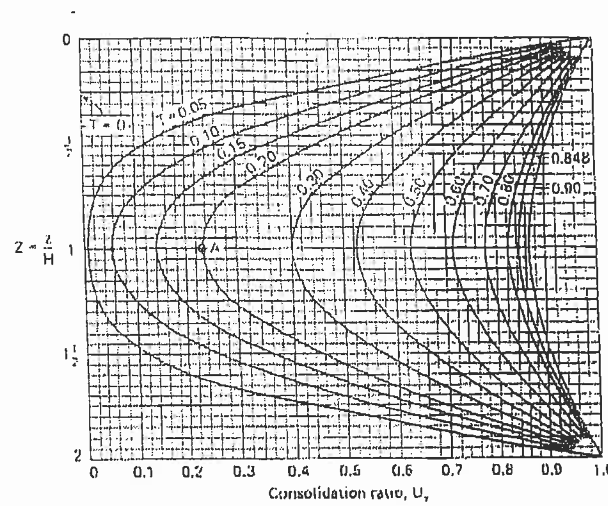
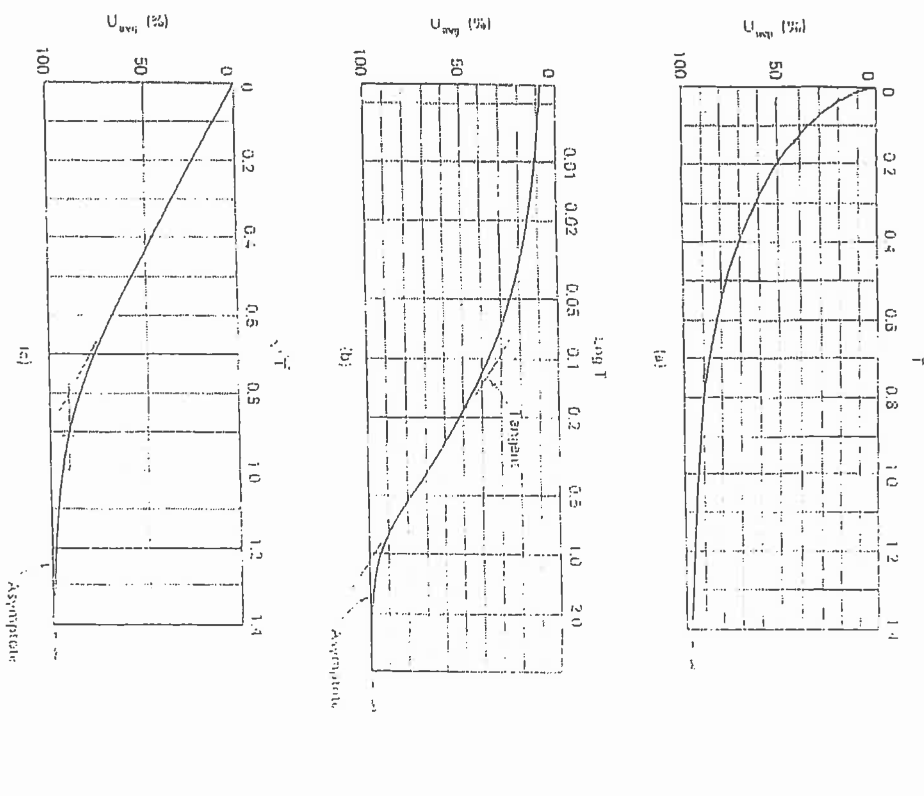

ASTM Clay size
Sieve numbers
4
10
40 30
60
100
200
SOIL A
SOIL B
Particle Size (mm)
0.001
0.01
0.1
1
10
100
Percent finer (%)
0
10
20
30
40
50
60
70
80
90
100

Figure Q.1





All charts presented here were extracted form: An Introduction to Soil Mechanics, Holtz and Kovacs



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Formulas and Charts

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

$$\sigma' = \sigma - u$$

$$\tau_f = c' + \sigma' \tan\phi'$$

$$S_c = C_r\left(\frac{H_o}{1+e_o}\right)\log\frac{\sigma'_p}{\sigma'_{vo}} + C_c\left(\frac{H_o}{1+e_o}\right)\log\frac{\sigma'_{vf}}{\sigma'_p}$$

$$T = \frac{c_v t}{H_{dr}^{\ 2}}$$

$$q = k\Delta h\frac{N_f}{N_d}$$

$D_{15f} \leq 5*D_{85S}$

$D_{15f} \geq 5*D_{15S}$

$$h_t = h_p + z = \frac{u}{\gamma_w} + z$$

$$C_u = \frac{D_{60}}{D_{10}}$$

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

$$i = \frac{\Delta h}{l}$$

$$\rho_d = \frac{\rho_t}{(1+w)}$$

$$\psi' = \arctan(\sin\phi') \qquad a = c'\cos\phi'$$

$e = V_v / V_s$ (void ratio)
$n = V_v / V_t$ (porosity)
$w = M_w / M_s$ (moisture content)
$S = V_w / V_v$ (saturation)

$$p = \frac{\sigma_1 + \sigma_3}{2} \qquad q = \frac{\sigma_1 - \sigma_3}{2}$$

$$k_N = \frac{H}{\left(\frac{H_1}{k_1} + \frac{H_2}{k_2} + \frac{H_3}{k_3}\right)}$$

$$k_p = \frac{k_1H_1 + k_2H_2 + k_3H_3}{H}$$

$k = CD_{10}^2$ (C=100, k = cm/s & D_{10} = cm)

$\rho' = \rho_{sat} - \rho_w \qquad \rho_w = 1000\ kg/m^3$

$\gamma_w = 9.81\ kN/m^3$

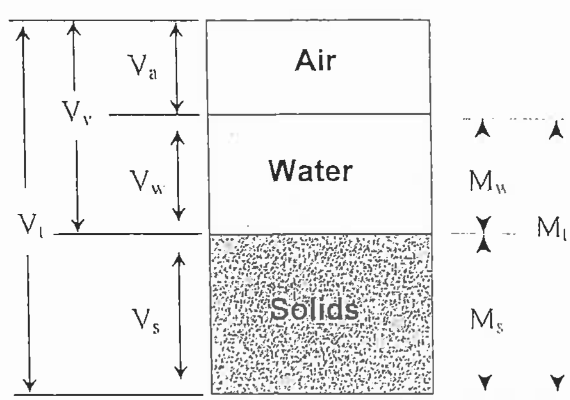
Force → Newton (N) → 1 N = 1 kg m/s^2
Pressure → Pascal (Pa) → 1 Pa = 1N/m^2
→ 1 kPa = 1 kN/m^2

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

$$\Delta\sigma_{v(avg)} = \frac{(\Delta\sigma_{v(top)} + 4\Delta\sigma_{v(mid)} + \Delta\sigma_{v(bot)})}{6}$$

$$K_a = \frac{1 - \sin\phi'}{1 + \sin\phi'} \qquad K_p = 1/K_a$$

$$\sigma'_h = \sigma'_v K_a - 2C'\sqrt{K_a} \qquad \sigma'_h = \sigma'_v K_p + 2C'\sqrt{K_p}$$



Major Divisions			Group Symbols [†]	Typical Names	Laboratory Classification Criteria
1	2		3	4	6
Coarse-grained Soils More than half of material is larger than No. 200 [‡] (75 μm) sieve size.	Gravels More than half of coarse fraction is larger than No. 4 sieve size. (4.75 mm)	Clean Gravels (little or no fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines.	$C_u = \frac{D_{60}}{D_{10}}$ greater than 4; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3 (See Sec. 2-5)
			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines.	Not meeting all gradation requirements for GW
		Gravels with Fines (appreciable amount of fines)	GM	Silty gravels, gravel-sand-silt mixtures.	Atterberg limits below A-line, or PI less than 4 — Above A-line with PI between 4 and 7 are borderline cases requiring use of dual symbols.
			GC	Clayey gravels, gravel-sand-clay mixtures.	Atterberg limits above A-line with PI greater than 7
	Sands More than half of coarse fraction is smaller than No. 4 sieve size. (4.75 mm)	Clean Sands (little or no fines)	SW	Well-graded sands, gravelly sands, little or no fines.	$C_u = \frac{D_{60}}{D_{10}}$ greater than 6; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3 (See Sec. 2-5)
			SP	Poorly graded sands, gravelly sands, little or no fines.	Not meeting all gradation requirements for SW
		Sands with Fines (appreciable amount of fines)	SM	Silty sands, sand-silt mixtures.	Atterberg limits below A-line, or PI less than 4 — Limits plotting in hatched zone with PI between 4 and 7 are borderline cases requiring use of dual symbols.
			SC	Clayey sands, sand-clay mixtures.	Atterberg limits above A-line with PI greater than 7
Fine-grained Soils More than half of material is smaller than No. 200 (75 μm) sieve size.	Silts and Clays	Liquid limit less than 50	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.	Plasticity Chart — For laboratory classification of fine-grained soils
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.	
			OL	Organic silts and organic silty clays of low plasticity.	
	Silts and Clays	Liquid limit greater than 50	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.	
			CH	Inorganic clays of high plasticity, fat clays.	
			OH	Organic clays of medium to high plasticity, organic silts.	
Highly Organic Soils			Pt	Peat and other highly organic soils	

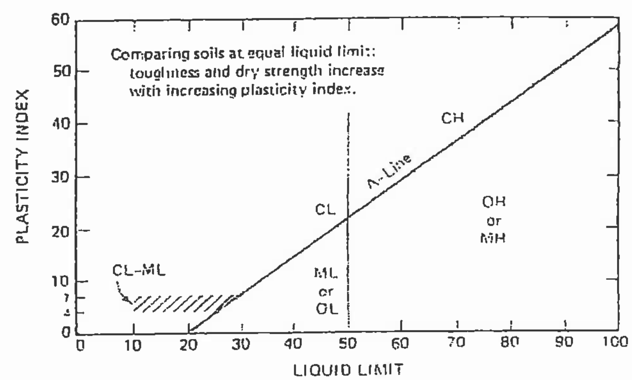
(For visual classification, 5 mm may be used as equivalent to the No. 4 sieve size)

The No. 200 sieve size is about the smallest particle visible to the naked eye.

Use grain size curve in identifying the fractions as given under field identification.

Determine percentages of gravel and sand from grain size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size) coarse-grained soils are classified as follows:
Less than 5%: GW, GP, SW, SP
More than 12%: GM, GC, SM, SC.
5% to 12%: Borderline cases requiring use of dual symbols.

Plasticity Chart
For laboratory classification of fine-grained soils



† 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