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%.

20 marks

Table Q1

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

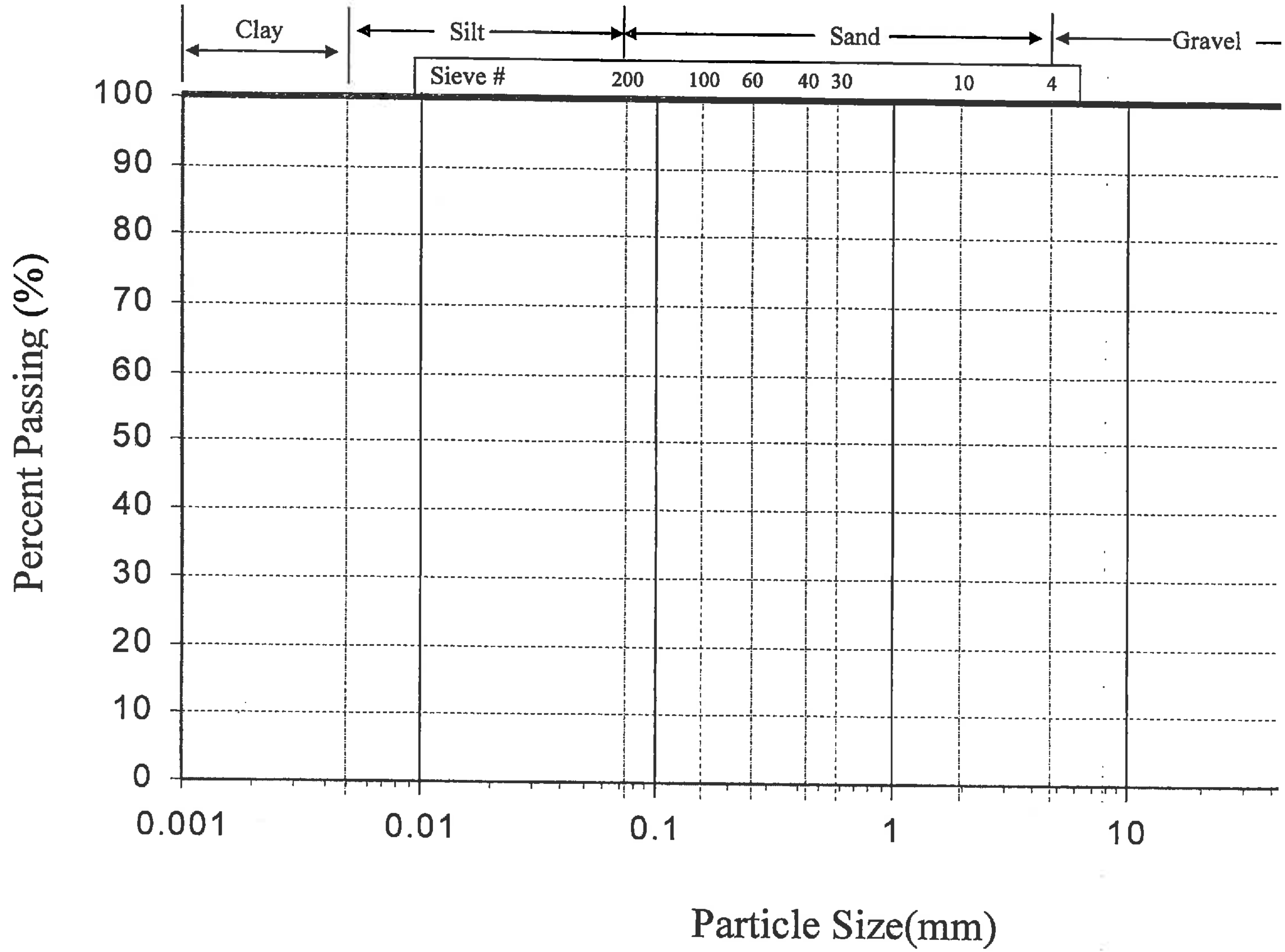
Clay
Silt
Sand
Gravel
Sieve #
200
100
60
40
30
10
4
Percent Passing (%)
100
90
80
70
60
50
40
30
20
10
0
0.001
0.01
0.1
1
10
Particle Size(mm)

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=**1.2**g/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=**1.2**g/cm^3).

Question 3. Lateral earth Pressures / Slope Stability

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

10 marks

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, σ'_p = 310kPa. 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 Cv = 2.41 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

20 marks

Refer to the dam and the flow net shown in **Figure Q5**: L = 30 m, H = 20 m, h_t = 10 m, D = 3 m, γ_{sat} = 21.3 kN/m^3, γ_w = 9.81 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 x10^{-3}cm/s.

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

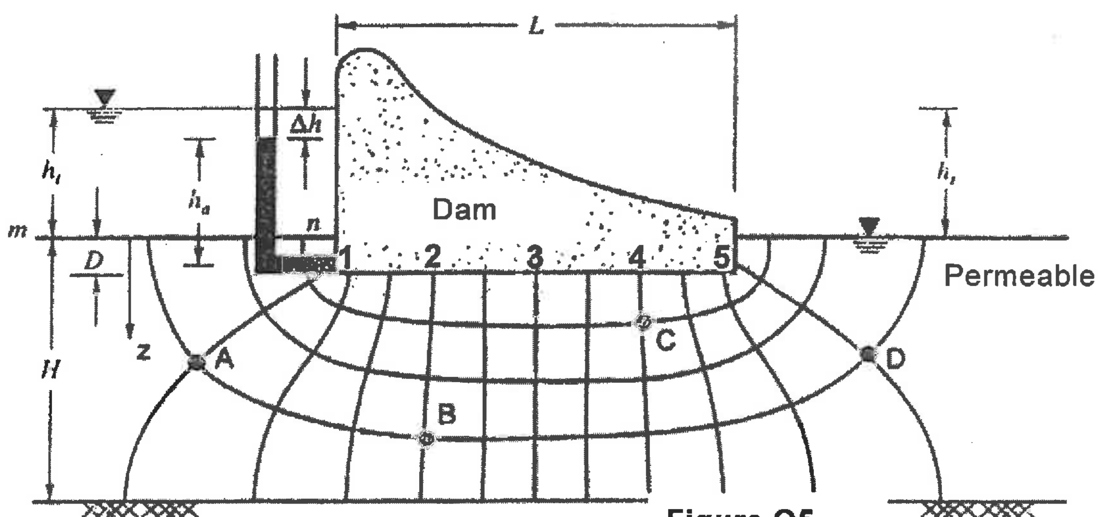

Figure Q5

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

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

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

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

$I_P = 0.73(w_L - 20)$

$$I_D = \frac{e_{max} - e}{e_{max} - e_{min}}$$

$$I_L = \frac{w - w_P}{w_L - w_P}$$

$$Activity = \frac{w_L - w_P}{\%clay}$$

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

$\rho' = \rho_{sat} - \rho_w$

$$n = \frac{e}{1 + e}$$

$$Se = wG_s$$

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

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

$$v = ki$$

$$k = \frac{\gamma_w}{\eta}\overline{K}$$

$$v_s = \frac{v}{n}$$

$$q = vA = kiA$$

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

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

k = QL/hA

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

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

$$p = \frac{\sigma_1 + \sigma_3}{2}$$

$$q = \frac{\sigma_1 - \sigma_3}{2}$$

Force → Newton (N) → 1 N = 1 kg m/s^2

Pressure → Pascal (Pa) → 1 Pa = 1N/m^2
→ 1 kPa = 1 kN/m^2

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

$$\tau_{rupt} = c' + \sigma' \tan\phi'$$

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

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

$$T = \frac{c_v t}{H_{dr}^2} \quad c_v = \frac{k}{m_v\gamma_w}$$

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

$$T = \frac{\pi}{4}\left(\frac{U}{100}\right)^2 \qquad U < 60\%$$

$$T = 1.781 - 0.933\log(100 - U) \qquad U > 60\%$$

United Soil Classification System

			Field Identification Procedures (Excluding particles larger than 75 mm and basing fractions on estimated mass)			Grp Sym	Typical Names	Information Required for Describing Soils
COARSE GRAINED SOILS (MORE THAN HALF OF MATERIAL IS LARGER THAN 75 µm)	GRAVELS (MORE THAN HALF OF COARSE FRACTION IS LARGER THAN 4.75 mm)	CLEAN GRAVELS (little or no fines)	Wide range in grain size & substantial amounts of all intermediate particle sizes			GW	WELL GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	GIVE TYPE; NAME, IF NECESSARY; INDICATE APPROX % OF SAND & GRAVEL; MAX. SIZE; ANGULARITY, SURFACE CONDITION & HARDNESS OF GRAINS; LOCAL OR GEOLOGIC NAME & OTHER PERTINENT DESCRIPTIVE INFORMATION; & SYMBOL IN PARENTHESES. FOR UNDISTURBED SOILS ADD INFORMATION ON STRATIFICATION, DEGREE OF COMPACTNESS, CEMENTATION, MOISTURE CONDITIONS & DRAINAGE CHARACTERISTICS
			Predominantly one size of a range of sizes with some intermediate sizes missing			GP	POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	
		GRAVEL WITH FINES (appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below)			GM	SILTY GRAVELS, POORLY GRADED GRAVEL-SAND-SILT MIXTURES	
			Plastic fines (for identification procedures see CL below)			GC	CLAYEY GRAVELS, POORLY GRADED GRAVEL-SAND-CLAY MIXTURES	
	SANDS (MORE THAN HALF OF COARSE FRACTION IS SMALLER THAN 4.75 mm)	CLEAN SANDS (little or no fines)	Wide range in grain size & substantial amounts of all intermediate particle sizes			SW	WELL GRADED SANDS, LITTLE OR NO FINES	
			Predominantly one size of a range of sizes with some intermediate sizes missing			SP	POORLY GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	
		SANDS WITH FINES (appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below)			SM	SILTY SANDS, POORLY GRADED SAND-SILT MIXTURES	
			Plastic fines (for identification procedures see CL below)			SC	CLAYEY SANDS, POORLY GRADED SAND-CLAY MIXTURES	
	IDENTIFICATION PROCEDURES ON FRACTION SMALLER THAN 425 µm							
			DRY STRENGTH (CRUSHING CHARACTERISTICS)	DILATENCY (REACTION TO SHAKING)	TOUGHNESS (CONSISTENCY NEAR PLASTIC LIMIT)			
FINE GRAINED SOILS (MORE THAN HALF OF MATERIAL IS SMALLER THAN 75 µm)	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 35%	NONE	QUICK	NONE	ML	INORGANIC SILTS & SANDY SILTS OF SLIGHTLY PLASTICITY, ROCK FLOUR	GIVE TYPE; NAME, IF NECESSARY, INDICATE DEGREE & CHARACTER OF PLASTICITY, AMOUNT & MAXIMUM SIZE OF COARSE GRAINS, COLOUR IN WET CONDITION, ODOUR, IF ANY, LOCAL OR GEOLOGIC NAME & OTHER PERTINANT INFORMATION & SYMBOL IN PARENTHESES. FOR UNDISTURBED SOILS AND INFORMATION ON STRUCTURE, STRATIFICATION, CONSISTENCY IN UNDISTURBED & REMOULDED STATES, MOISTURE & DRAINAGE CONDITIONS
			MEDIUM TO HIGH	NONE TO VERY SLOW	MEDIUM	CL	SILTY CLAYS (INORGANIC), GRAVELLY CLAYS, SANDY CLAYS, LEAN CLAYS	
			SLIGHT TO MEDIUM	SLOW	SLIGHT	OL	ORGANIC SILY OF LOW PLASTICITY, ORGANIC SANDY SILTS	
		LIQUID LIMIT BETWEEN 35% AND 50%	NONE TO SLIGHT	SLOW TO QUICK	SLIGHT	Mi	INORGANIC COMPRESSIBLE FINE SANDY SILT WITH CLAY OF MEDIUM PLASTICITY, CLAYEY SILTS	
			HIGH	NONE	MEDIUM TO HIGH	CI	SILTY CLAYS (INORGANIC) OF MEDIUM PLASTICITY	
			SLIGHT TO MEDIUM	VERY SLOW	SLIGHT	OI	ORGANIC SILTY CLAYS OF MEDIUM PLASTICITY	
		LIQUID LIMIT GREATER THAN 50%	SLIGHT TO MEDIUM	SLOW TO NONE	MEDIUM	MH	INORGANIC SILTS, HIGHLY COMPRESSIBLE MICACEOUS OR DIATOMACEOUS FINE SANDY SILTS, ELASTIC SILTS	
			HIGH TO VERY HIGH	NONE	HIGH	CH	CLAYS (INORGANIC) OF HIGH PLASTICITY, FAT CLAYS	
			MEDIUM TO HIGH	NONE TO VERY SLOW	SLIGHT TO MEDIUM	OH	ORGANIC CLAYS OF HIGH PLASTICITY	
HIGHLY ORGANIC SOILS			IDENTIFIED BY COLOUR, ODOUR, SPONGY FEEL & FREQUENTLY BY FIBROUS TEXTURE			PL	PEAT & OTHER HIGHLY ORGANIC SOILS	

USE GRAIN SIZE CURVE IN IDENTIFYING THE FRACTIONS AS GIVEN UNDER FIELD IDENTIFICATION

LABORATORY CLASSIFICATION CRITERIA

DETERMINE PERDENTAGES OF GRAVEL & SAND FROM GRAIN SIZE CURVE. DEPENDING ON PERCENTAGE OF FINES (FRACTION SMALLER THAN 75 µm) COARSE GRAINED SOILS ARE CLASSIFIED AS FOLLOWS:

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

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

LESS THAN 5%; GW, GP, SW, SP
MORE THAN 12% GM, GC, SM, SC
5% TO 12% BORDERLINE CASES REQ. USE OF DUAL SYMBOLS

GW	$C_U > 4;\ 1 < C_c < 3$	
GP	NOT MEETING ALL GRADATION REQUIREMENTS FOR GW	
GM	ATTERBERG LIMITS BELOW A-LINE, OR $I_P < 4$	ABOVE A-LINE WITH I_P BETWEEN 4 AND 7 ARE BORDERLINE CASES REQUIRING USE OF DUAL SYMBOLS
GC	ATTERBERG LIMITS ABOVE A-LINE WITH $I_P > 7$	
SW	$C_U > 6;\ 1 < C_c < 3$	
SP	NOT MEETING ALL GRADATION REQUIREMENTS FOR SW	
SM	ATTERBERG LIMITS BELOW A-LINE, OR $I_P < 4$	ABOVE A-LINE WITH I_P BETWEEN 4 AND 7 ARE BORDERLINE CASES REQUIRING USE OF DUAL SYMBOLS
SC	ATTERBERG LIMITS ABOVE A-LINE WITH $I_P > 7$