UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 4 Examination in Engineering: September 2023

Module Number: CE4303 Module Name: Engineering Geology and Soil Mechanics

[Three Hours]

[Answer **all questions**, each question carries ten marks]

Q1. The geological map developed at a site for a proposed dam construction over a valley is shown in Figure Q1.1. The map includes topographic contours drawn at 20 m interval and the outcrops of 5 beds of 4 different types of rock. Also included in the map is the axis of the proposed dam. The elevations are given in meters above sea level (masl). In order to assess the suitability of the site for the dam foundation it is required to well-understand the extent of the beds and the attitude (or the orientation) of the bedding planes.

a) Construct structure contours for the bedding planes with appropriate labeling. Clearly state any assumptions.

[2.5 Marks]

b) Determine the true dip of bedding.

[1.0 Marks]

c) Determine the apparent dip of bedding along line X-X'.

[1.5 Marks]

d) Draw the cross-section X-X' on true scale.

[4.0 Marks]

e) Comment on the thickness of the beds of rock types B and D with respect to the bed of rock type C sandwiched between the types B and D.

[1.0 Marks]

[Note: The page containing the geologic map should be detached from the question paper and attached to the answer book.]

Q2. a) Earth is like a giant rock factory; old rocks are weathered to form soils and new rocks are formed at the same time. Illustrate the above statement in the form of the 'Rock Cycle'. When preparing your illustration pay attention to identify the types of materials and the processes that change materials from one type to another.

[5.0 Marks]

b) Identify two major types of plate boundaries, recognize distinctive features that are associated with those, and provide an example for each case.

[3.0 Marks]

c) Faults are one of many types of geologic structures that occur in association with crustal deformation. Differentiate between normal faults and reverse faults paying attention to relative movement of rock blocks and the stress states under which the faulting occurs. You may use suitable sketches to support your answer.

[2.0 Marks]

Q3. a) Using a hydro-mechanical analogy explain the time dependent process of effective stress development in saturated fine-grained soils upon application of surface loading.

[2.5 Marks]

b) The subsurface soil profile at a low-lying site selected for a construction of a sports stadium consists of 2.0 m thick layer of saturated sand followed by 6.0 m thick layer of saturated clay. Weathered bedrock is encountered underlying the clay layer. The water table is located at the ground surface. The subsurface soil profile is shown in Figure Q3.1. The specific gravity of sand and clay can be taken as 2.65 and 2.70, respectively. At their undisturbed in-situ state, sand has a void ratio of 0.5 while, clay has a void ratio of 0.8. The unit weight of water is 9.81 kN/m^3.

i) Construct a phase diagram and derive the following equation with usual notations.

$$\gamma_{sat} = \frac{(G_s + e)\gamma_w}{(1 + e)}$$

[1.0 Marks]

ii) Calculate the total vertical stress, pore water pressure, and vertical effective stress at points A, B, and C. Plot the variation of these parameters over the 8.0 m deep soil profile.

[5.5 Marks]

iii) A 3.0 m thick granular fill is to be placed at the site to improve the ground conditions. The placement of the fill shall be expected to induce consolidation of the clay layer. Determine the expected change in vertical effective stress at the middle of the clay layer immediately after the fill placement and many years after the fill placement. The fill is to be constructed at a dry unit weight of 20 kN/m^3. Justify your answers.

[1.0 Marks]

Q4. a) Soil compaction is frequently used as a measure of improving ground conditions.

i) Explain what is meant by soil compaction. You may use phase diagrams as suitable to facilitate your explanation.

[0.5 Marks]

ii) Describe how soil moisture content affects the level of compaction that can be achieved with a given type of soil. Use a suitable sketch to facilitate your description.

[1.0 Marks]

b) For the purpose of constructing an engineered fill soil is to be obtained from a borrow pit. The specific gravity of soil at the borrow pit is 2.65, the void ratio is 0.5, and the in-situ moisture content is 10.2%. The fill is to be constructed at a minimum dry unit weight of 18.5 kN/m^3 using the soil at a moisture content of 14.5%. For this purpose, a calculated amount of water is to be added to each truck load during soil transportation. The finished volume of the fill is 10,000 m^3. The unit weight of water can be taken as 9.81 kN/m^3. The acceleration of gravity on Earth is 9.81 N/kg.

i) Determine the volume of excavation that is needed at the borrow pit.

[2.0 Marks]

ii) Determine the number of 20-tonne [1 tonne = 1000 kg] truckloads that are needed to transport the excavated soil from borrow pit to the construction site.

[2.0 Marks]

iii) Determine the required amount of water in terms of volume that needs to be added per full truck-load of soil to achieve the required compaction moisture content.

[1.5 Marks]

c) During construction of the engineered fill in Section (b) above, the sand cone test was performed in the field for quality controlling. The sand cone test results are given in Table Q4.1. Determine the dry unit weight of compacted engineered fill and comment on the adequacy of the achieved level of compaction.

[3.0 Marks]

Q5. a) Soils are broadly divided into two groups, namely coarse grained and fine grained. Briefly explain these two groups of soils, paying attention to laboratory testing for identification and criteria for classification.

[3.0 Marks]

b) Sieve analysis test data obtained for a soil sampled between 3.0 m and 3.5 m depth at a proposed development site are given in Table Q5.1. Liquid limit test was carried out using the Casagrande cup device and the liquid limit was found to be 62%. A small specimen of test soil used for liquid limit testing formed cracks and crumbled when rolled into a thread of 3 mm (1/8") diameter at a corresponding moisture content of 38%.

i) Determine the plasticity index of the soil.

[1.0 Marks]

ii) Determine the liquidity index of the soil, if the in-situ moisture content of the soil is reported as 44.2%.

[0.5 Marks]

iii) Identify different states at which a fine-grained soil can exist at varying moister content and then identify the state at which the given soil exists at its in-situ moisture content.

[1.0 Marks]

iv) Determine the void ratio of soil at its in-situ moisture content, if specific gravity of soil is 2.72. Clearly state any assumptions that you may use.

[1.5 Marks]

v) Classify the soil in accordance with the Unified Soil Classification System (USCS) to obtain a group symbol and a group name.
[Note: You may refer to Figure Q5.1., FigureQ5.2, and Figure Q5.3]

[3.0 Marks]

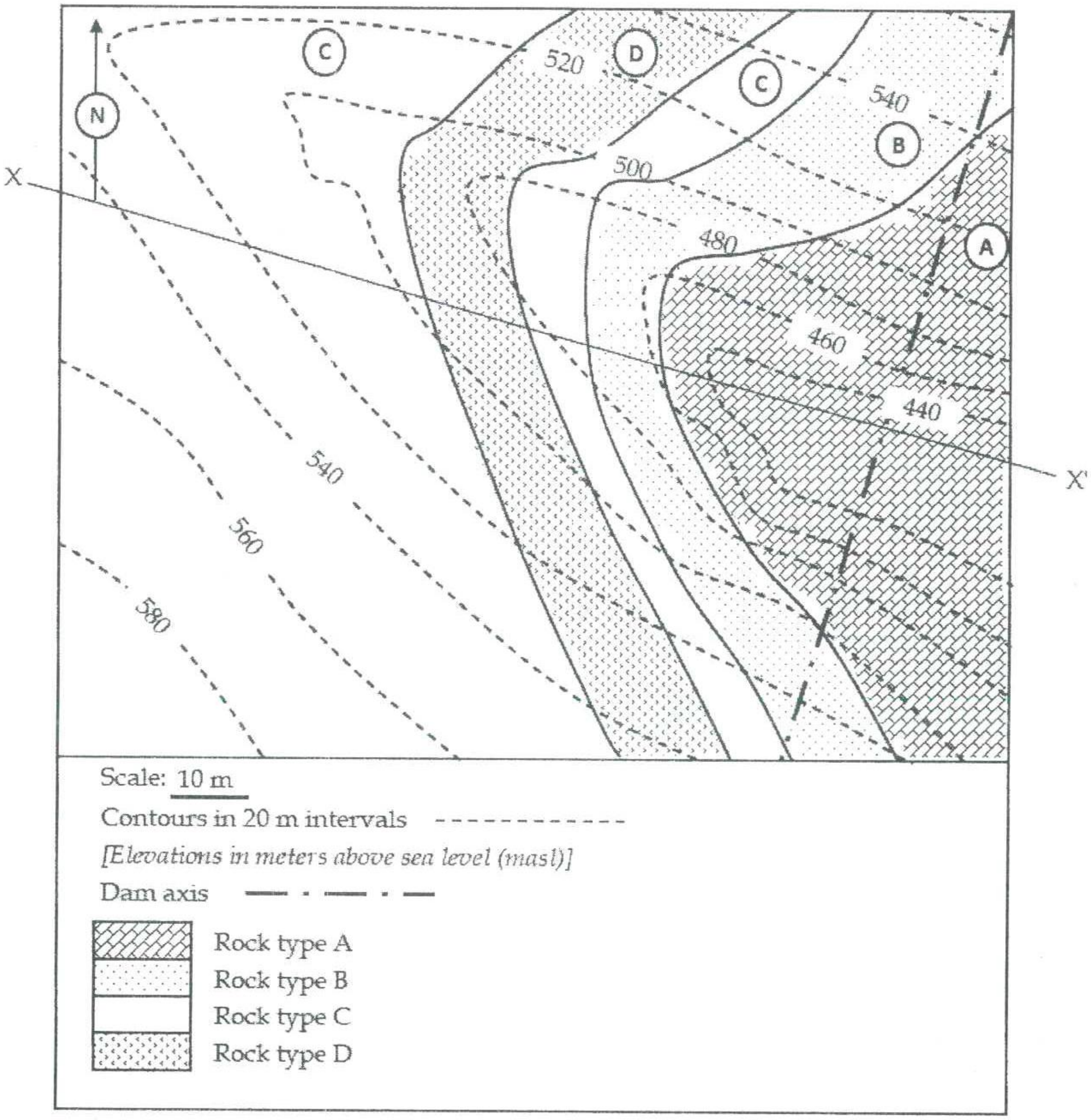

Figure Q1.1 Geologic Map

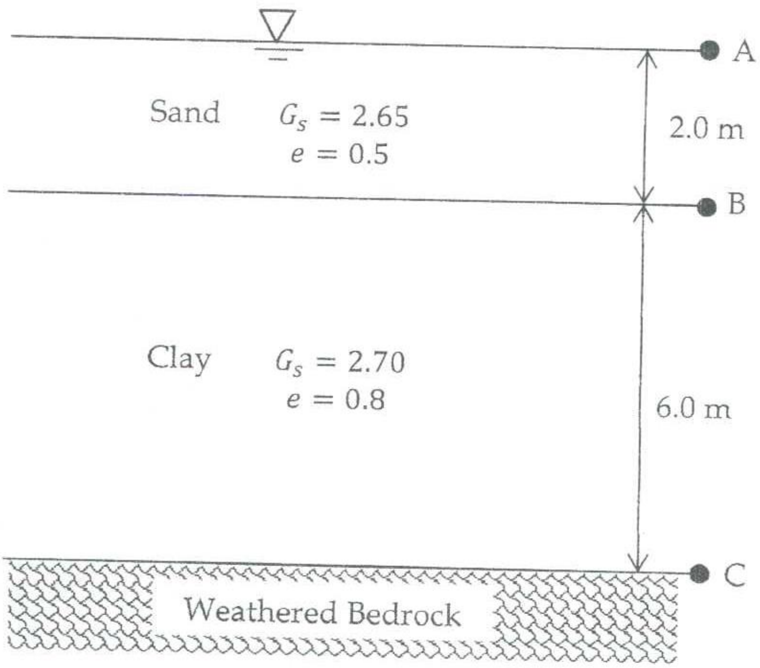

Figure Q3.1: Subsurface Profile

Table Q4.1 Sand Cone Test Results

Density of sand (g/cm^3)	1.57
Mass of sand required to fill the cone, M_c (g)	545
Mass of sand + Jar (before use), M_f (g)	7590
Mass of sand + Jar (after use), M_e (g)	4562
Mass of moist soil excavated from the hole (g)	3205
Water content of moist soil excavated from the hole, w (%)	8.5

Table Q5.1 Sieve analysis test data

Sieve No. (Sieve Opening, mm)	3/8″ (9.53)	4 (4.75)	10 (2.00)	20 (0.850)	40 (0.425)	100 (0.150)	200 (0.075)
% Finer	100	90.8	84.4	77.5	71.8	65.6	62.8

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests[A]				Soil Classification	
				Group Symbol	Group Name[B]
COARSE-GRAINED SOILS More than 50 % retained on No. 200 sieve	Gravels (More than 50 % of coarse fraction retained on No. 4 sieve)	Clean Gravels (Less than 5 % fines[C])	$Cu \geq 4.0$ and $1 \leq Cc \leq 3.0$[D]	GW	Well-graded gravel[E]
			$Cu < 4.0$ and/or $[Cc < 1$ or $Cc > 3.0]$[D]	GP	Poorly graded gravel[E]
		Gravels with Fines (More than 12 % fines[C])	Fines classify as ML or MH	GM	Silty gravel[E,F,G]
			Fines classify as CL or CH	GC	Clayey gravel[E,F,G]
	Sands (50 % or more of coarse fraction passes No. 4 sieve)	Clean Sands (Less than 5 % fines[H])	$Cu \geq 6.0$ and $1.0 \leq Cc \leq 3.0$[D]	SW	Well-graded sand[I]
			$Cu < 6.0$ and/or $[Cc < 1.0$ or $Cc > 3.0]$[D]	SP	Poorly graded sand[I]
		Sands with Fines (More than 12 % fines[H])	Fines classify as ML or MH	SM	Silty sand[F,G,I]
			Fines classify as CL or CH	SC	Clayey sand[F,G,I]
FINE-GRAINED SOILS 50 % or more passes the No. 200 sieve	Silts and Clays Liquid limit less than 50	inorganic	PI > 7 and plots on or above "A" line[J]	CL	Lean clay[K,L,M]
			PI < 4 or plots below "A" line[J]	ML	Silt[K,L,M]
		organic	$\frac{\text{Liquid limit – oven dried}}{\text{Liquid limit – not dried}} < 0.75$	OL	Organic clay[K,L,M,N] Organic silt[K,L,M,O]
	Silts and Clays Liquid limit 50 or more	inorganic	PI plots on or above "A" line	CH	Fat clay[K,L,M]
			PI plots below "A" line	MH	Elastic silt[K,L,M]
		organic	$\frac{\text{Liquid limit – oven dried}}{\text{Liquid limit – not dried}} < 0.75$	OH	Organic clay[K,L,M,P] Organic silt[K,L,M,Q]
HIGHLY ORGANIC SOILS	Primarily organic matter, dark in color, and organic odor			PT	Peat

Figure Q5.1 Unified Soil Classification System (USCS) - Part 1

[A] Based on the material passing the 3-in. (75-mm) sieve.
[B] If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.
[C] Gravels with 5 to 12 % fines require dual symbols:
- GW-GM well-graded gravel with silt
- GW-GC well-graded gravel with clay
- GP-GM poorly graded gravel with silt
- GP-GC poorly graded gravel with clay

[D] $Cu = D_{60}/D_{10}$ $\quad Cc = \dfrac{(D_{30})^2}{D_{10} \times D_{60}}$

[E] If soil contains ≥15 % sand, add "with sand" to group name.
[F] If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.
[G] If fines are organic, add "with organic fines" to group name.
[H] Sands with 5 to 12 % fines require dual symbols:
- SW-SM well-graded sand with silt
- SW-SC well-graded sand with clay
- SP-SM poorly graded sand with silt
- SP-SC poorly graded sand with clay

[I] If soil contains ≥15 % gravel, add "with gravel" to group name.
[J] If Atterberg limits plot in hatched area, soil is a CL-ML, silty clay.
[K] If soil contains 15 to <30 % plus No. 200, add "with sand" or "with gravel," whichever is predominant.
[L] If soil contains ≥30 % plus No. 200, predominantly sand, add "sand" to group name.
[M] If soil contains ≥30 % plus No. 200, predominantly gravel, add "gravelly" to group name.
[N] PI ≥ 4 and plots on or above "A" line.
[O] PI < 4 or plots below "A" line.
[P] PI plots on or above "A" line.
[Q] PI plots below "A" line.

Figure Q5.2 Unified Soil Classification System (USCS) - Part 2

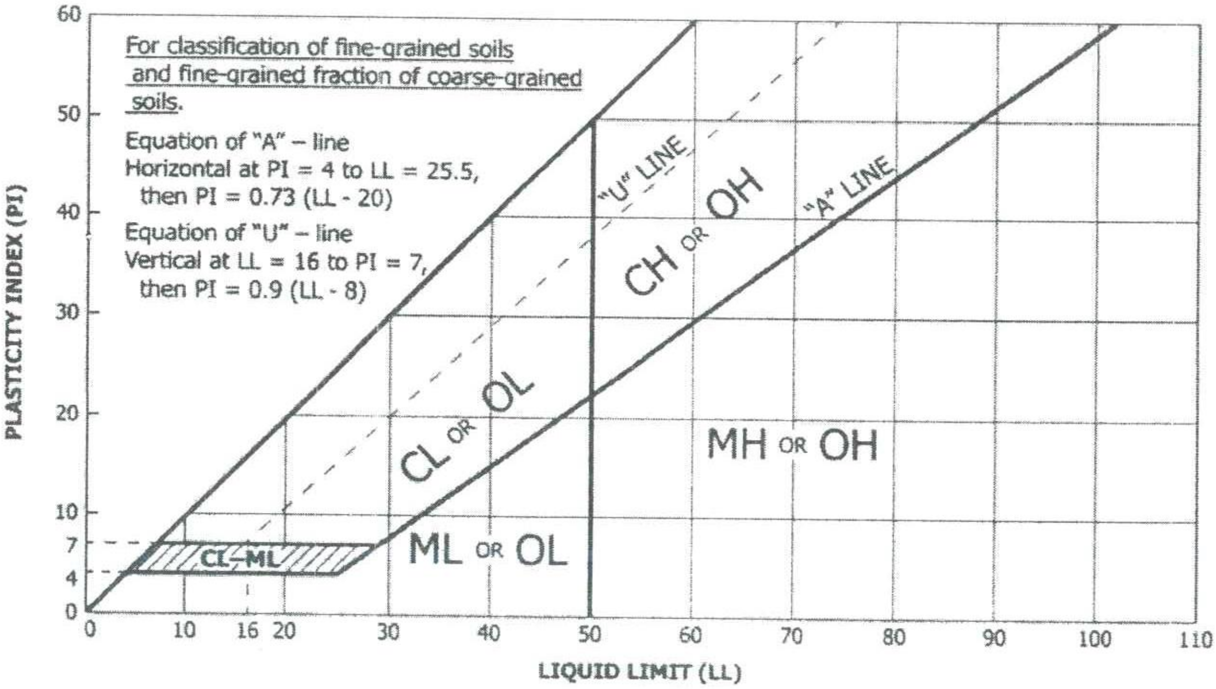

Figure Q5.3 Plasticity Chart