UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 4 Examination in Engineering: January 2022

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

[Three Hours]

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

Q1. A highway construction project requires performing a cut through a rock outcrop along a certain stretch of the proposed highway. The geological investigation at the site identified the rock mass to be heavily foliated and therefore to be consisting of sheet-like planar structures. The points A, B, and C are located on the trace of the contact plane between two such sheets as shown on the surface contour map given in Figure Q1.1. The location coordinates of these points are also provided on the map. In order to assess the risk of rock slope failure in relevance to the proposed construction it is important to well-understand the attitude (or the orientation) of these planes.

a) Define the terms "strike" and "dip" with respect to planar geologic structures as that are encountered at the aforementioned project.

[2.0 Marks]

b) Identify the third reference parameter that is required (in addition to strike and dip) in completely specifying the attitude (or the orientation) of a planar structure.

[1.0 Marks]

c) Formulate a "3 point problem" and determine the strike and dip of the foliation planes.

[5.0 Marks]

d) Determine the apparent dip of the foliation planes on the face of a near vertical cut that may be made to facilitate the road construction aligned in the north-south direction.

[2.0 Marks]

Q2. a) Explain "differentiation" with respect to formation of the Earth.

[2.0 Marks]

b) Based on the physical state, subdivide the Earth's interior into distinct regions. Provide brief explanations to these regions. Use a suitable sketch to illustrate the relative presence of these regions.

[3.0 Marks]

c) Identify 2 major types of plate boundaries, recognize distinctive features that are associated with those, and provide an example for each case.

[3.0 Marks]

d) During crustal deformation, rocks undergo different types of faulting. Briefly explain 2 types of faults with the use of simple illustrations.

[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.

[3.0 Marks]

b) The subsurface soil profile at a low-lying site consists of 1.5 m thick layer of saturated sand followed by 6.0 m thick layer of saturated clay. The clay layer is underlain by a silty sand layer of considerable thickness. The water table is located at the ground surface. The subsurface soil profile is shown in Figure Q3.1. The saturated unit weights of sand, clay, and silty sand are 18.5 kN/m^3, 19 kN/m^3, and 19.5 kN/m^3, respectively. The unit weight of water can be taken as 9.81 kN/m^3.

i) 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 7.5 m deep soil profile.

[5.0 Marks]

ii) A 4.0 m thick fill consisting of silty sand material is to be placed at the site to induce consolidation of the native clay layer, that is, the site is to be preloaded. Assuming static groundwater conditions 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.

[1.0 Marks]

iii) As a result of preloading uniform one-dimensional vertical settlement of 500 mm was accumulated at the site over a 2-year period. Assuming all settlement can be attributed to vertical compression of the clay layer, determine the expected saturated unit weight of clay at the end of the 2-year period. Make use of phase diagrams to perform this calculation.

[1.0 Marks]

Q4. a) Soil compaction is frequently used as a measure of improving ground conditions in various civil engineering projects. 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.

[2.0 Marks]

b) For the purpose of selecting suitable soils to meet material specifications for a road embankment construction, the Standard Proctor Compaction test was performed in the laboratory on a soil sample obtained from a borrow pit. The specification requires the embankment fill to be constructed at 98% Standard Proctor Maximum Dry Unit Weight which is not less than 16.0 kN/m^3. The test results are given in Table Q4.1. The volume of the mould is 944 cm^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) Draw the compaction curve and obtain the maximum dry unit weight and the optimum moisture content. *[Note: Use the graph sheet provided in Figure Q4.1 for this purpose and attach the sheet to the answer book]*

[2.0 Marks]

ii) Assuming that specific gravity of the soil is 2.65 draw 0% air voids line. With usual notations the fraction of air voids is given by the following equation:

$$\gamma_d = \frac{(1-N_a)G_s\gamma_w}{(1+\omega G_s)}$$

Also, estimate the minimum degree of saturation corresponding to 98% Standard Proctor Maximum Dry Unit Weight.

[2.0 Marks]

iii) The finished volume of the road embankment is 50,000 m^3. The in-situ bulk unit weight of soil at the borrow pit is 18 kN/m^3 at a moisture content of 11.5%. Given that the capacity of a truck is 10 m^3, determine the number of truck-loads of soil required for embankment construction. Assume a swell factor of 1.1 in your calculations. Also, determine the minimum volume of water that needs to be added per truck-load of soil to achieve the required compaction.
[Note: The swell factor is the ratio of the material volume in its loose excavated state to the material volume in undisturbed in-situ state]

[4.0 Marks]

Q5. a) Recognize two criteria that can be used to subdivide soils into groups. Then, subdivide soils using these criteria and provide brief explanations to each soil group.

[3.0 Marks]

b) Sieve analysis test data for soil sampled between 2.0 m and 2.5 m depth in a trial pit at a proposed residential development site are given in Table Q5.1 while, liquid limit test data for the soil obtained using the Casagrande cup device are given in Table Q5.2. Also, it was observed that 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 19%. The in-situ moisture content of the soil is reported as 24.2%.

i) Determine the liquid limit of the soil using the semi-log graph sheet provided (Figure Q5.1).
[Note: Attach the graph sheet to the answer book]

[1.5 Marks]

ii) Determine the plasticity index of the soil.

[0.5 Marks]

iii) Determine the liquidity index of the soil.

[0.5 Marks]

iv) Considering different states at which a fine-grained soil can exist at varying moister content, identify the state at which the given soil exists at its in-situ moisture content.

[0.5 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 Q5.2., FigureQ5.3, and Figure Q5.4]

[4.0 Marks]

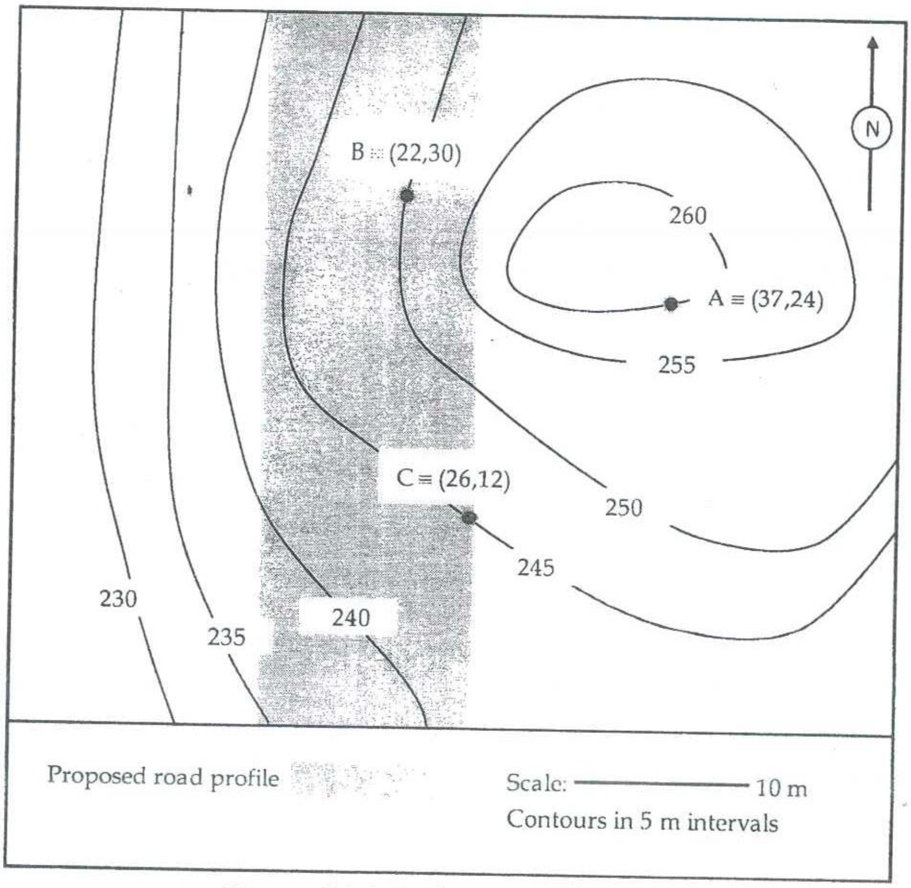

Figure Q1.1 Surface Contour Map

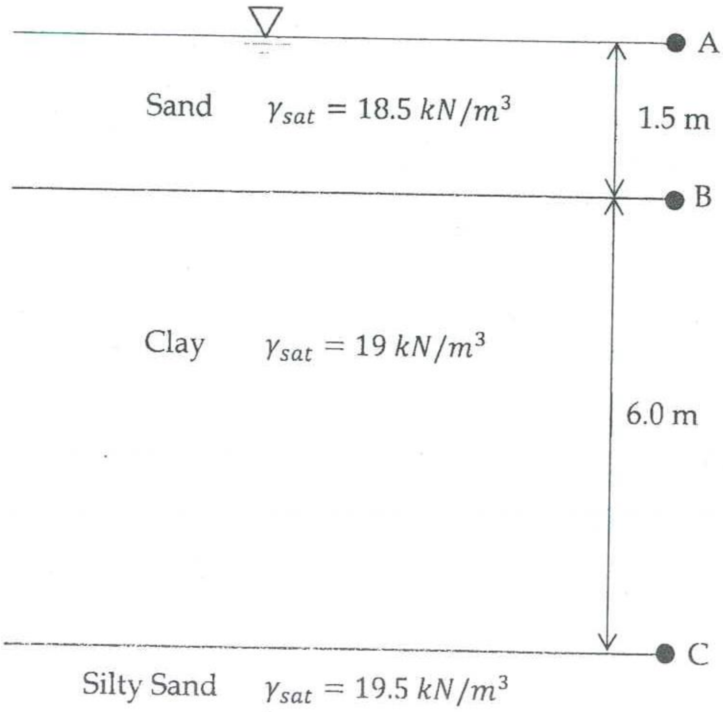

Figure Q3.1: Subsurface Profile

Table Q4.1 Standard Proctor Compaction Test Results

Moisture content (w) %	6.82	10.05	14.02	17.53	21.84	24.71
Mass of moist soil contained within the Proctor mould (g)	1563	1691	1882	1947	1854	1803

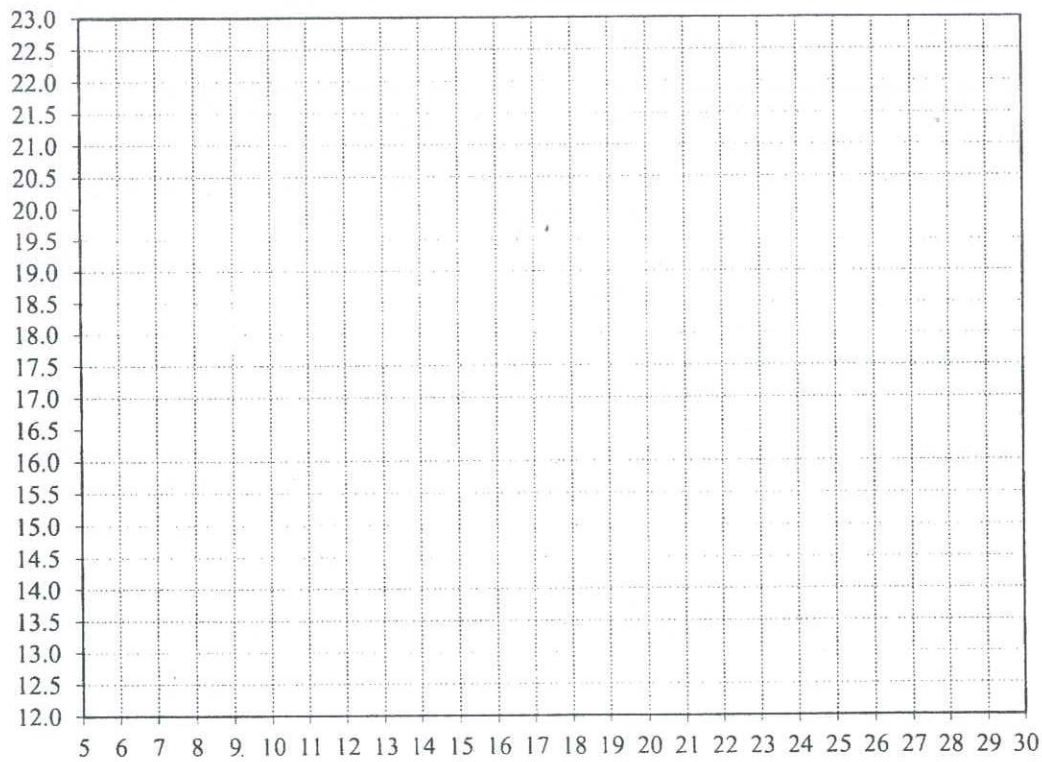

Figure Q4.1 Standard Proctor Compaction Test – Compaction Curve

Table Q5.1 Sieve Analysis Test Data

Sieve No:	Sieve Size (mm)	% Passing by mass
No. 4	4.75	98.2
No. 10	2.00	91.3
No. 20	0.85	83.4
No. 40	0.425	77.5
No. 100	0.15	74.6
No. 200	0.075	70.2

Table Q5.2 Liquid Limit Test Data Obtained with Casagrande Cup Device

Number of Blows	11	15	22	30	38
Moisture content (%)	46.1	39.5	34.9	27.6	23.9

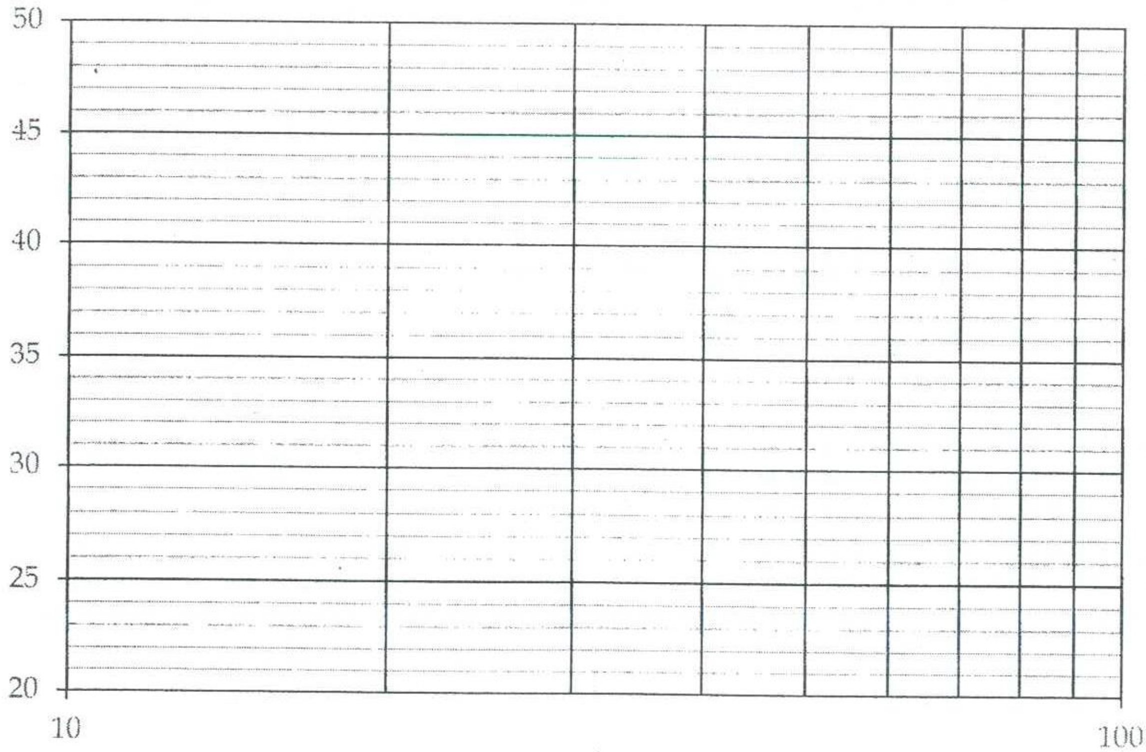

Figure Q5.1 Semi-log Plot – Liquid Limit Test

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests[A]				Soil Classification: Group Symbol	Soil Classification: 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 Q5.2 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] $Cu = D_{60}/D_{10}$ $Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$
[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 Q5.3 Unified Soil Classification System (USCS) - Part 2

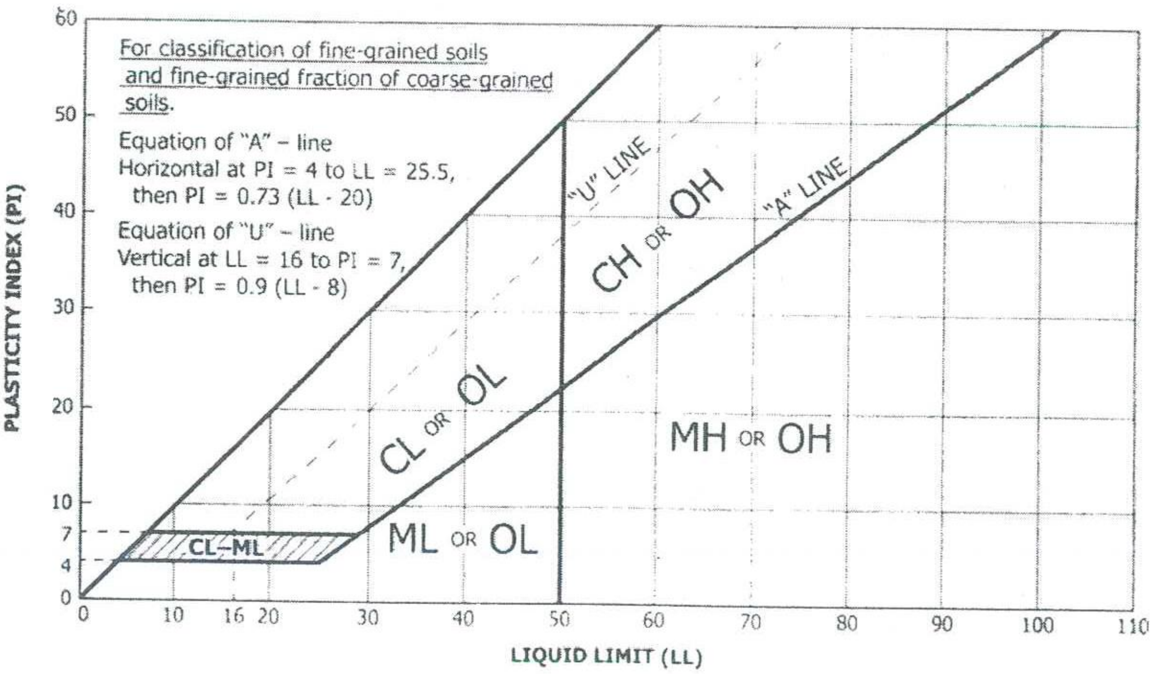

Figure Q5.4 Plasticity Chart