UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 4 Examination in Engineering: November 2022

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

[Three Hours]

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

Q1. A proposed irrigation project requires water to be diverted from one location to another via a tunnel. The map given in Figure Q1.1 includes topographic contours drawn at 10 m intervals and the trace of the proposed tunnel. The elevations are given in masl (meters above sea level). Also included in the map are the locations of points A, B, and C that define the t race of a weak plane (i.e., a lineament) which is associated with extreme weathering. In order to assess the impact of the weak plane on the proposed tunnel it is important to well-understand the attitude (or the orientation) of the plane.

a) Formulate a "3 point problem" and determine the strike, dip, and the dip direction of the weak plane.

[3.0 Marks]

b) Complete the trace of the weak plane on map view.

[2.0 Marks]

c) Determine the depth at which the weak plane would be encountered in a vertical borehole drilled at Point D.

[1.0 Marks]

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

[3.0 Marks]

e) Determine the shortest distance between the weak plane and the tunnel axis at cross section X-X', if the tunnel axis is at an elevation of 480 masl at this location.

[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) The Earth's structure is composed of several distinct layers (or subdivisions) of different physical state. Create a suitable sketch that illustrates the relative presence, extent, and the physical state of these layers.

[2.5 Marks]

b) The Earth's crust consists of rocks and soils.

i) Classify rocks based on their origin, provide a brief explanation to each class, and name one type of rock that belongs to each class.

[1.5 Marks]

ii) In relevance to formation of deposits of transported soils, define and explain the surface process "transportation". When formulating your answer pay attention to the transportation agents, associated deposition characteristics, and the changes to the physical properties of weathered products that take place during the transportation process.

[3.5 Marks]

c) Crustal deformation results in various forms of geologic structures. Differentiate between the following structures. You may use suitable sketches to support your answer.

i) Dikes and sills

[0.5 Marks]

ii) Normal faults and reverse faults

[1.0 Marks]

iii) Horsts and grabens

[1.0 Marks]

Q3. a) Effective stress in soil is approximately, the average particle "contact stress" or the average intergranular stress. Justify the above statement using first principles of physics.

[1.5 Marks]

b) Effective stress controls strength of soil and therefore, affects soil's bearing capacity to withstand loads transferred via foundation structures. A residential development is to be carried out at an urban site and the foundation structures are to be constructed at a depth of 1.0 m below existing ground surface. As an undergraduate student with keen interest in the mechanics of soils you are to investigate the changes in effective stress beneath foundations upon variations in groundwater regime. The subsurface profile at the site as shown in Figure Q3.1 consists of a 6.0 m thick layer of sand followed by a 9.0 m thick layer of saturated clay. The clay layer is underlain by impermeable bedrock. The groundwater table at the site is located 5.0 m below existing ground surface. The sand above the groundwater table can be considered as dry. The specific gravity of sand grains can be taken as 2.6. The saturated unit weights of sand and clay below groundwater table are 19.0 kN/m^3 and 18.5 kN/m^3, respectively. The unit weight of water can be taken as 9.81 kN/m^3.

i) Construct phase diagrams for saturated and dry states of sand and derive following equations with usual notations.

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

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

[2.0 Marks]

ii) Determine dry unit weight of sand.

[0.5 Marks]

iii) Calculate the total vertical stress, pore water pressure, and vertical effective stress at points A, B, C, and D. Plot the variation of these parameters over the 15 m deep soil profile.

[4.5 Marks]

iv) Now consider a 5.0 m rise in groundwater table as a result of seasonal rains. In other words, the groundwater table is now considered at the existing ground surface. Assuming static groundwater conditions determine the change in effective stress at the base of proposed foundation structures at the depth of Point E shown in Figure Q3.1.

[1.0 Marks]

v) Recognize, with justification, how the effective stress at Point E would change, if the water levels at the site are considered to rise further.

[0.5 Marks]

Q4. a) Soil compaction is frequently used as a measure of improving ground conditions. List two forms of improvement that can be achieved with compaction.

[1.0 Marks]

b) The Standard Proctor Compaction test is often combined with the sand cone test performed in the field for quality controlling of engineered fills. Compaction test results for a clayey silt obtained from a borrow pit are given in Table Q4.1. The volume of the mold is 944 cm^3. The soil material was used as an engineered fill at particular facility development site and the sand cone test was performed to assess the level of field compaction. The sand cone test results are given in Table Q4.2. 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]*

[6.0 Marks]

ii) Determine the dry unit weight of compaction at the engineered fill.

[2.5 Marks]

iii) Determine the relative compaction obtained in the field.

[0.5 Marks]

Q5. a) State how the use of Casagrande cup device allows standardization of the Liquid Limit test.

[1.5 Marks]

b) In the specimen preparation for the liquid limit test, specimen is smoothed in the Casagrande cup devise prior to testing to form a leveled surface. Explain how the test results can be affected when incorrectly smoothed at an angle to the horizontal using more soil than that should be used.

[1.0 Marks]

c) Soil sampled between 4.0 m and 4.5 m depth at a proposed development site was tested in the laboratory for index properties. Liquid limit test was carried out using the Casagrande cup device. The results are shown in Table Q5.1. 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 23%.

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.

[1.0 Marks]

iii) Determine the liquidity index of the soil, if the in-situ moisture content of the soil is reported as 38.2%.

[0.5 Marks]

iv) Determine the void ratio of soil at its in-situ moisture content, if specific gravity of soil is 2.7. 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. Based on a sieve analysis test, it is given that, the mass percentages passing No. 4, No. 40, and No. 200 sieves are 95.4, 75.3, and 68.4, respectively. *[Note: You may refer to Figure Q5.2., FigureQ5.3, and Figure Q5.4]*

[3.0 Marks]

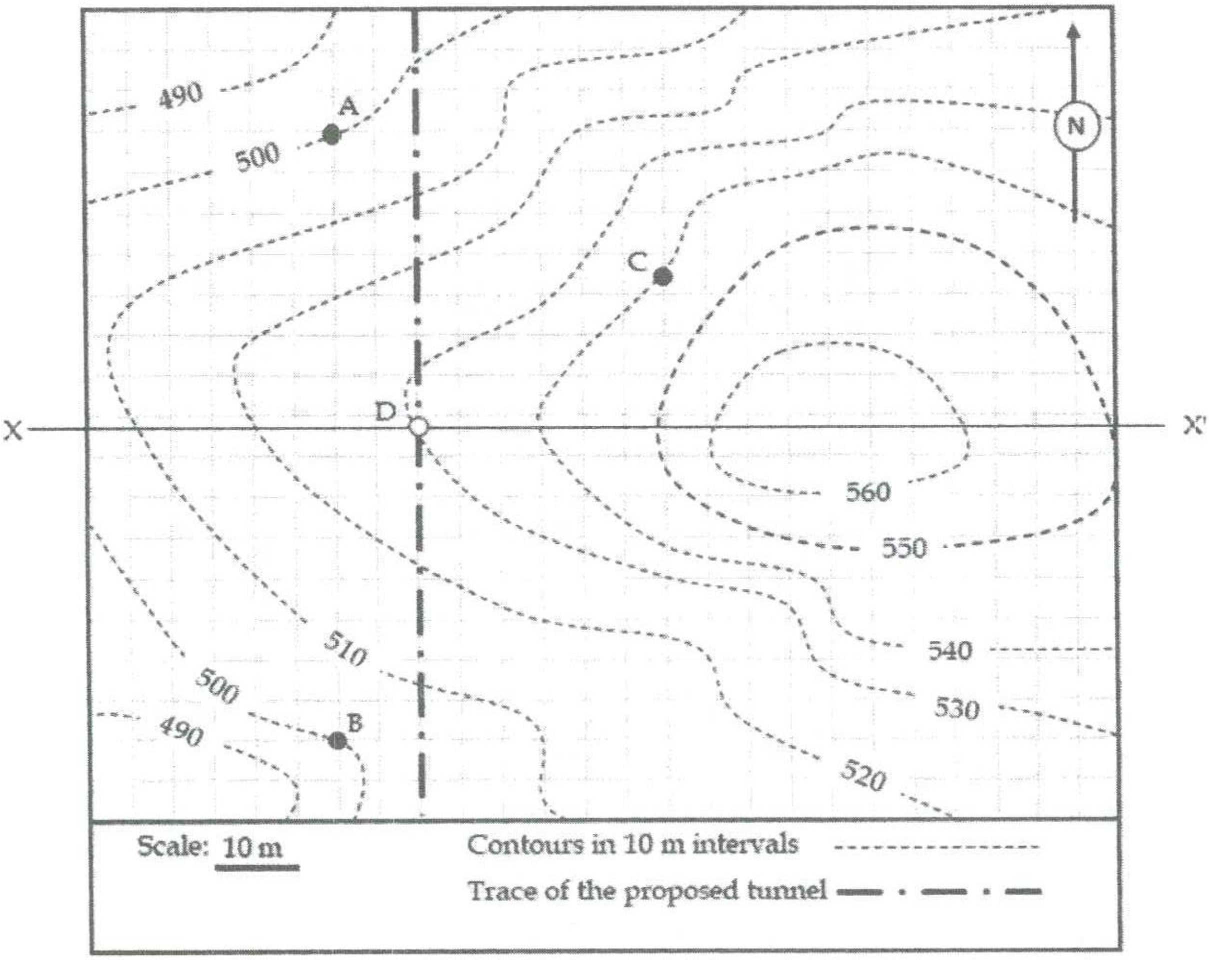

Figure Q1.1 Geologic Map

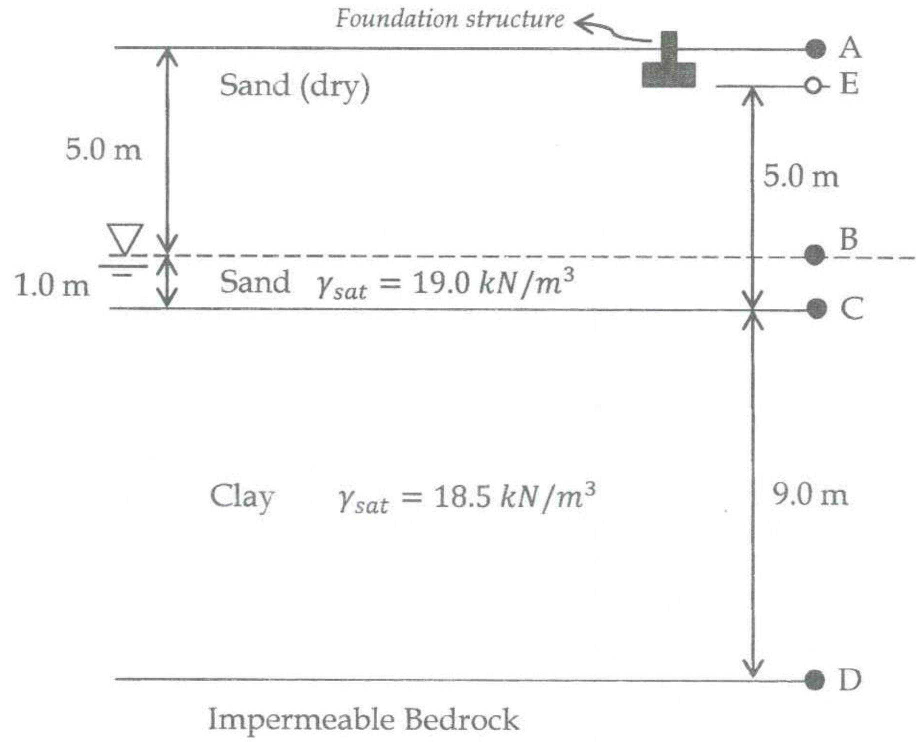

Figure Q3.1: Subsurface Profile

Table Q4.1 Standard Proctor Compaction Test Results

Moisture content (w) %	6.10	8.23	9.45	10.89	12.32	14.11
Mass of moist soil contained within the Proctor mold (g)	1511	1817	1954	2017	2000	1938

Table Q4.2 Sand Cone Test Results

Density of sand (g/cm³)	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)	4780
Mass of moist soil excavated from the hole (g)	3007
Water content of moist soil excavated from the hole, w (%)	10.2

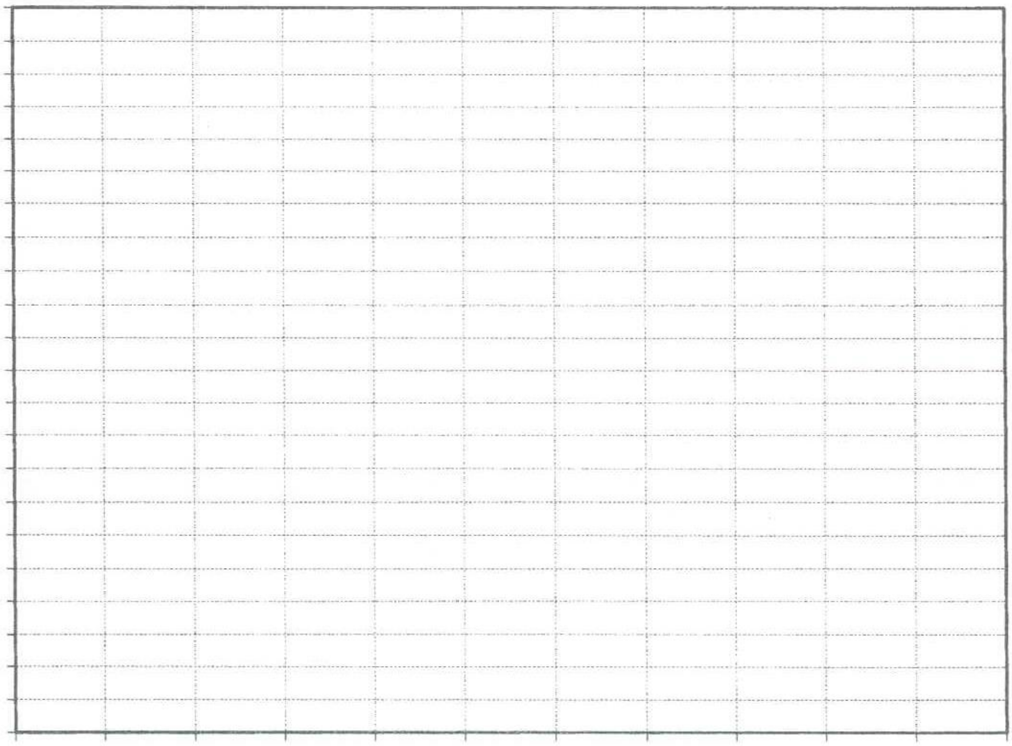

Figure Q4.1 Standard Proctor Compaction Test – Compaction Curve

Table Q5.1 Liquid Limit Test Data Obtained with Casagrande Cup Device

Number of Blows	6	12	20	28	32
Moisture content (%)	52.5	47.1	43.2	38.6	37.0

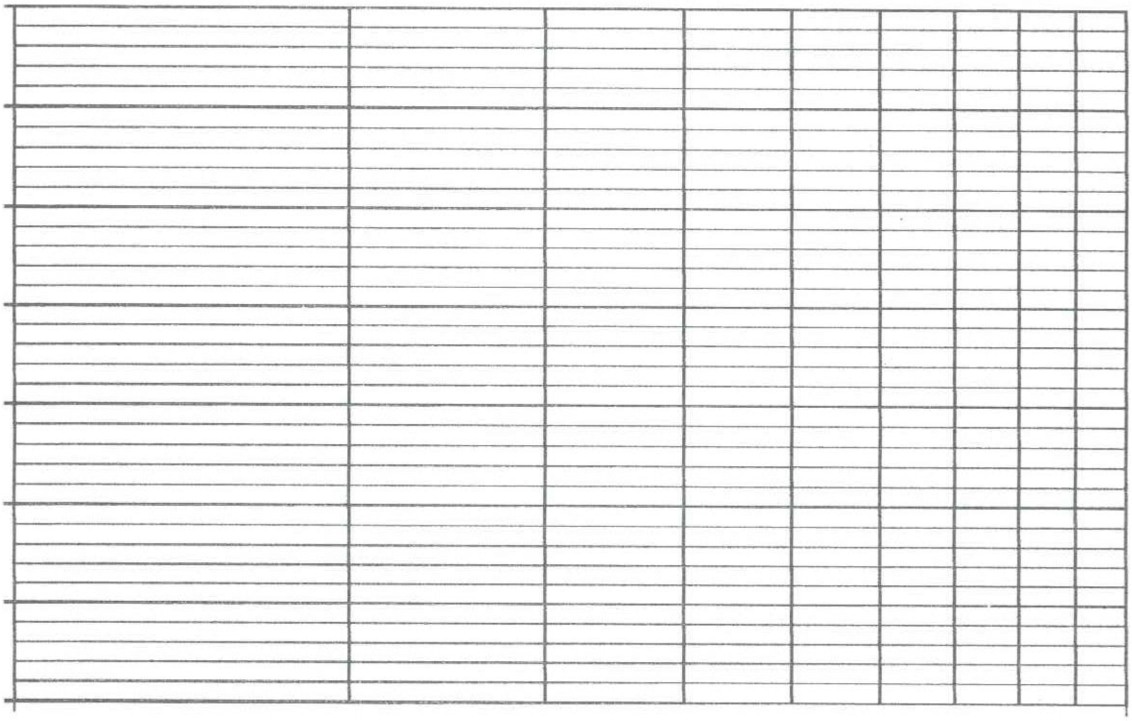

Figure Q5.1 Semi-log Plot – Liquid Limit Test

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

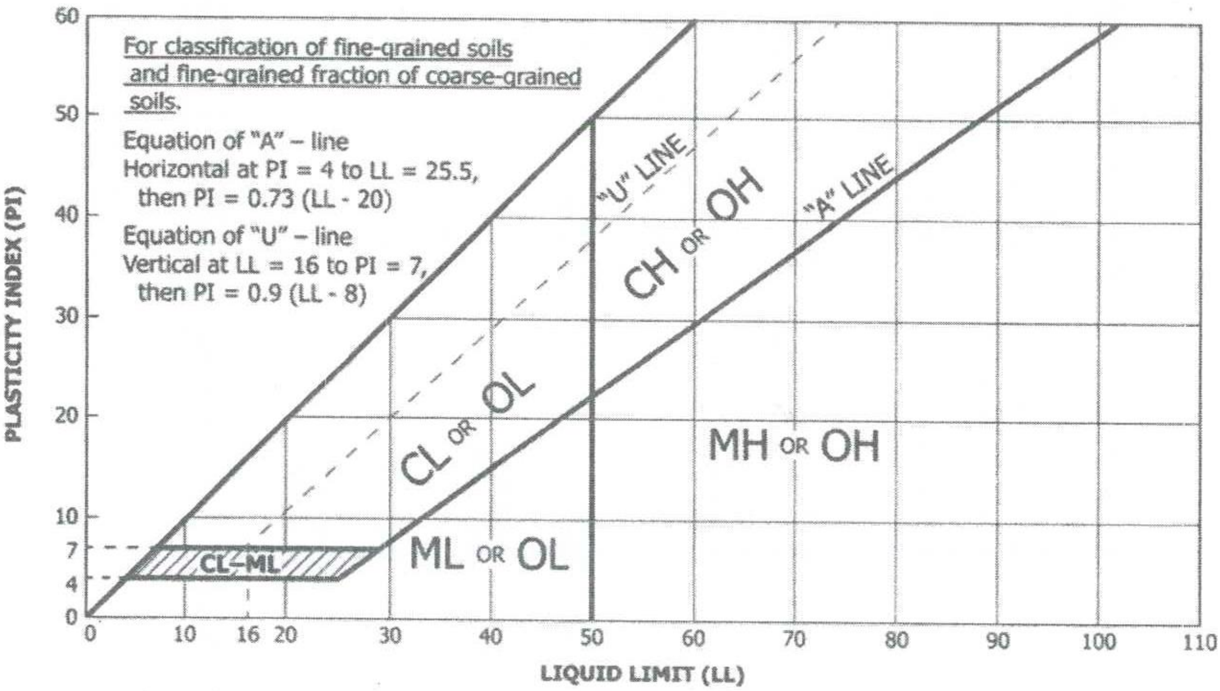

Figure Q5.4 Plasticity Chart