UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 4 Examination in Engineering: February 2020

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

[Three Hours]

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

Q1. Answer the following questions using the geological map shown in Figure Q1.1.

a) Draw the structure contours for the bedding planes between different types of rock shown in the geological map.
[Note: Make sure to label the structure contours appropriately and identify the upper/lower sandstone/shale on the map.]

[2.0 Marks]

b) Determine the true dip of the lower sandstone bed.

[2.0 Marks]

c) Draw the geological cross-section along line AB on a graph sheet.
[Note: clearly indicate the vertical exaggeration.]

[4.0 Marks]

d) Determine the true thickness of the mudstone bed.

[2.0 Marks]

[Note: The geological map and the geological cross-section should be attached to the answer book.]

Q2. a) Igneous rocks are of magmatic origin. Explain how igneous rocks differ from each other.

[2.5 Marks]

b) Briefly Explain the following forms of magmatic intrusions with suitable sketches;

i) Dikes
ii) Sills

[1.0 Marks]

c) Identify the sedimentary stages of the rock cycle and provide a brief explanation to each stage.

[3.0 Marks]

d) Explain the phenomenon of sorting with respect to sediment transportation by water currents.

[2.5 Marks]

e) Differentiate between residual and sedimentary soils by listing at least 2 factors.

[1.0 Marks]

Q3. The subsurface soil profile at a low-lying site consisted of 1.8 m thick layer of saturated sand followed by 4.0 m thick layer of saturated clay. Weathered bedrock was encountered underlying the clay layer. The water table was 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 2.66 and 2.72, 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 coefficient of lateral earth pressure of sand and clay can be taken as 0.3 and 0.4, respectively. The unit weight of water is 9.81 kN/m^3.

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

i) Saturated unit weight $\gamma_{sat} = \frac{(G_S+e)\gamma_W}{(1+e)}$

[1.0 Marks]

b) Plot the total vertical stress, pore water pressure, vertical effective stress, and the horizontal effective stress variation over the 5.8 m deep overburden soil profile considering the stresses at points A, B, and C.

[6.0 Marks]

c) The site was later observed to be inundated as a result of the seasonal rains. The free water surface was found 0.5 m above the existing ground surface. Assuming static groundwater conditions determine the vertical effective stress at Point C.

[1.0 Marks]

d) As a result of a prolonged drought which followed the rains, the groundwater table in the area receded to 3.0 m below existing ground surface (i.e., the depth corresponding to location of Point D shown in Figure Q3.1). However, the zone above the groundwater table within the clay layer remained at 100% saturation due to capillary effect.

i) Assuming static groundwater conditions obtain the pore water pressure distribution within the capillary zone between Points B and D.

[1.0 Marks]

ii) Identify the effect of capillarity on effective stress in soil.

[1.0 Marks]

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

[1.0 Marks]

b) List two factors which affect the level of compaction that can be achieved with a given type of soil. Use suitable sketches to briefly explain the way the listed factors affect the level of compaction.

[2.0 Marks]

c) For the purpose of selecting suitable soils to meet the material specifications for an expressway embankment, the Modified 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 95% Modified

Proctor Maximum Dry Unit Weight which is not less than 16.0 kN/m^3. The test results are given in Figure Q4.1.

i) Inspect the Modified Proctor Compaction test results to obtain the maximum dry unit weight and the optimum moisture content. State if the soil from the borrow pit is suitable for the purpose.

[1.5 Marks]

ii) What is the range of acceptable placement moisture content?

[0.5 Marks]

iii) During the construction phase, as a measure of quality control, sand cone tests were completed for each compacted layer of embankment. The test results for one such test is given in Table Q4.1. Check if the compactness condition of the embankment fill at the test location meets the specification. The acceleration of gravity on Earth is 9.81 N/kg^{-1}.

[2.5 Marks]

d) Construction of an earthen dam requires 1 million cubic meters of soil compacted to a void ratio of 0.8. In the vicinity of the proposed dam, three borrow pits were identified as having suitable materials. The cost of purchasing and excavating the soil are the same for each borrow pit while, the soil transportation cost is different for each borrow pit. Table Q4.2 includes the in-situ void ratio for soil at each borrow pit together with the swell factor and the associated transportation cost. Determine which borrow pit would be the most economical.

[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.]

[2.5 Marks]

Q5. A field geotechnical investigation carried out at a proposed facility development site encountered a 4.0 m thick layer of saturated clay underlain by a sand bed. As a part of the investigation, soil samples were obtained for laboratory testing. The Table Q5.1 presents sieve analysis test data for the clay. The liquid limit test data for clay obtained using the Casagrande cup device are given in Table Q5.2. The natural moisture content of the clay is reported as 38% while, the plastic limit is 23%.

a) Explain the relationship between volume and moisture content of fine grained soils with the use of a suitable sketch. Clearly indicate the different soil states and the boundaries between these different states.

[2.0 Marks]

b) Determine the liquid limit of the clay using the semi-log graph sheet provided (Figure Q5.1).

[Note: Attach the graph sheet to the answer book.]

[2.0 Marks]

c) Also determine the plasticity index and the liquidity index of the clay.

[1.0 Marks]

d) What is the state at which the clay exists at its natural moisture content?

[1.0 Marks]

e) Classify the clay in accordance with the Unified Soil Classification System (USCS).
[Note: You may refer to Figure Q5.2. FigureQ5.3, and Figure Q5.4.]

[2.0 Marks]

f) In order to improve the compressibility properties of the clay, it was decided to preload the site. Accordingly, a 2.0 m thick layer of fill was placed at the existing ground surface. The unit weight of the fill material is 20 kN/m^3. What would be the change in pore water pressure at the middle of the clay layer immediately after the placement of the fill? Justify your answer.

[2.0 Marks]

Geology Map

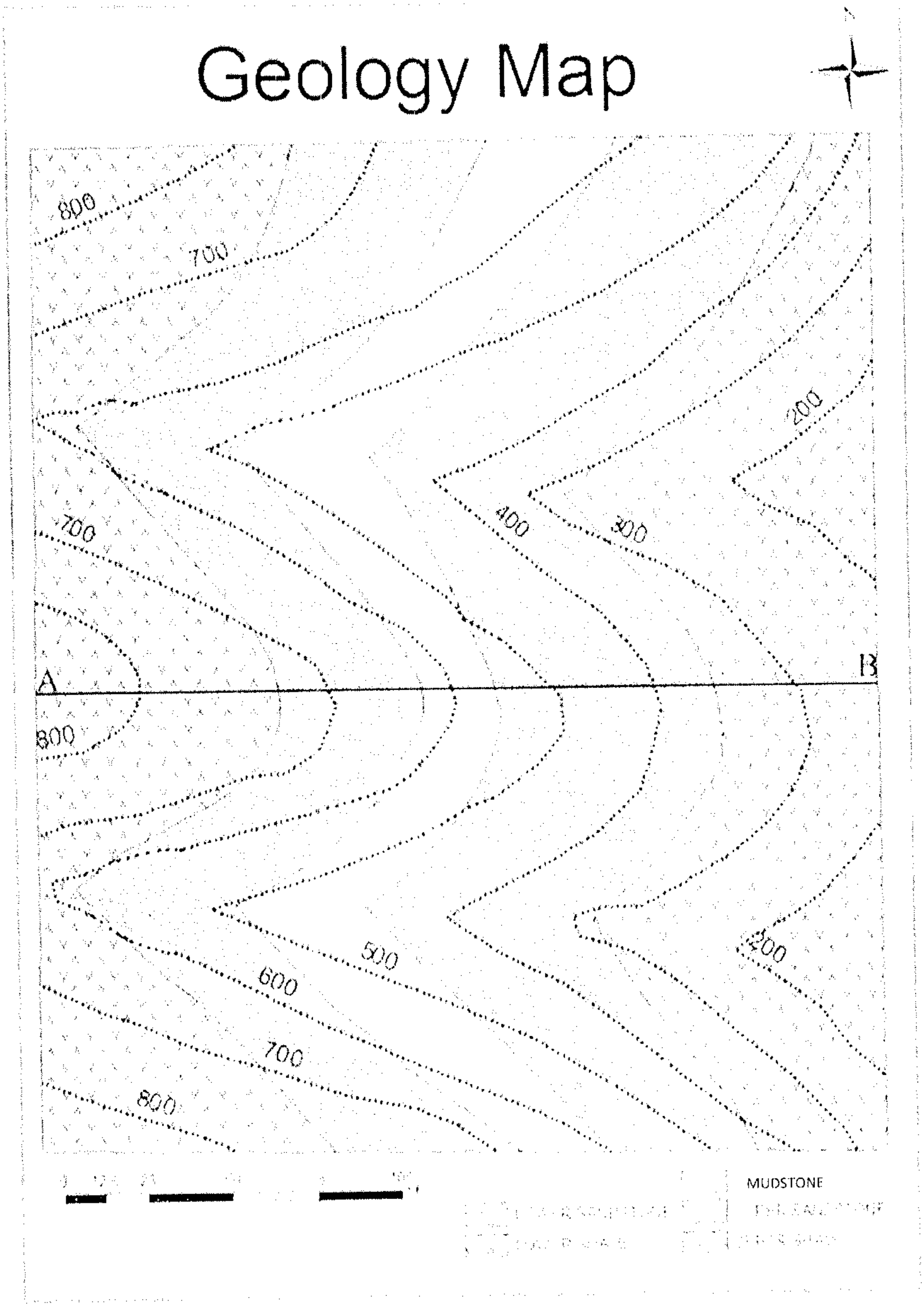

Figure Q1.1 Geological Map

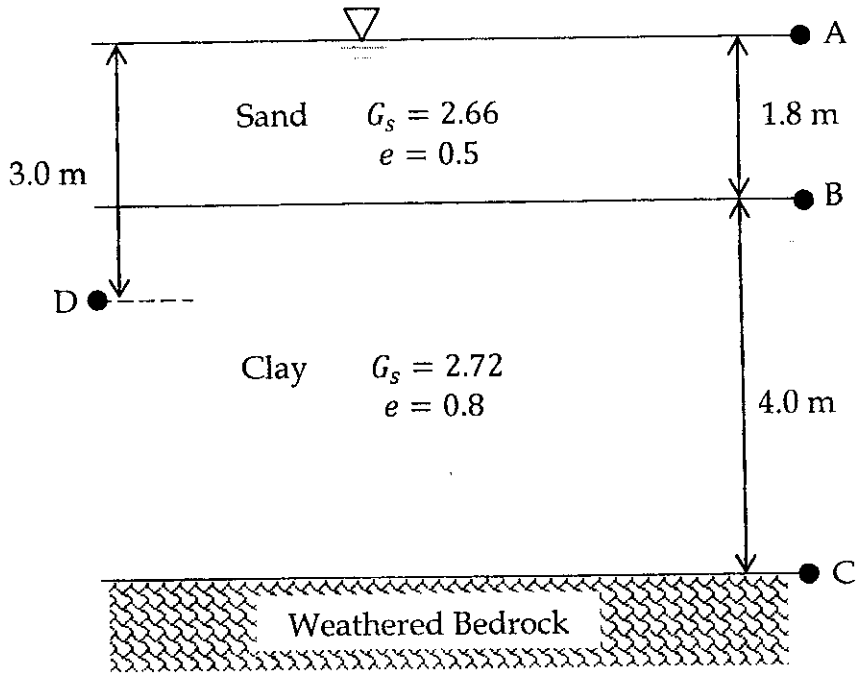

Figure Q3.1: Subsurface Profile

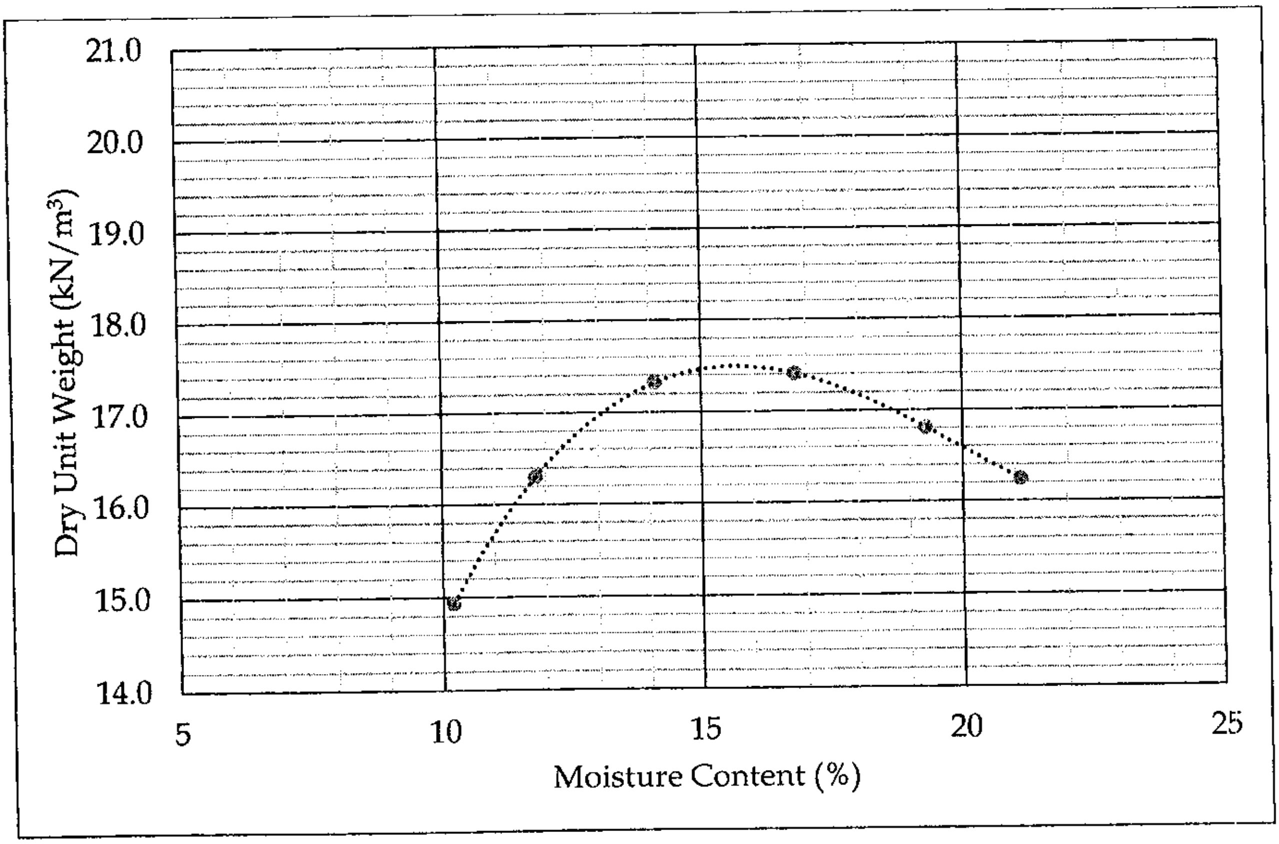

Figure Q4.1 Modified Proctor Compaction test results

Table Q4.1 Sand Cone test results

Density of sand (g/cm³)	1.34
Mass of sand required to filled the cone (g)	396
Determination of Moisture Content	
Mass of can (g)	9.98
Mass of can + Moist soil (g)	112.85
Mass of can + Dry soil (g)	98.87
Determination of Dry Unit Weight	
Mass of sand + Jar before use (g)	7315
Mass of sand + Jar after use (g)	6034
Mass of container (g)	144.8
Mass of container + Moist soil (g)	1385

Table Q4.2 Data relevant to sourcing earth material from borrow pits

Borrow pit	In-situ Void ratio	Swell factor	Transportation cost (Rs./m³)
1	1.8	1.1	600
2	0.9	1.2	1000
3	1.5	1.1	750

Table Q5.1 Sieve analysis test data

Sieve No:	Sieve Size (mm)	% Finer by mass
No. 4	4.75	90.8
No. 10	2	84.4
No. 20	0.85	77.5
No. 40	0.425	71.8
No. 100	0.15	65.6
No. 200	0.075	59.3

Table Q5.2 Liquid limit test data obtained with Casagrande cup device

Number of Blows	10	15	20	28	32
Moisture content (%)	52.5	47.1	43.2	38.6	37

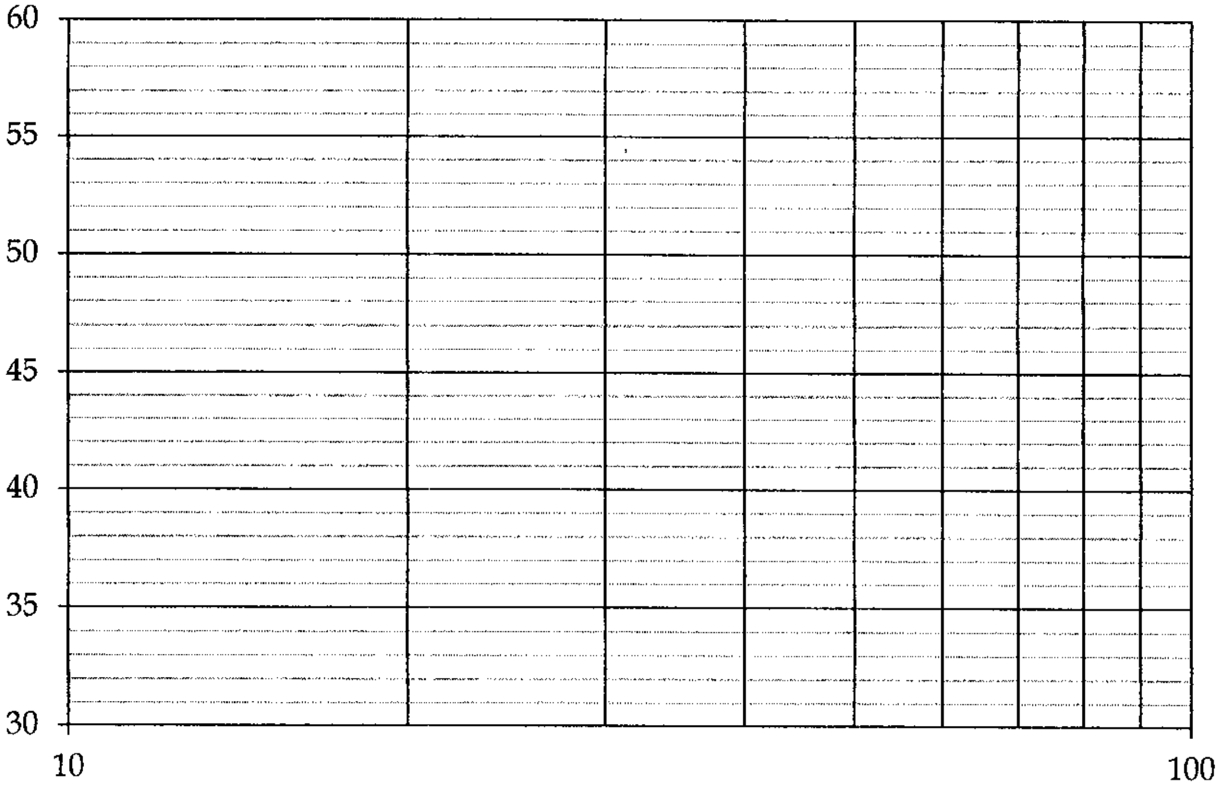

Figure Q5.1 Semi-log plot - liquid limit test

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

[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

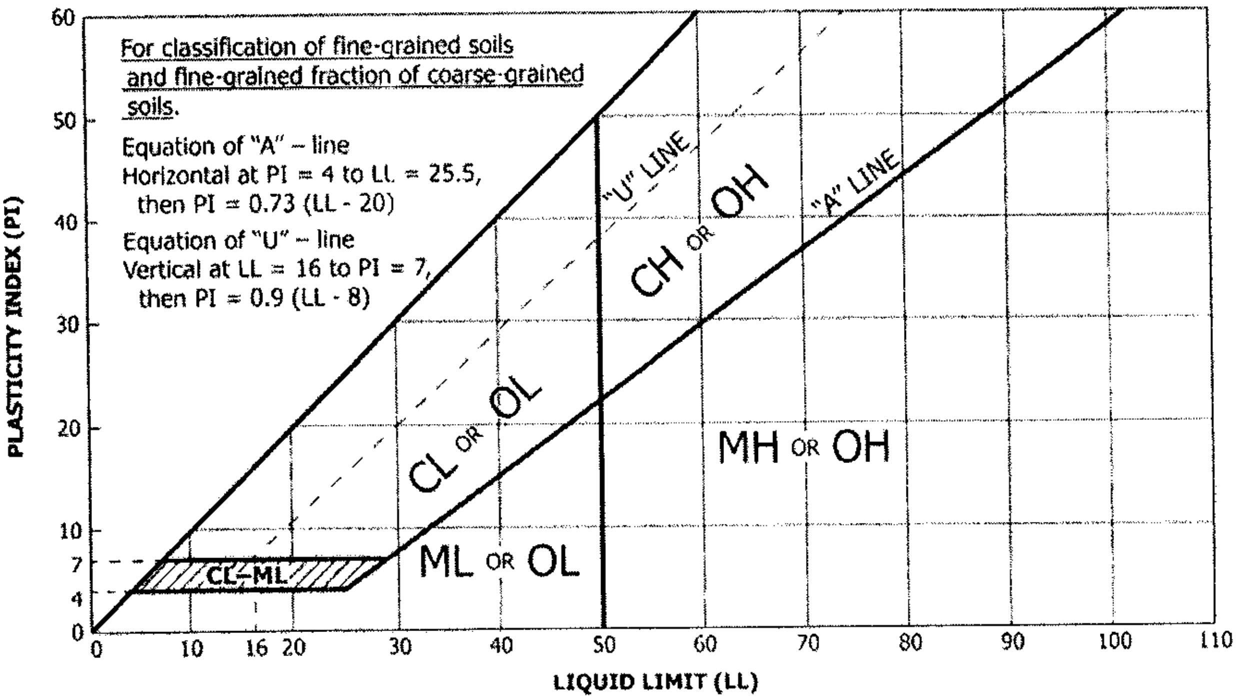

Figure Q5.4 Plasticity Chart