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Full Length Research Paper

Classification of Soils and Their Plasticity Index of the University of Cape Coast Research Station at Twifo Wamaso

[1]Gyamera, E. A, [2]Kuma, J. S and *[1]Okae-Anti, D

[1]Department of Soil Science, School of Agriculture, University of Cape Coast, Cape Coast, Ghana
[2]Department of Geological Engineering, University of Mines and Technology, Tarkwa, Ghana
*Corresponding Author's E-mail: gyamengineering@yahoo.com

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The textural characteristics and plasticity index of soils have been determined by grain size distribution test, and Atterberg Limits test respectively, on twenty sample locations spread over 150 acres at the University of Cape Coast (UCC) research station at Twifo Nwamaso in the central Region of Ghana. The soil tests were conducted at depths of 0.5 m and 1.0 m at each location. Unified Soil Classification System was adopted for the soil classification since grain size distribution had a significant effect on the engineering properties of the soil. The soil was classified as well or uniformly graded sand, sandy gravel, gravelly sand, silty sand, and sand with some clay. From the modified plasticity chart, 72% of the fine particles were observed to be silt with high and very high plasticity.

Keywords: Classification, plasticity, index, soil, histosols, atterberg limit

INTRODUCTION

Twifo Wamaso which consists basically of secondary forest lies within the forest belt of the country with good soil fertility favorable for the cultivation of tropical plants like cocoa, oil palm, plantation, cassava, etc. Rapid growth of vegetation is due to high temperature and heavy rainfall, which in effect, gives the forest a luxuriant and evergreen look all year round.

It lies within Latitude 05º 37′N and Longitude 01º 32′W on an average altitude of 60 m to 350 m above mean sea level. The area is generally hot with a temperature ranging between 26ºC and 32ºC with relatively high humidity ranging from 65-75%. The highest mean temperatures occur between March and April whereas the lowest is recorded in August.

Basic granitic intrusives and granites underlie almost all the study area. The granites are either of Bongo, Dixcove or Cape Coast type. Major rock types comprise well-foliated, medium grained, potash rich muscovite biotite granites, grano-diorites and pegmatites Anon, (2008) observed that, Granites found in the study area are post Tarkwaian and can be divided into three groups:

- Bongo Granites;
- Dixcove Granite Complex;
- Cape Coast Granite complex.

The Cape Coast Granite complex consists of well foliated and medium grained muscovite-bioitite granite, granodiorites and pegmatites. It is often associated with schists and gneisses and intrudes the lower Birrimian meta-sediments (Anon, 2008). One characteristic of the granite is that, it is not inherently permeable, but secondary permeability and porosity have developed as a result of fracturing and weathering. The hydraulic potential depends on the degree of fracturing and on the potential recharge of the aquifer, which is directly related to the annual rainfall and water streaming. For this reason, the underlying granites have been categorized

Table 1. Procedure for cassagrande liquid limit test

Step	Methodology
1	Liquid limit apparatus was first examined to make sure it was clean and then with no side play at the hinge. The next thing was to check the height through which the cup falls, it should be 100 mm.
2	Not less than 200 g of the air-dried soil was made to pass through a 425 um sieve to remove the coarser particles.
3	Soil that has been spread was on the glass plate was thoroughly mixed with distil water using palette knife until it became a thick paste.
4	The soil was remixed using the palette knife; Ensuring the cup is resting on the base. The sample was press down to exclude any trapped air. It was then leveled off using the palette knife paralleled to the base with a minimum depth of 10 mm.
5	The counter was set to read zero.
6	By using chamfered edge of the grooving tool, the samples were divided by drawing the grooving tool along the diameter of the cup that passes through the centre of the hinge.
7	The handle of the machine was turned anticlockwise at a speed of 2 turns per second. The number of blows needed to close the groove formed in (6) above for distances of 13 mm was recorded. This was made between 40 to 50 blows for the first test, when more than 50 blows were needed; more water was added and the process, repeated.
8	Portions of material, which had just flowed, were placed together into a previously weighed and numbered moisture content container. The container with its contents was weighed, oven dried and re-weighed to determine the moisture content.
9	The material remaining in the cup was returned to the glass-plate; remixed with the rest of the sample together with a little more water to obtain a uniform softer consistency. Procedures 4-8 were repeated to obtain a lower count of blows.
10	The experiment was conducted for at least 4 different moisture contents so that the number of blows was fairly evenly distributed between about 50 and 10 and with two each side of 25. The moisture content of each tin from each blow-count was calculated
11	A plot of the average moisture contents against the average number of blows on the semi-log graph paper was made. Then the best straight line of fit was drawn through the points. The water content corresponding to 25 blows to the nearest 0.1% was then read. This result was quoted to the nearest whole number as the liquid limit.

into two groups: those located in the southwestern savanna zone and those in the forest zone (Anon, 2008).

Soil studies, conducted in parts of the study area, have been focused upon its agricultural suitability. Anon (1996) observed that the soils are dominated by oxysols and heavily leached, acidic and clayey. The study area is located in a tropical environment and generally exhibits a well-developed soil profile.

MATERIALS AND METHODS

Atterberg limits

The empirical boundaries between each of the principal physical states of cohesive soil viz the liquid, plastic, semi-solid, and solid states are called Atterberg limits. The water content is the variable factor and hence used as an indicator for the consistency limits.

a) Liquid Limit (Cassagrande Method)

i) Apparatus

Liquid Limit device, grooving tool, palette knife, distil water, moisture content containers, balance, glass plate, and, an oven capable of maintaining temperatures up to 110°C

Procedure

The step by step procedures has been summarized in Table 1

b) Plastic Limit Procedure

The plastic limit procedure is summarized in Table 2.

Particle Size Distribution (Dry Sieving)

Particle size distribution test was done to determine the relative proportions of various sizes within the mass of the soil. An important application of particle size distribution is in connection with groundwater flow problems where it provides an indication of in-situ

Table 2. Determination of plastic limit

Step	Methodology
1	50 g of soil samples was used for this test.
2	The samples were mixed with enough water to form a homogeneous dry paste, just plastic enough to be rolled into a ball of about 15 mm diameter.
3	The ball of soil was rolled between the hand and the glass plate until a thread 3 mm diameter was formed. The thread was then reshaped into a ball. This process was repeated until the 3 mm thread started to crumble.
4	The threads were placed in moisture content container, weighed, dried with the purpose of determine the moisture content.
5	This test procedure was repeated for about 3 times
6	The moisture content for each test was calculated and the mean of the three moisture contents was determined to the nearest whole number. This is the plastic limit.
7	Plasticity Index was then determined from the difference between the plastic limit and the liquid limit.

permeability and also in geotechnical processes such as grouting and chemical injection.

a) **Apparatus**

Set of sieves (depending on the maximum particle size), Balances Sieve, brush, Moisture content tins, Drying oven, Scoop.

b) **Procedure**

A representative sample was dried in an oven. A reasonable quantity depending on the size of the particles was taken for the test. By cone and quartering method, the samples were evenly reduced in size. The whole specimen was weighed and corrected to the nearest 1 g after it had been dried in an oven and had allowed to cool. With the receiver at the base, each sieve was weighed to the nearest 0.1 gm and putting them together in descending order of aperture size. The dried samples were placed in the top sieve, covered with the lid and hand-shaken for 10-15 minutes.

After that time, the material retained on each sieve was examined to see that it consisted of only individual particles. Any agglomeration of particles not naturally cemented together was broken down and sieved further. 100 ml of water was added to a soil placed in a flask. The flask was shook thoroughly having added 25 ml of sodium hexametaphosphate solution. It was again vigorously shaken for 30 minutes. The material retained on each sieve was weighed. Where the amount retained exceeded the given in the table provided, the material was subdivided into smaller portions and received. Percentage passing each sieve size was plotted as ordinate against the particle size, which was drawn to a log scale on the particle size sheet.

Sedimentation (Pipette Method)

Sedimentation method was done to determine the particle size distribution of fine grain soils. The sedimentation test for fine particle analysis makes use of suspension of particles in water of a known concentration. The principle is that the falling velocity of a sphere in a fluid is a function of the diameter of the sphere. This is governed by Stoke's Law, the larger particles settle at the bottom more quickly than the smaller particles. The density of the suspension is measured at specific time intervals.

a) Apparatus

Sampling pipette, two 500ml glass sedimentation tubes, glass weighing bottles, 63um sieve and other sieves, balance, drying oven, stop clock, constant temperature bath, conical beaker, filtration equipment, 100ml measuring cylinder, 5ml pipette, glass rod fitted with rubber policeman, reagents, hydrogen peroxide. HCL, sodium hexametaphosphate, and distilled water.

b) Procedure

A sufficiently, small, representative sub sample of the airdried soil was obtained by quartering or riffling (approx.
30 g of sandy soil and 12 g for clayey soil). A small portion of the original soil was tested with few drops of

HCL. Effervescence was observed followed by acid treatment by washing. Soil samples were placed in a conical beaker, and 50 ml of distilled water was added to it. The suspension was gently boiled until the volume was reduced to 40 ml. Suspension was allowed to cool, and 75 ml of H_2O_2 was added and the mixture was left overnight. 100 ml of water was added to a soil placed in a flask. The flask was shaking thoroughly having added 25 ml of sodium hexametaphosphate solution. It was again vigorously shaken for 30 minutes.

The suspension was then washed through a 63 µm sieve using not more than 150 ml water, the suspension passing through/transferred to a 500 ml sedimentation tube. Distilled water was then added to make up to the 500 ml. The material retained on 63 µm sieve was dried and sieved separately.

The sedimentation tube containing the soil suspension was transferred to a constant temperature bath, with inserted rubber bung and was allowed to stand in water up to the 500 ml mark until it had reached the constant temperature. Similarly, a sedimentation tube containing 25 ml sodium hexametaphosphate diluted with distilled water to exactly 500 ml was left standing in the constant temperature bath until it had reached the temperature of the bath, after an hour. On reaching this temperature, both tubes were removed and thoroughly shaken by inverting the tubes several times. They were replaced in the bath. Stop-clock was started as the tube containing the soil suspension was returned to the bath. The rubber bungs from both tubes were then removed.

RESULTS AND DISCUSSION

Results of Atterberg limits

The Atterberg limits test was used basically to measure the nature of fine-grained fractions in the samples. This test was also conducted in order to know the proportion of silt and clay in the fine particles.

To further classify the soils based on its fines, the graph (figure 1) were plotted in order to determine the plastic and liquid limits as well as the plasticity index of the soil at twenty locations at the depths of 0.5 m and 1.0 m. The results have been presented in Table 3

Tables 4a and 4b, show the summary of Atterberg Limits result for the thirty six soil samples. Those soils with high plasticity index of more than 25 are expansive clays that make poor road beds or foundations (Brady and Weil, 1993). The data in Table 3 were then plotted on the modified plasticity chart as shown in figure 2.

It is observed from the chart that, majority of the samples plotted below the A-line, and clustered between intermediate and very high plasticity with some few of them having low and extremely high plasticities. It is also observed that most of the soil fines are silt with a few classifying as clay. The plots marked red and blue on the plasticity chart are for 0.5 m and 1.0 m depth respectively.

From the graph, a total of 72% of the soils plot in the zone of high and very high plasticity. It therefore suggests that the water holding capacity of the soils is moderately higher and the clays within are the expansive types. In case of building in this type of soil, the ground should be compressed enough to increase its density to avoid differential settlement with time. However, crops will do well even in the dry season; because, the soils are able to keep water for considerably long time.

22.2% of the soils are classified in the range of low and extremely high plasticity with only 5.6% having intermediate plasticity.

The textural classification adopted is as follows: (i) If the main size group is more than 60% and none of the remaining size fraction attains 20%, then the name of the main size group alone is used.

(ii) If, on the other hand, any of the remaining groups is present with 20% or more, it is added to qualify the main constituent. A loam is a soil containing sand, silt and clay in roughly equal proportions (Kuma and Younger, 2002)

For plants and crops cultivation purposes, the Textural Triangle was used to classify the soil. The results are presented in table 5a and 5b.

CONCLUSION

- The soil is predominantly well graded with high to very high plasticity.
- Considerable portion of the land provide good grounds for buildings and roads construction as indicated by their grading, plasticity, and the topography of the land.
- Few portions are good for irrigation as indicated by their texture, grain size, and plasticity index.
- Most of the fine grain soils are silt; since they were found to appear below the A-line when plotted on the modified plasticity chart.
- The soil is typically organic (Histosols)
- Based on the Unified Soil Classification System, the soil is classified as sand, sandy gravel, gravel sand, silty sand with intermediate to very high Plasticity.
- From the Textural Triangle the soil is predominantly Sandy Loam, Loamy Sand and Sand.

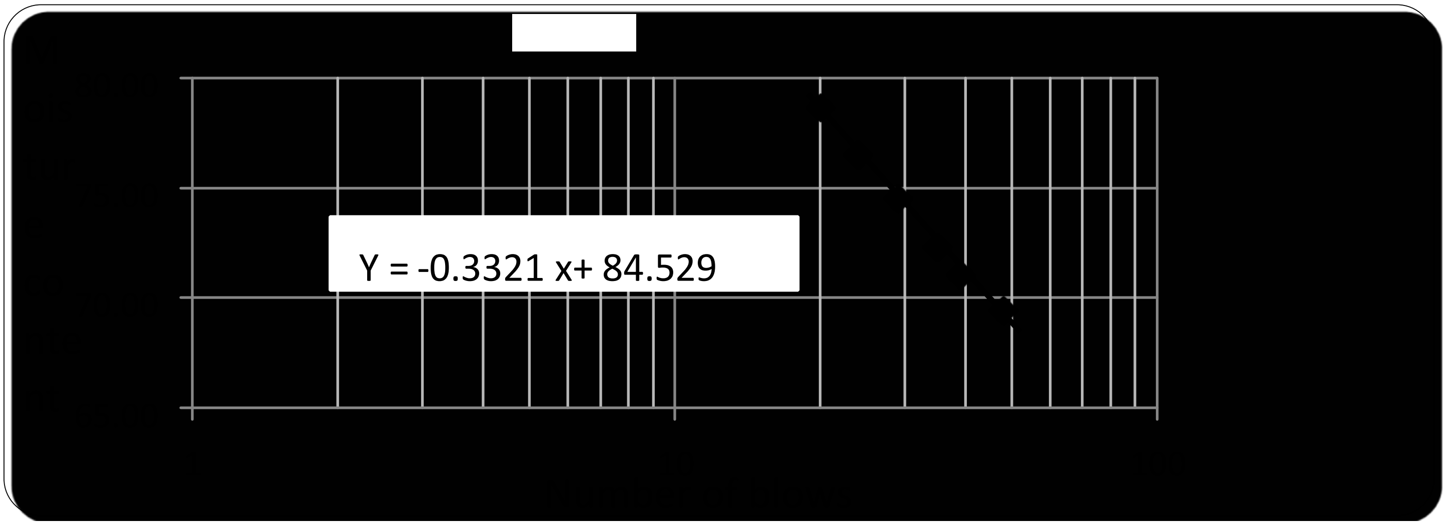

Figure 1: Graph for determination of Atterberg limits for the BL1S1 soil samples.

Table 3: Atterberg limits for the 36 soil samples.

Sample No	Liquid Limit	Plastic Limit	Plasticity Index	Sample No	Liquid Limit	Plastic Limit	Plasticity Index
BL1 S1 0.5 m	60.39	31.69	28.70	CL4 S7 0.5 m	51.99	28.13	23.86
BL1 S1 1.0 m	64.74	39.71	25.03	CL4 S7 1.0 m	78.80	33.45	45.35
CL S1 0.5	56.54	34.45	22.09	CL4 S8 0.5 m	54.55	31.20	23.35
CL S1 1.0 m	68.34	37.87	30.47	CL4 S8 1.0 m	81.16	35.67	45.49
CL1 S2 0.5	48.22	34.63	13.59	BL1 S6 0.5 m	57.82	31.61	26.21
CL1 S2 1.0 m	83.33	45.74	37.59	BL1 S6 1.0 m	76.22	41.32	34.90
BL2 S2 0.5 m	75.50	35.98	39.52	CL5 S9 0.5 m	67.36	32.63	34.73
BL2 S2 1.0 m	76.21	37.06	39.15	CL5 S9 1.0 m	91.63	43.15	48.48
CL1 S3 0.5 m	68.05	38.79	29.26	CL5 S10 0.5 m	69.19	35.31	33.88
CL1 S3 1.0 m	82.14	44.90	37.24	CL5 S10 1.0 m	91.70	46.58	45.12
BL3 S3 0.5 m	41.47	25.77	15.70	BL1 S7 0.5 m	37.17	21.69	15.48
BL3 S3 1.0 m	72.24	40.94	31.30	BL1 S7 1.0 m	53.82	26.15	27.67
BL1 S4 0.5 m	25.84	18.27	7.57	CL6 S11 0.5 m	60.02	33.55	26.47
BL1 S4 1.0 m	38.39	20.56	17.83	CL6 S11 1.0 m	80.24	38.73	41.51
CL3 S5 0.5 m	31.68	23.96	7.72	CL6 S12 0.5 m	76.75	40.66	36.09
CL3 S5 1.0 m	65.71	34.68	31.03	CL6 S12 1.0 m	74.59	41.91	32.68
BL1 S5 0.5 m	74.93	41.93	33.00	CL1 S13 0.5 m	15.69	14.83	0.86
BL1 S5 1.0 m	75.78	38.63	37.15	CL1 S13 1.0 m	34.20	21.64	12.56

Classification adopted is:
PI < 35 is low plasticity
35 ≤ PI ≤ 50 is intermediate plasticity
50 ≤ PI ≤ 70 is high plasticity 70
≤ PI ≤ 90 is very high plasticity >
90 is extremely high plasticity

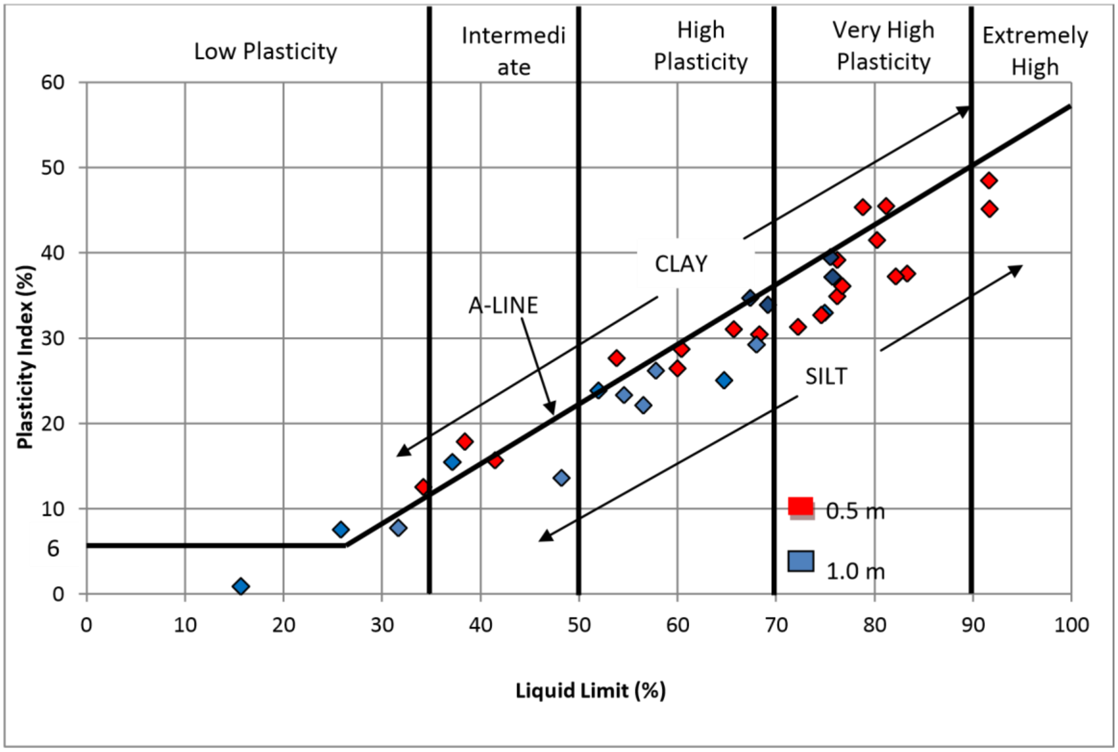

Figure 2: Modified plasticity chart with plots of the samples containing fine particles.

Table 4a: Classification of the soil at each sample location.

Sample No	Location	Percentage Grain Fractions Gravel	Sand	Silt	Clay	Sample Classification
CL1 S1	0.5 m	8.63	68.30	11.57	11.50	Well graded Sand
	1.0 m	41.38	37.41	14.71	6.50	Well graded Sandy gravel with silt
CL1 S2	0.5 m	39.40	43.34	13.56	3.70	Well graded Gravelly sand with silt
	1.0 m	24.87	40.54	15.09	19.50	Well graded Gravelly sand with clay
BL2 S2	0.5 m	41.88	33.25	16.56	8.30	Well graded Sandy gravel with silt
	1.0 m	11.51	55.62	22.77	10.10	Well graded Silty sand
CL1 S3	0.5 m	49.24	34.47	5.39	10.90	Well graded Sandy gravel
	1.0 m	18.24	49.94	22.02	9.80	Well graded Silty Sand
BL3 S3	0.5 m	49.28	44.87	2.92	2.93	Well graded Sandy gravel
	1.0 m	41.88	36.53	14.94	6.64	Well graded Sandy gravel with silt
CL1 S4	0.5 m	4.72	92.54	1.74	1.00	Uniformly graded Sand
	1.0 m	4.25	93.17	1.07	1.50	Uniformly graded Sand
BL1 S4	0.5 m	17.68	66.35	7.97	8.00	Well graded Sand
	1.0 m	17.48	62.98	5.64	13.90	Well graded Sand
CL3 S5	0.5 m	30.58	58.71	7.90	2.81	Well graded Gravelly sand
	1.0 m	22.81	54.61	22.58	0.00	Well graded Gravelly sand with silt
CL3 S6	0.5 m	5.49	93.32	0.00	1.20	Uniformly graded Sand
	1.0 m	11.06	88.25	0.09	0.60	Uniformly graded Sand
BL1 S5	0.5 m	63.27	25.76	2.97	8.00	Well graded Sandy gravel

Table 4b: Classification of the soil at each sample location.

	1.0 m	31.78	45.88	14.30	8.04	Well graded Sandy gravel with silt
CL4 S8	0.5 m	8.70	70.07	16.70	4.53	Well graded Sand with some silt
	1.0 m	6.67	49.29	39.44	4.60	Well graded Silty sand
BL1 S6	0.5 m	63.27	28.76	3.97	4.00	Well graded Sandy gravel
	1.0 m	12.10	65.20	8.30	14.41	Well graded Sand with clay
CL5 S9	0.5 m	35.71	40.02	19.17	5.10	Well graded Gravelly sand with silt
	1.0 m	11.19	65.18	15.03	8.60	Well graded Sand with silt
CL5 S10	0.5 m	52.38	40.80	3.94	2.88	Well graded Sandy gravel
	1.0 m	39.32	43.04	11.24	6.40	Well graded Gravelly sand
BL1 S7	0.5 m	5.17	87.09	3.90	3.84	Well graded Sand
	1.0 m	3.39	74.68	17.23	4.70	Well graded Sand with silt
CL6 S11	0.5 m	7.30	55.92	29.00	7.78	Well graded Silty sand
	1.0 m	12.82	74.32	4.30	8.56	Well graded Sand
CL6 S12	0.5 m	18.31	55.34	13.20	13.15	Well graded Sand with gravel
	1.0 m	13.29	59.18	9.20	18.33	Well graded Sand with clay
CL1 S13	0.5 m	49.24	28.97	14.99	6.80	Well graded Sandy gravel with silt
	1.0 m	13.50	74.71	7.30	4.50	Well graded Sand
CL4 S7	0.5 m	7.26	65.18	21.10	6.46	Well graded Silty sand
	1.0 m	63.98	31.94	1.47	2.60	Well graded Sandy gravel
BL1 S1	0.5 m	49.94	38.93	6.18	4.95	Well graded Sandy gravel
	1.0 m	33.34	48.99	10.60	7.07	Well graded Gravelly sand

Table 5a: Classification of the soil using the Textural Triangle.

Sample	**Percentage Grain Fractions**					
Sample No	**Location**	**Gravel**	**Sand**	**Silt**	**Clay**	**Classification**
CL1 S1	0.5 m	8.63	68.30	11.57	11.50	Sandy Loam
	1.0 m	41.38	37.41	14.71	6.50	Loamy Sand
CL1 S2	0.5 m	39.40	43.34	13.56	3.70	Loamy Sand
	1.0 m	24.87	40.54	15.09	19.50	Sandy Loam
BL2 S2	0.5 m	41.88	33.25	16.56	8.30	Sandy Loam
	1.0 m	11.51	55.62	22.77	10.10	Sandy Loam
CL1 S3	0.5 m	49.24	34.47	5.39	10.90	Loamy Sand
	1.0 m	18.24	49.94	22.02	9.80	Sandy Loam
BL3 S3	0.5 m	49.28	44.87	2.92	2.93	Sand
	1.0 m	41.88	36.53	14.94	6.64	Loamy Sand
CL1 S4	0.5 m	4.72	92.54	1.74	1.00	Sand
	1.0 m	4.25	93.17	1.07	1.50	Sand
BL1 S4	0.5 m	17.68	66.35	7.97	8.00	Loamy Sand
	1.0 m	17.48	62.98	5.64	13.90	Sandy Loam
CL3 S5	0.5 m	30.58	58.71	7.90	2.81	Sand
	1.0 m	22.81	54.61	22.58	0.00	Loamy Sand
CL3 S6	0.5 m	5.49	93.32	0.00	1.20	Sand
	1.0 m	11.06	88.25	0.09	0.60	Sand
BL1 S5	0.5 m	63.27	25.76	2.97	8.00	Sand
	1.0 m	31.78	45.88	14.30	8.04	Loamy Sand
CL4 S8	0.5 m	8.70	70.07	16.70	4.53	Loamy Sand

Table 5b: Classification of the soil using the Textural Triangle.

	1.0 m	6.67	49.29	39.44	4.60	Sandy Loam
BL1 S6	0.5 m	63.27	28.76	3.97	4.00	Sand
	1.0 m	12.10	65.20	8.30	14.41	Sandy Loam
CL5 S9	0.5 m	35.71	40.02	19.17	5.10	Sandy Loam
	1.0 m	11.19	65.18	15.03	8.60	Sandy Loam
CL5 S10	0.5 m	52.38	40.80	3.94	2.88	Sand
	1.0 m	39.32	43.04	11.24	6.40	Loamy Sand
BL1 S7	0.5 m	5.17	87.09	3.90	3.84	Sand
	1.0 m	3.39	74.68	17.23	4.70	Sandy Loam
CL6 S11	0.5 m	7.30	55.92	29.00	7.78	Sandy Loam
	1.0 m	12.82	74.32	4.30	8.56	Sand
CL6 S12	0.5 m	18.31	55.34	13.20	13.15	Sandy Loam
	1.0 m	13.29	59.18	9.20	18.33	Sandy Loam
CL1 S13	0.5 m	49.24	28.97	14.99	6.80	Loamy Sand
	1.0 m	13.50	74.71	7.30	4.50	Sand
CL4 S7	0.5 m	7.26	65.18	21.10	6.46	Sandy Loam
	1.0 m	63.98	31.94	1.47	2.60	Sand
BL1 S1	0.5 m	49.94	38.93	6.18	4.95	sand
	1.0 m	33.34	48.99	10.60	7.07	Loamy sand

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