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RESEARCH ARTICLE

Characterization of Residual Soil of Changsari, Kamrup District of Assam, North East India

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The traits of residual soils are dependent upon the environmental factors of climate, parent materials, topography and drainage, and time. The structures and designs of buildings are greatly affected by the properties of soils; such as plasticity, compressibility, or strength. A proper foundation soil is needed for the stability of engineering structures like dams, buildings, bridges, tunnels, towers, etc. one that is built into or on top of the soil. Changsari is situated on the north bank of the Brahmaputra River, Kamrup district of Assam. Based on the geotechnical investigations, the region comprises four different soil horizons; i.e. Horizon A, Upper Horizon B, Lower Horizon B and Horizon C, classified as Clay (or organic soil) with low plasticity, Silt with high plasticity, Silt with low plasticity, and Clay with low plasticity respectively. The cohesive strength (C) decreases with depth, and the grain sizes vary in each horizon. The results of the geotechnical investigations show that the geotechnical characteristics of the residual soils discovered in the three separate research areas follow a consistent pattern.

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Introduction

Residual soils develop and remain in the area where they are formed. They are directly generated by the physical and chemical weathering[1] of the rock beneath them, and as a result, the environmental elements of climate, parent material, topography and drainage, and time all affect how they look and behave. Regolith is a geological name for the complete in-situ unconsolidated surface coating that the soil makes up. The lower part of a regolith, referred to as saprolite, that has undergone chemical weathering, retained its natural texture and eventually graded into the bedrock and becomes cohesive while preserving its natural texture, and is only referred to as soil in pedological terms if it has a thickness of 0.3 to 2.0 meters or more.[2] Buildings, dams, bridges, tunnels, highways, towers, and other civil engineering projects are built either below or on top of the soil. A proper foundation is needed for their stability. The qualities of soil must be evaluated to determine whether it is suitable for usage as a foundation or as a building material.[3] Lack of knowledge of the characteristics of the soil may result in construction errors. Instead of relying on a visual inspection or a soil's apparent similarity to other soils, it is preferable to evaluate a soil's suitability for a certain usage using its geotechnical properties. The type of soil will determine the loading capacity.[4] An engineer can better grasp clay's consistency or plasticity by considering the liquid limit and plasticity index. Although shearing strength changes for all clays at plastic limits, it is constant at liquid limits.[5] According to Karsten[6] among the geotechnical soil qualities, the shear strength of soils is particularly important because it is one of the crucial metrics for analyzing and resolving stability issues, calculating earth pressure, the bearing capacity of footings and foundations, slope stability or stability of embankments and earth dams[7].

There are residual soils all over the world,

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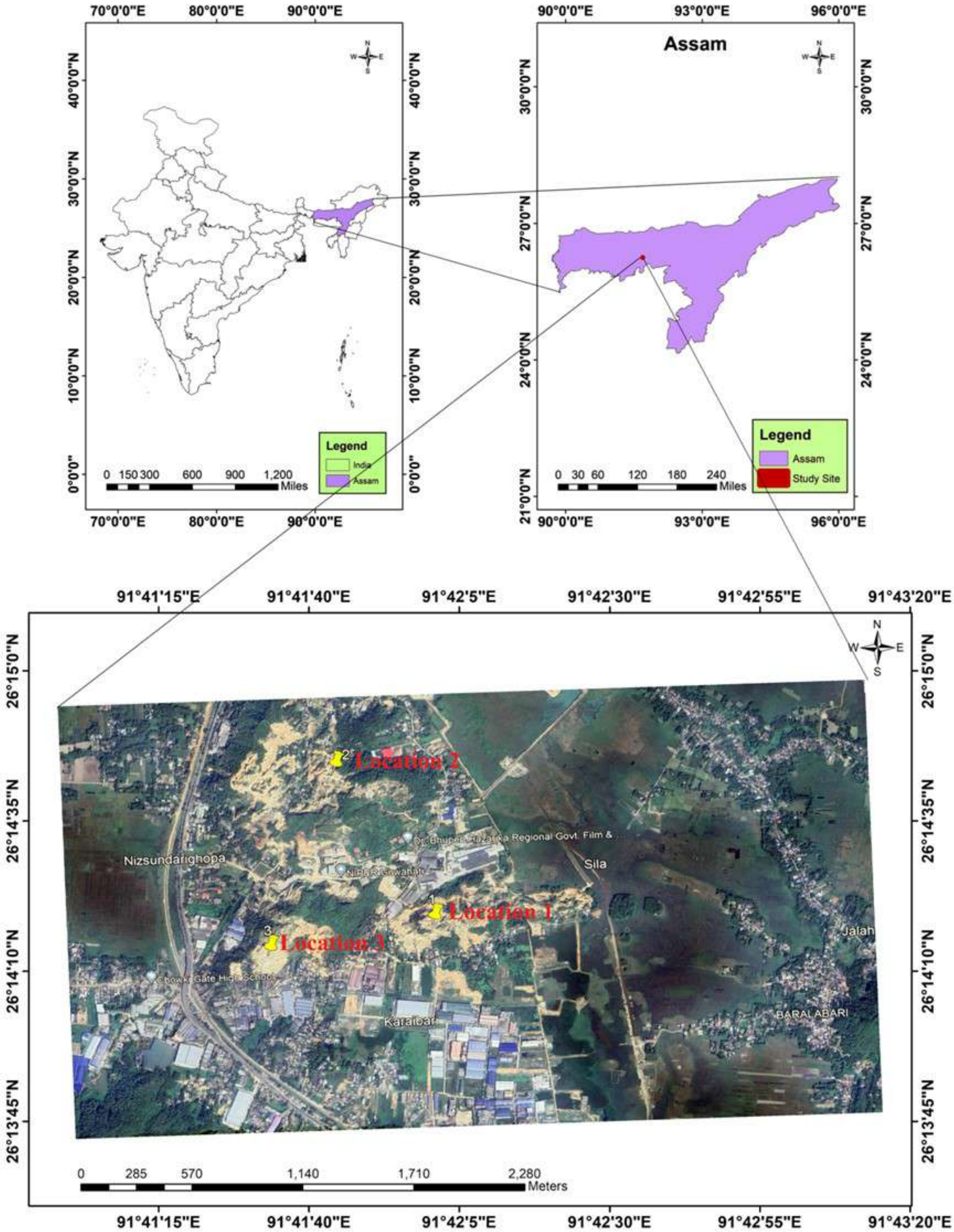

Figure 1. Location map of the study area

and they are widely employed in foundation construction and as building materials. Up until un-weathered rock is reached, residual soil layers in tropical regions are frequently thick and may extend for several hundred meters. Therefore, these factors should be known before the engineering work is started because this type of soil determines the key soil and foundation engineering conditions.[8] Typically, residual soils are found above the groundwater table.[9] As a result, the soils are often dry and have low pore-water pressure. The water content and negative pore water pressure of unsaturated soils[10] are, especially in areas near groundwater.[9] In reaction to climate changes, the soil's hydraulic characteristics, shear strength, and volume change.[9] It is noteworthy that relatively few textbooks discuss residual soils and their geotechnical characteristics; hence, it is crucial to comprehend these characteristics because residual soils serve as the fundamental foundations for the construction of engineering buildings.

The geotechnical characteristics of residual soil are still the subject of very few studies. This study will give us more in-depth to a few geotechnical properties of residual soils.[11] The objectives of the study include the determination of the geotechnical properties of residual soil[11] and understanding the variations of these properties in the different soil horizons by correlating the geotechnical properties in the different locations.

Materials and Methods

Geotechnical studies of the residual soils were undertaken under two broad heads, i.e. filed investigation and laboratory investigation. The basic requirements to carry out field studies are GPS, scale, measuring tape, peak hammer, haversack, pen, notebook, marker, plastic bag, and shear box. The soils were observed visually and depending on their color and texture, and were assigned into different horizons. The disturbed soil samples were collected from the field,[12] for laboratory investigation. Based on IS 2720 (Part 5): 1985,[13] the plasticity index of the soil was determined, where it is calculated by subtracting the plastic limit of the soil from its liquid limit of the soil. The specific gravity of the soils was determined (IS 2720 (Part 4)-1985) for each sample. It is used in the phase relationship of solids, water, and air in each volume of soils (IS 2720 (Part 4)-1985). Grain size analysis is done to identify the sedimentary settings of unconsolidated sediments.[14] Through the quantitative study of the percentage of various particle sizes,[15] the physical characteristics of clastic sedimentary and the nature of sediment rocks can be obtained.[16] A direct shear test is employed to obtain the shear strength of the soil.[17] The apparatus consists of a shear box and its assembly consists of a loading device, weight plate, proving rings, micrometer dial gauge, stopwatch, and digital balance. The proving ring needs to be of the right capacity and inclined with a dial gauge that is accurate to 0.0002. The dial gauge on the micrometer should be precise to 0.01 mm. The dial gauge needs to be able to quantify both horizontal distribution and the specimen's compression or expansion.

Results

Identification and Classification of Soil Profile

There were four separate horizons, each of which can be differentiate by its color, and were

Table 1: Sampling location

Sl. No.	Location	Coordinates
1.	1	26°14′17.79″N, 91°42′0.45″E
2.	2	26°14′43.21″ N, 91°41′44.01″E
3.	3	26°14′12.56″ N, 91°41′33.11″E

Table 2: Thickness of different locations

Sl. No.	Location	Soil Horizons	Average Thickness (In m)
1.	1	A	0.20
		B (Upper)	0.81
		B (Lower	1.80
		C	4.19
2.	2	A	0.30
		B (Upper)	0.90
		B (Lower	2.65
		C	1.35
3.	3	A	0.20
		B (Upper)	0.85
		B (Lower	2.00
		C	4.00

Table 3: Plasticity Index (Ip) for each horizon in different locations

Loc	Horizon	Liquid Limit (W_L)	Plastic Limit (W_P)	Plasticity Index (I_p) ($W_L - W_P$)
1.	A	42.29	25.87	16.42
	Upper B	58.83	40.24	18.59
	Lower B	49.24	34.77	14.47
	C	16.05	-	5.96
2.	A	39.95	23.66	16.29
	Upper B	63.30	44.88	18.42
	Lower B	57.37	42.41	14.92
	C	12.85	-	3.59
3.	A	31.96	20.25	11.71
	Upper B	54.22	28.87	25.35
	Lower B	41.96	24.47	17.49
	C	16.55	-	6.33

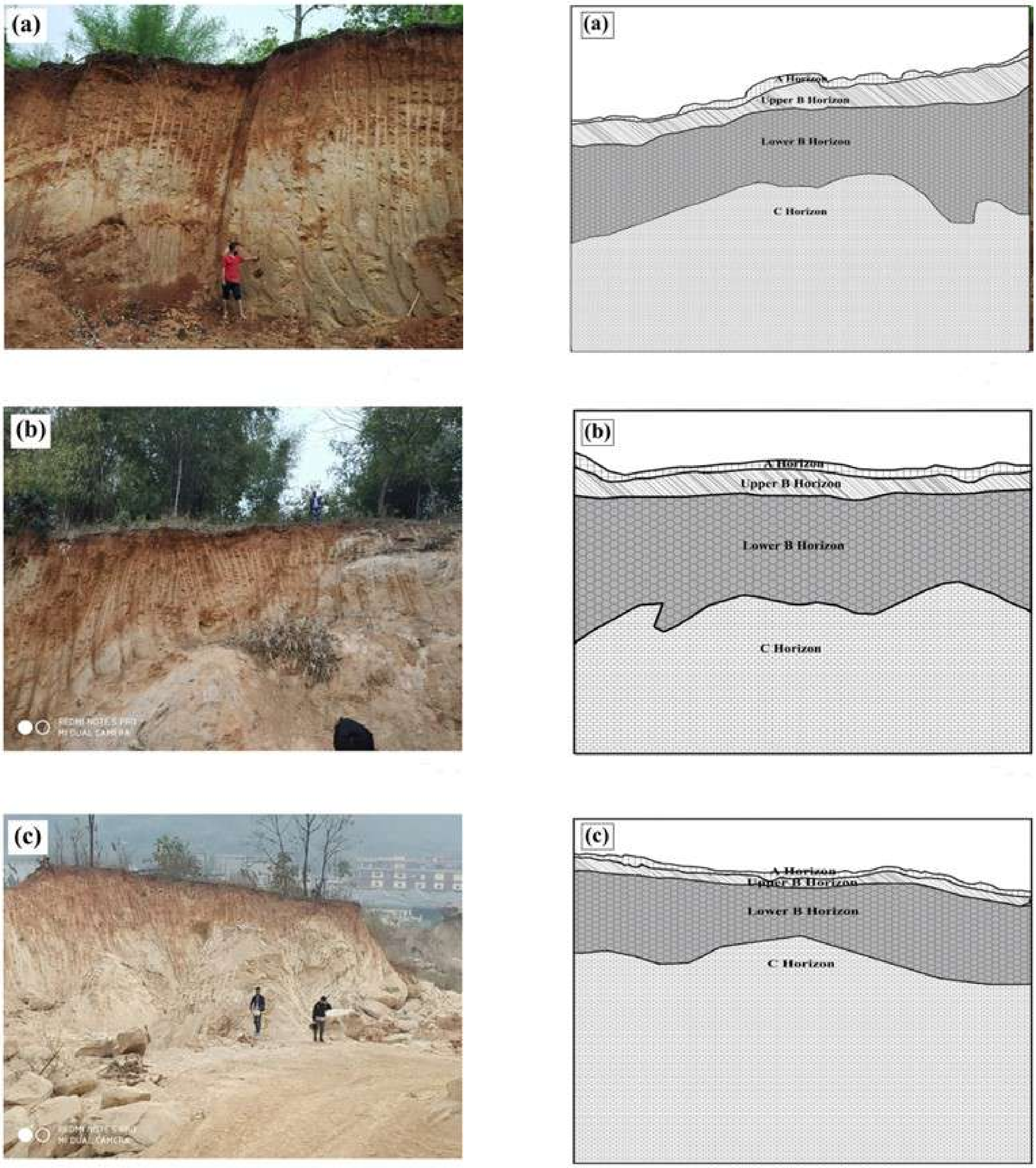

Figure 2: Soil Profile of three locations; (a) Location 1 (b) Location 2 (c) Location 3

identified as Horizon A, B (Upper and Lower), and C. The coordinates of each location are given Table 1.

A thin layer of black topsoil made up Horizon A. The upper B horizon, which is a reddish-brown color, was beneath Horizon A. Lower B horizon, which resembles the Upper B horizon in appearance but has a paler color, undercuts the latter. The bottom layer (Horizon C), which is exposed, is made up of weathered bedrock material that is friable and still retains part of the rock's original texture. It is located below the zone of considerable biological activity. All three of the sites where samples were taken revealed this kind of soil profile. The bedrock is Quartzo-feldspathic Gneiss, which is the basement rock of the Shillong Plateau.

Identification and Classification of Soil Profile

The Plasticity Index is calculated by subtracting the plastic limit (wp) from its liquid limit(wL). The liquid limit (WL), plastic limit (wP) and plasticity index (IP) (12) are summarized in Table 3.

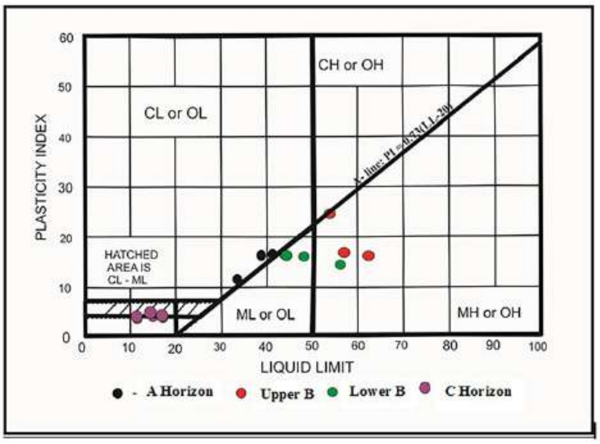

Figure 3 Plasticity chart of each horizons from three sampling sites

From the plasticity value obtained, the plasticity chart is given in Figure 3

From the plasticity chart, 'A Horizon' can be classified as CL (Clay with Low plasticity) or OL (Organic soil with low plasticity). Upper B Horizon is MH (Silt with high plasticity) or OH (Organic soil with high plasticity). Lower B Horizon can be ML (Silt with low plasticity) or OL (Organic soil with low plasticity). C Horizon is classed as CL (Clay with Low plasticity) or ML (Silt with low plasticity).

Determination of Specific Gravity

From the laboratory analysis, the specific gravity of the soil lies within the range of 2.03 to 2.42. The summarized values for each soil horizon are given in Table 4.

Table 4: Specific Gravity of each horizon form the three locations

Loc	A Horizon	Upper B Horizon	Lower B Horizon	C Horizon
1	2.19	2.10	2.20	2.31
2	2.37	2.18	2.03	2.39
3	2.33	2.19	2.24	2.42

Determination of Grain Size

For different locations, grain size analyses were performed for each soil horizons and summarized in table 6. From the analyses, the different horizons for different locations are well-graded, and sand size grain is the most dominant

Direct Shear Test

It is performed from three locations, where

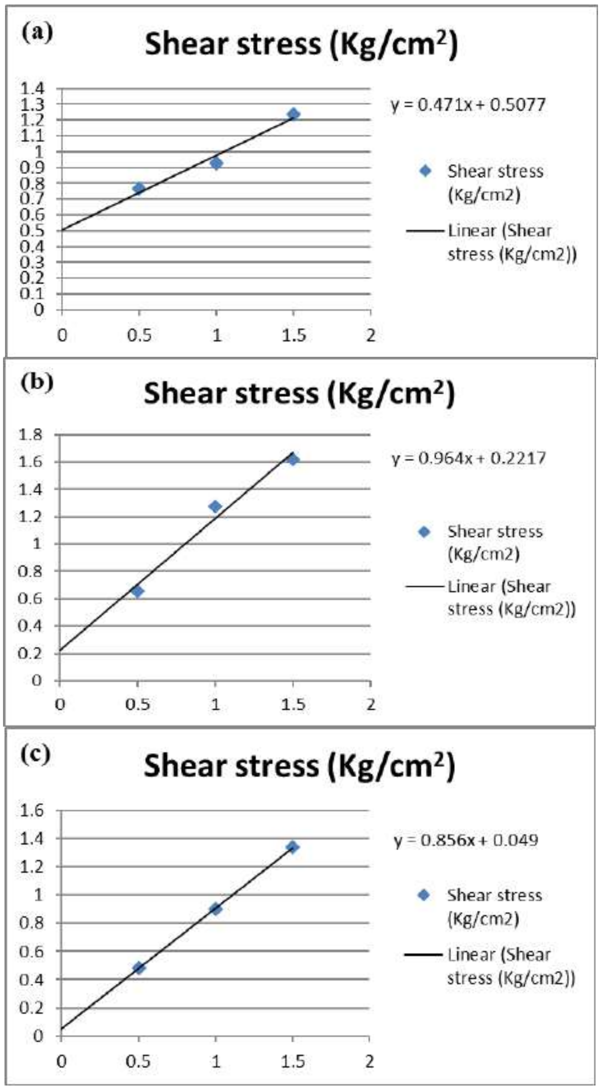

Figure 4: Normal stress values for different shear in location 1; (a) Upper B Horizon, (b) Lower B Horizon, (c) C Horizon

Table 5: Grain Size Distribution Analysis of three locations

Location	Soil Horizon	D_{60} (in mm)	D_{30} (in mm)	D_{10} (in mm)	C_u	C_c	Soil Content	Sorting
1.	A	0.7	0.12	0.065	$\frac{D60}{D10}$ 10.77	$\frac{D^2 30}{D10\ X\ D60}$ 0.316	Sand-55% Silt & Clay-23.46%	Well-Graded
	B (Upper)	0.55	0.075	0.04	$\frac{D60}{D10}$ 13.75	$\frac{D^2 30}{D10\ X\ D60}$ 0.255	Sand-57% Silt & Clay-32%	Well-Graded
	B (Lower)	0.42	0.14	0.07	$\frac{D60}{D10}$ 6	$\frac{D^2 30}{D10\ X\ D60}$ 0.667	Sand-70% Silt & Clay-16%	Well-Graded
	C	0.72	0.21	0.073	$\frac{D60}{D10}$ 9.86	$\frac{D^2 30}{D10\ X\ D60}$ 0.832	Sand 81% Silt & Clay-11%	Well-Graded
2.	A	2	0.52	0.055	$\frac{D60}{D10}$ 36.364	$\frac{D^2 30}{D10\ X\ D60}$ 2.46	Sand-41% Silt & Clay-18%	Well-Graded
	B (Upper)	0.7	0.12	0.056	$\frac{D60}{D10}$ 12.5	$\frac{D^2 30}{D10\ X\ D60}$ 0.367	Sand-58% Silt & Clay-24%	Well-Graded
	B (Lower)	0.9	0.28	0.06	$\frac{D60}{D10}$ 15	$\frac{D^2 30}{D10\ X\ D60}$ 1.452	Sand-72% Silt & Clay-14%	Well-Graded
	C	1.2	0.46	0.09	$\frac{D60}{D10}$ 13.33	$\frac{D^2 30}{D10\ X\ D60}$ 1.96	Sand 70% Silt & Clay-9%	Well-Graded
3.	A	1.7	0.32	0.072	$\frac{D60}{D10}$ 23.61	$\frac{D^2 30}{D10\ X\ D60}$ 0.837	Sand-50% Silt & Clay-13%	Well-Graded
	B (Upper)	0.6	0.1	0.045	$\frac{D60}{D10}$ 13.33	$\frac{D^2 30}{D10\ X\ D60}$ 0.37	Sand-62% Silt & Clay-25%	Well-Graded
	B (Lower)	0.73	0.18	0.035	$\frac{D60}{D10}$ 20.86	$\frac{D^2 30}{D10\ X\ D60}$ 1.27	Sand-73% Silt & Clay-17%	Well-Graded
	C	1.3	0.48	0.07	$\frac{D60}{D10}$ 18.57	$\frac{D^2 30}{D10\ X\ D60}$ 2.53	Sand 48% Silt & Clay-10%	Well-Graded

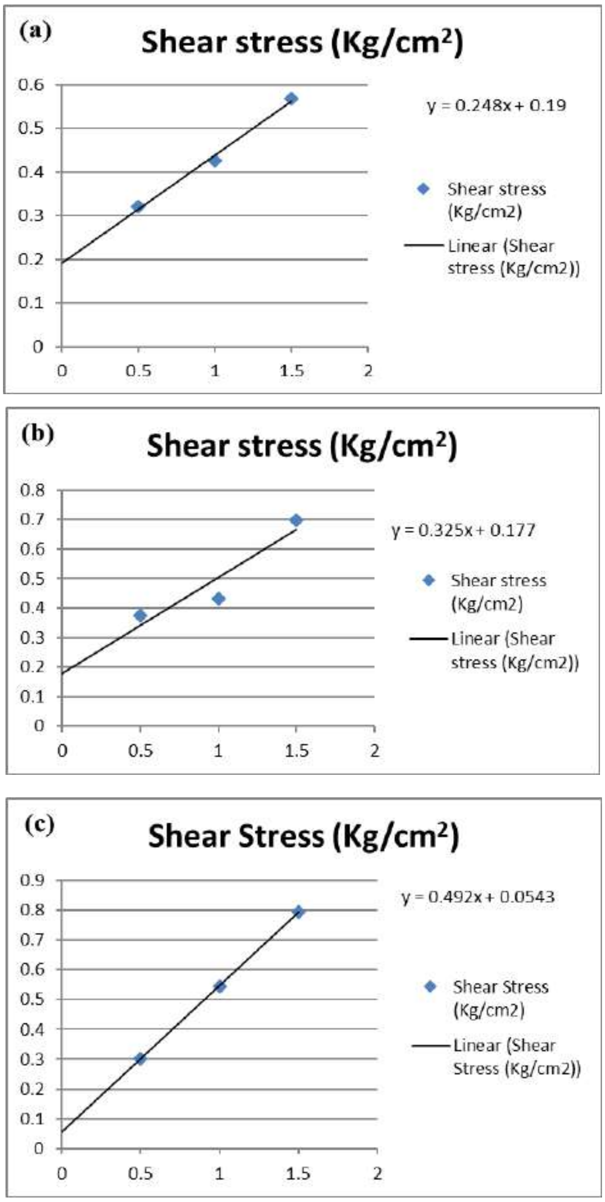

Figure 5 Normal stress values for different shear in location 2; (a) Upper B Horizon, (b) Lower B Horizon, (c) C Horizon

Upper B Horizon from location 2 has the lowest value, i.e. 12.79° and its cohesion is 0.38 kg/cm2. Lower B Horizon from location 1 has the highest angle of friction, i.e. 43.83° and cohesion value of 0.21 kg/cm2.

C Horizon is composed mostly of sand-sized grains. When the shear box is used for sampling undisturbed soil in the field, due to the low cohesion of the soil, samples cannot be taken for laboratory tests. Hence, a direct shear test is not performed for C Horizon in location 3.

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Discussion

The main objective of the study is to investigate the geotechnical characteristics of the residual soils found in the hills of Changsari, Kamrup (Rural) District, Assam. Four different soil horizons make up the region's soil profile, and each of these layers has a unique set of features.

A Horizon is classified as CL or OL, i.e. Clay or Organic soil with low plasticity. The specific gravity is found to be 2.19 - 2.37. It is well-graded with around 40% sand and 20% silt or clay. The Upper B Horizon is classified as MH or OH, i.e. Silt or Organic soil with high plasticity. The specific gravity ranges from 2.10-2.19. It is well-graded with 60% sand and 25% silt or clay. The Cohesive Strength (C) ranges from 0.19 – 0.51 kg/cm2, and the angle of internal friction (Φ) ranges from 12.79° - 25.22°. Lower B Horizon is classified as ML or OL, i.e. Silt or Organic soil with low plasticity. The specific gravity is found to be 2.03 - 2.34. It is well-graded with 70% sand and 16% silt or clay. The cohesive strength (C) ranges from 0.14 - 0.21 kg/cm2 and the angle of internal friction (Φ) ranges from 18° - 43.83°. C Horizon is classified as CL or ML, i.e. Clay or Silt with low plasticity. The specific gravity ranges from 2.31-2.42. It is well-graded with 80% sand and 10% silt or clay. The cohesive strength (C) is 0.06 kg/cm2 and the angle of internal friction (Φ) is 26.2° - 40.56°.

It is found that the fine grain content and the plasticity increase from A Horizon to Upper B Horizon and then decrease down the soil profile. The cohesive strength (C) also decreases with

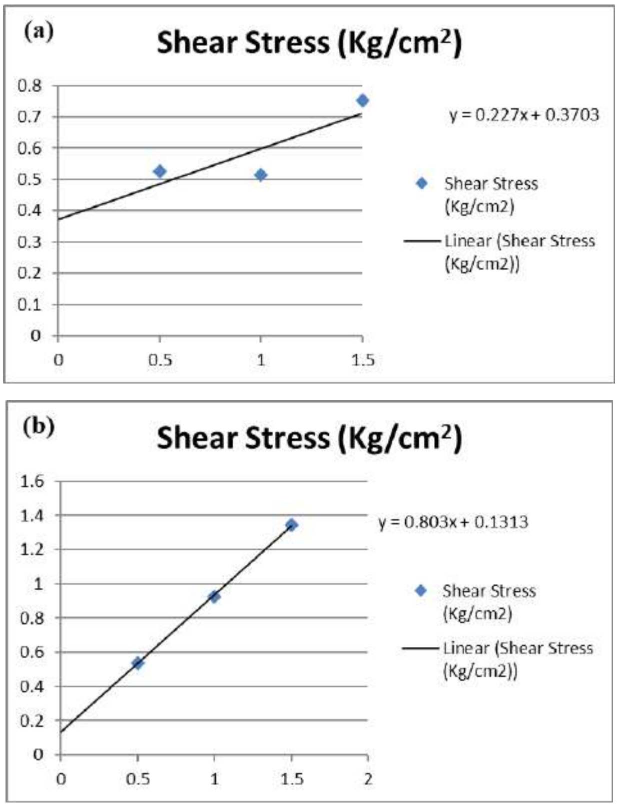

Figure 6: Normal stress values for different shear in location 3; (a) Upper B Horizon, (b) Lower B Horizon

Table 6: Direct Shear Test for location 1

Location	Horizon	Normal Stress (kg/ cm²)	Shear Stress (kg/ cm²)	Cohesion (kg/cm²)	Angle of Friction
1.	B (Upper)	0.5	0.768	0.51	25.22°
		1	0.929		
		1.5	1.239		
	B (Lower)	0.5	0.658	0.21	43.83°
		1	1.277		
		1.5	1.622		
	C	0.5	0.480	0.06	40.56°-
		1	0.899		
		1.5	1.336		
2.	B (Upper)	0.5	0.320	0.19	13.93°
		1	0.426		
		1.5	0.568		
	B (Lower)	0.5	0.374	0.18	18°
		1	0.433		
		1.5	0.699		
	C	0.5	0.302	0.06	26.20°
		1	0.543		
		1.5	0.794		
3.	B (Upper)	0.5	0.526	0.38	12.79°
		1	0.513		
		1.5	0.753		
	B (Lower)	0.5	0.538	0.14	38.76°
		1	0.924		
		1.5	1.340		
	C	0.5	0.302	0.06	26.20°
		1	0.543		
		1.5	0.794		

depth. These variations can be observed in the adjacent locations although the distance between locations 1 and 2, 2 and 3, 1 and 3 are 786.83 m, 1341.81 m and 890.28 m respectively. The geotechnical investigations reveal that there is a uniform pattern in the geotechnical properties of the residual soils found in the three different locations of the study area. .

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