Original Research Article

SITE INVESTIGATION AND SHEAR STRENGTH PROPERTIES OF SOIL

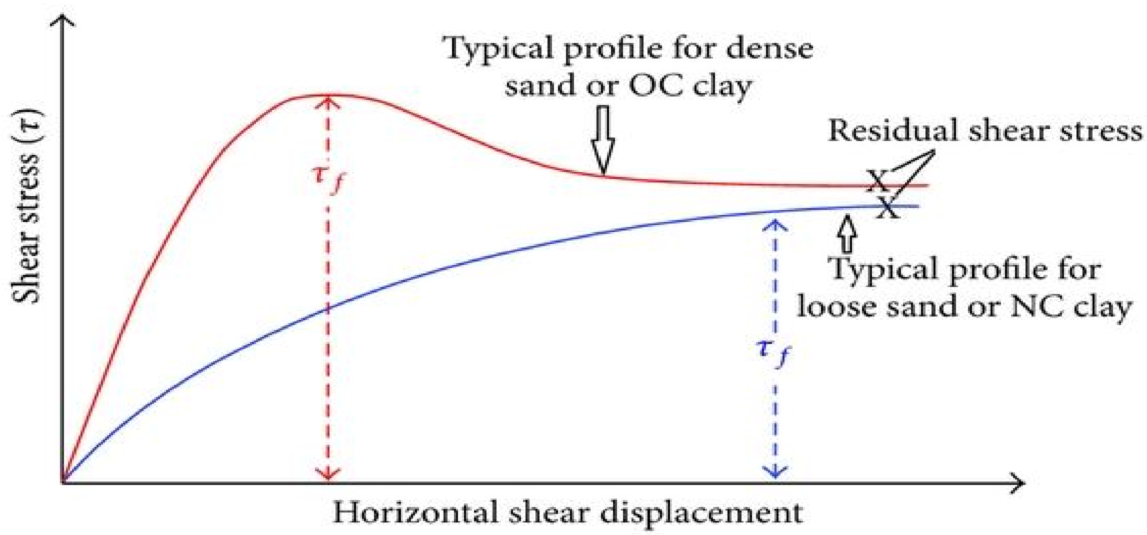
Abstract: This study examined the soil's shear strength qualities at various depths with natural soil moisture content. At various depths below the surface of the ground, ranging from 400mm to 24.75m for point 1 and 400mm to 11.25m for point 2, the soil sample was taken using the drilling method. Wet sieve analysis was used to determine the distribution of the grains, and each soil sample's natural moisture content was calculated. Other fundamental tests included the Atterberg limit test, specific gravity, and sieve analysis. The data revealed that silt and clay make up the soils at points 1 and 2, with the soil at point 2 being more plastic than the soil at point 1. In Addition, it was discovered from the results that soil shears more quickly at increasing in the depth of from ground surface and that the cohesiveness index and angle of internal friction are negatively associated.

Keywords: Soil, Moisture content, Shear strength, Liquid limit, Plastic limit, Plasticity index

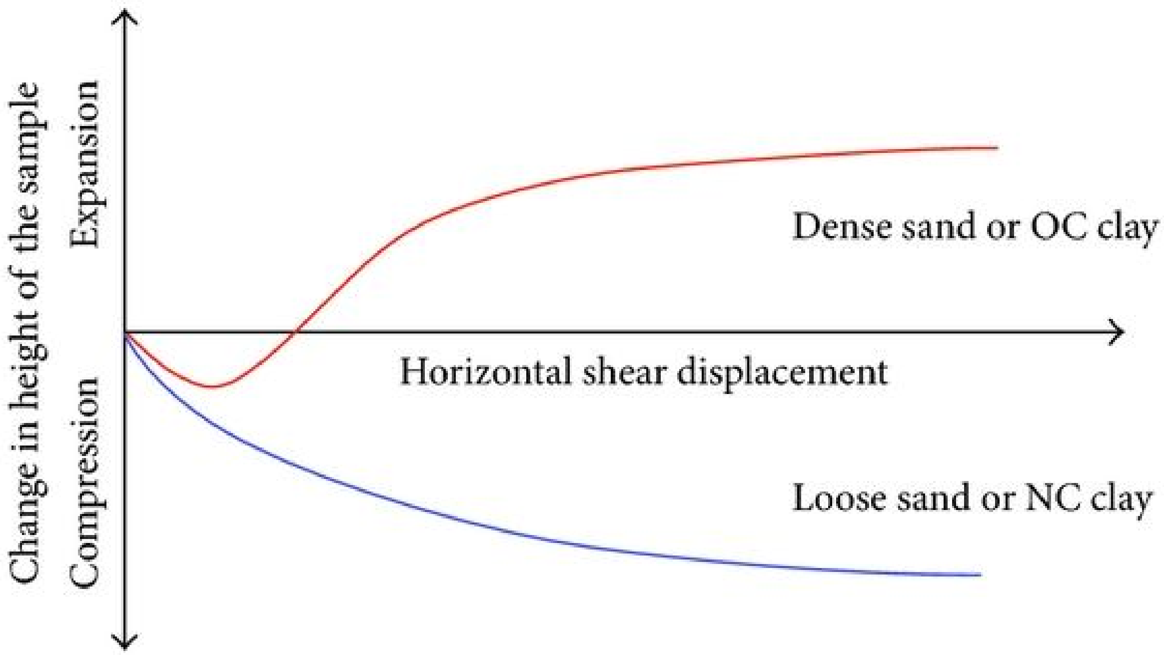
1.0 INTRODUCTION

In nature, soils are more frequently found as mixtures with different ratios of various constituents rather than as individual particles of gravel, sand, silt, clay, or organic matter. Grouping soils based on a set of clear criteria would enable the engineer to assess the performance of a particular soil. (Onyelowe, 2013). Soils are categorized into groups and subgroups based on shared engineering qualities. The following classification schemes are the most often employed in soil classifications: the American Association of State and Transportation Officials (AASHTO) and the Unified Soil Classification System (USCS) [1].

Shearing deformation is one of the most detrimental processes for land and environment degradation, and shear strength is essential for slope stability and soil erosion assessment.[2]. The direct shear test works by applying a normal load to the sample and driving it to fail along a predetermined plane. This allows for the direct measurement of the shear force capacity under particular circumstances as well as the calculation of the internal friction and cohesion angle. The shear resistance created within the sliding plane along a known section area of the sample is what is referred to as the shear stress in the shear box test. [3]. The general trends of direct shear tests on sand and clays are shown in graph 1 and 2.



Graph 1: Typical shear stress versus horizontal shear displacement of soils (OC stands for overconsolidated and NC stands for normally consolidated).



Graph 2: Typical vertical displacement versus horizontal shear displacement of soils (OC stands for over consolidated and NC stands for normally consolidated).

Particle size distribution is one of the numerous intrinsic features of soil that affect shear strength, which is dictated by the bonding forces of the soil matrix.[4], bulk density [5], degree of aggregation [6], and organic matter [7]. The most significant causes of bonding force variation, which affects shear strength, are changes in hydrologic conditions, rather than these intrinsic features of soil materials.[8]. One of the hottest subjects in soil mechanics and environmental engineering, the impact of water content on shear strength, has been thoroughly investigated. However, a variety of locations, soils, and experiment types have found varying trends regarding the correlation between shear strength qualities and water content. [9, 10, 11] e.g.. To fill the gap in the literature and close the discrepancy in the results from earlier research, this study is focused on classifying the soils collected from the study region and assessing the influence of variable moisture content on soil shear strength.

2.0 MATERIALS AND METHODS

2.1 Materials

2.1.1 Soil sample

The soil sample used in this study was obtained at 20, Louis Solomon Close, off Ahmadu Bello way, Victoria Island, Lagos." situated at latitude 6^{0}25'43.5'' N, longitude 3^{0}24'28.8''E for point 1 and latitude 6^{0}25'43.4'' N, longitude 03^{0}24'28.6 E'' for point 2.

2.2 Methods

2.2.1 Method of Obtaining Sample

As indicated in Table 1.0, soil samples were taken using the rotary drilling method at various depths below the surface, ranging from 400 mm to 24.75 m for point 1 and 400 mm to 11.25 m for point 2.

Table 1.0: Soil Moisture Content at Varying Depth

	Average moisture content	
Soil samples at various depth	**Point 1**	**Point 2**
400mm	7.55	7.53
2.25m	9.5	10.6
4.5m	-	12.8
6.75m	20.4	20.3
9.0m	-	23.11
11.25m	-	25.93
24.75m	73.5	-

Wet sieve analysis was used to determine the distribution of the soil grains, and each soil sample's natural moisture content was then calculated [12].

2.2.2 Particle Size Distribution

The soil particle size distribution was done in accordance with [13] standard specifications and the soils were classified using the AASHTO Classification System.

2.2.3 Plastic Limit, Plastic Index, and Plasticity Index

The soil plasticity index was calculated by subtracting the numerical difference between the soil's liquid limit (LL) and plastic limit (PL), as shown in equation 1.0, from the soil's liquid limit and plastic limit, which were established following [14].

PI = LL – PL (1.0)

2.2.4 Soil Shear Strength

The direct shear test method was used to determine the soil shear strength by [15].

3.0 RESULTS

3.1 Particle Size Distribution

The particle size distribution of the soil samples is presented in Figure 1.0 and was classified accordingly.

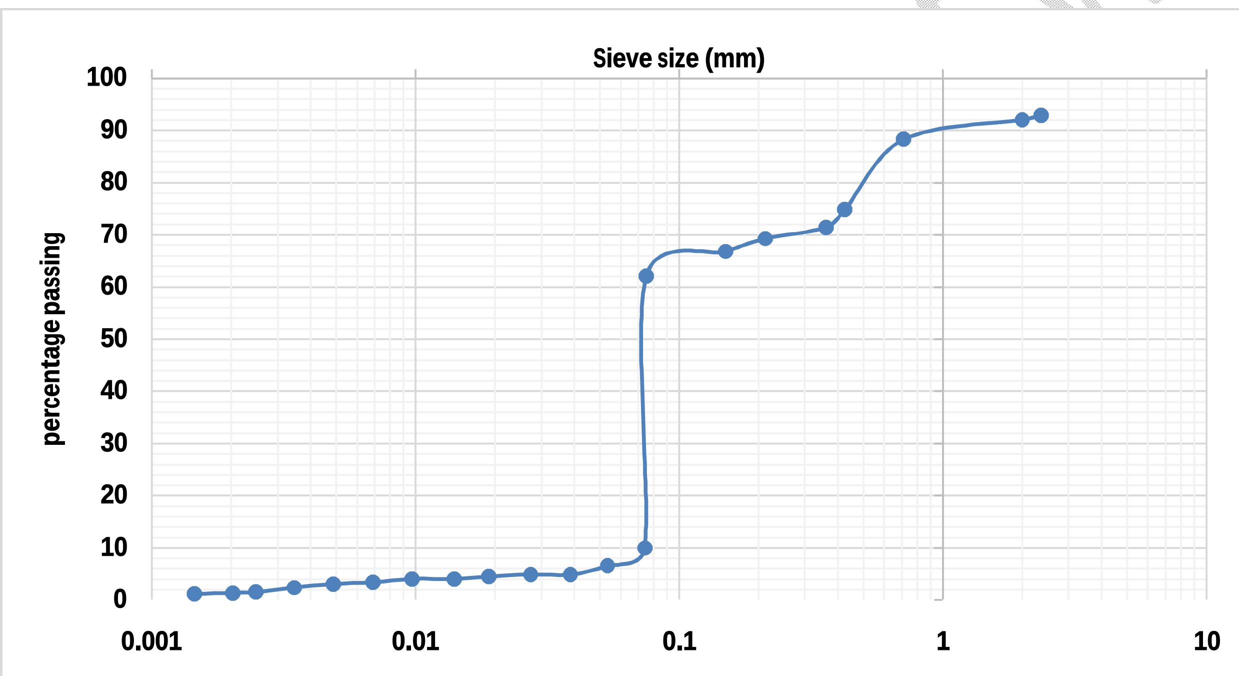


Figure 1.0: Percentage Passing Against Sieve Size

From the curves in Figure 1.0, the coefficient of uniformity (C_u) and coefficient of curvature (C_C) of the soil sample is given as;

C_c (coefficient of curvature) $= D_{30}^2 / (D_{60} * D_{10})$

C_u (coefficient of uniformity) $= D_{60} / D_{10}$

The soil sample's computed Cu and Cc were determined at different depths, and the results are shown in Tables 2.0 and 3.0 along with categorization and rating.

Table 2.0: Soil Classification and Rating at Various Depths for Point 1

Soil depth (m)	% Passing sieve #200	C_c	C_u	AASHTO classification	Type of material	Subgrade rate
0.4	62.10	0.87	1.00	A-6(7.2)	Clay soil	poor
2.25	57.85	8.40	15.60	A-4(3.5)	Silty soil	Fair
6.75	54.6	1.15	115.38	A-4(3.2)	Silty soil	Fair
24.75	40.65	1.13	200.00	A-7-6(3.28)	Clay soil	poor

The result from Table 2.0 shows that the C_c and C_u of the soil range from 0.87 – 8.40 and 1.00 – 200 respectively for point 1. Also, at 0.4m depth and 24.75m depth, the soil type was clay in a poor state, while at 2.25m depth to 57.85m depth, the soil type was silty in a fair state.

Table 3.0: Soil Classification and Rating at Various Depths for Point 2

Soil depth (m)	% Passing sieve #200	C_c	C_u	AASHTO classification	Type of material	Subgrade rate
0.4	61.5	1.01	1.88	A-6(8.48)	Clay soil	Poor
2.25	57.95	6.40	8.42	A-4(2.4)	Silty soil	Fair
4.5	41.55	0.68	32	A-4(0.9)	Silty soil	Fair
6.75	54.70	0.32	28	A-7-6(7.9)	Clayey soil	Poor
9.0	43.4	0.67	45	A-6(1.8)	Clayey soil	Poor
11.25	37.1	0.84	16.5	A-7-6(3.02)	Clayey soil	Poor

Table 3.0's outcome also reveals that the soil's Cc and Cu range for point 1 from 1.01 to 6.40 and 1.88 to 16.5 respectively. Additionally, the soil type was clayey in poor condition at depths of 0.4 m, 6.75 m, 9.0 m, and 11.25 m, and silty in fair condition at depths of 2.25 m to 4.5 m.

3.2 Specific Gravity

As seen in Figures 2 and 3, neither position's soil-specific gravity result showed a trend, instead falling within a range of 2.47 to 2.90.

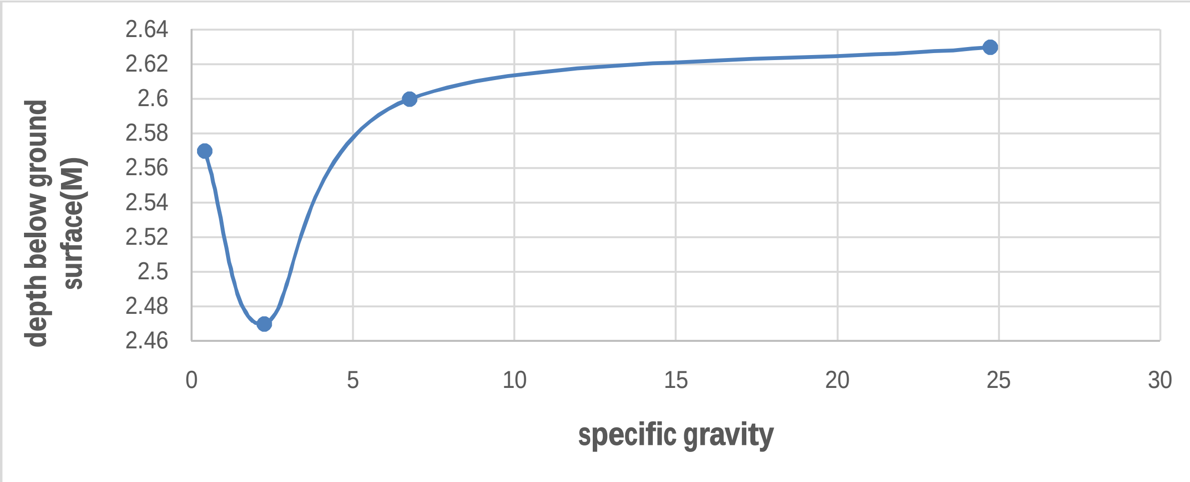


Figure 2.0: variation of specific gravity with depth for Point 1

According to Figure 2.0's findings, the specific gravity decreased between 0.4 and 2.25 meters while increasing steadily between 2.25 and 24.75 meters. This suggests that particular gravity may rise along with increasing depth.

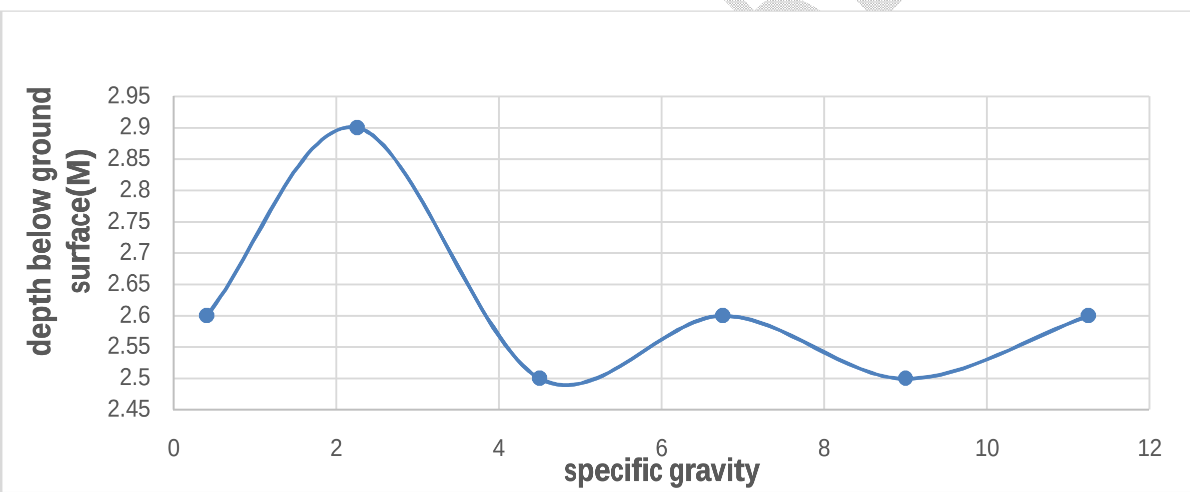


Figure 3.0: variation of specific gravity with depth for Point 2

According to Figure 3.0, the specific gravity grew from 0.4 to 2.25 meters, decreased to 2.25 to 4.5 meters, increased to 6.75 meters, decreased again to 9.0 meters, and finally increased to 11.25 meters. In contrast to point 1, point 2's specific gravity trend is erratic.

3.3 Plasticity Index

The results of calculating the soil plasticity index using the liquid limit and plastic limit are shown below.

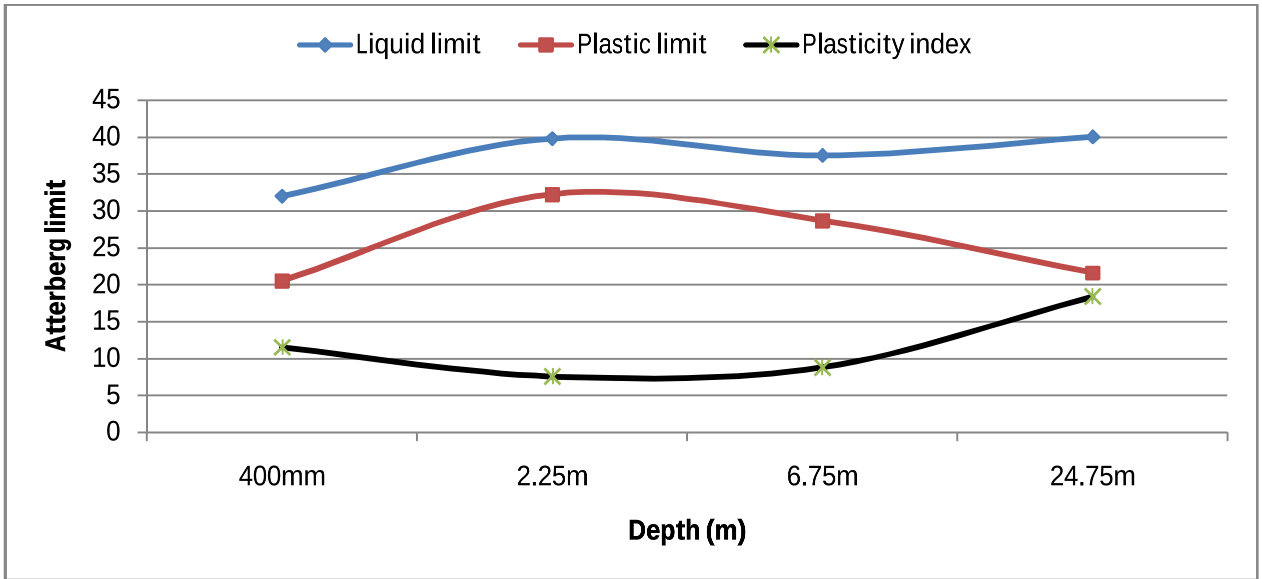


Figure 4.0: Atterberg limit of soil at Point 1

The outcome of figure 4.0 displays the soil's liquid limit, plastic limit, and plasticity index at various depths. The outcome, however, revealed that the PI is the antithesis of the LL and PL, ranging from 11.5 to 18.4, with a trend that decreased from 0.4 to 2.25 and then increased from 2.25 to 24.75. The results of this study revealed that the soil's PI displays medium plasticity (i.e., between 10 and 20), which is a sign that it is partly clayey and silty, as shown in Table 2.0. Hence, the soil is composed of silt and clay in nature. The results of this study revealed that the soil's PI displays medium plasticity (i.e., between 10 and 20), which is a sign that it is partly clayey and silty, as shown in Table 2.0. As a result, silt and clay make up the soil's natural composition.

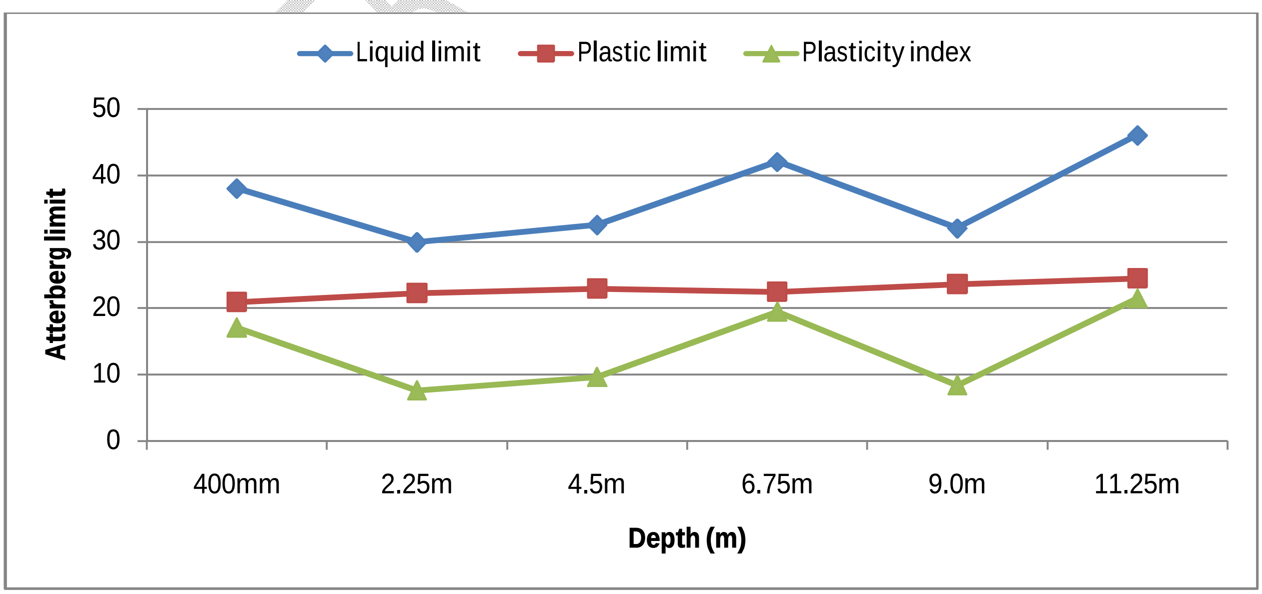


Figure 5.0: Atterberg limit of soil at Point2

The results from Table 4.0 demonstrate that the soil Atterberg limit at point 2 exhibits an irregular pattern and ranges from 17.1 to 21.5. This suggests that the PI of the soil at point 2 exhibits medium-high plasticity (i.e., between 10 and 20; 20 and 40), which is an indication that the soil in point 2 is highly plastic and can hold a significant amount of water in it in comparison to soil sample at point 1. Additionally, the results of the investigation demonstrated that the soil at point 2 is partially made up of silt and clay, which is supported by the result in Table 3.0.

3.4 Shear Strength

Results for the cohesiveness index and angle of internal friction for points 1 and 2 at various depths are shown in the figures below. Additionally, the result displays the coefficient of internal friction and cohesion index values of the at its natural moisture content.

Figure 6.0 : soil samples

Figure 7.0: Shear box set-up

Figure 8.0: Shear box apparatus

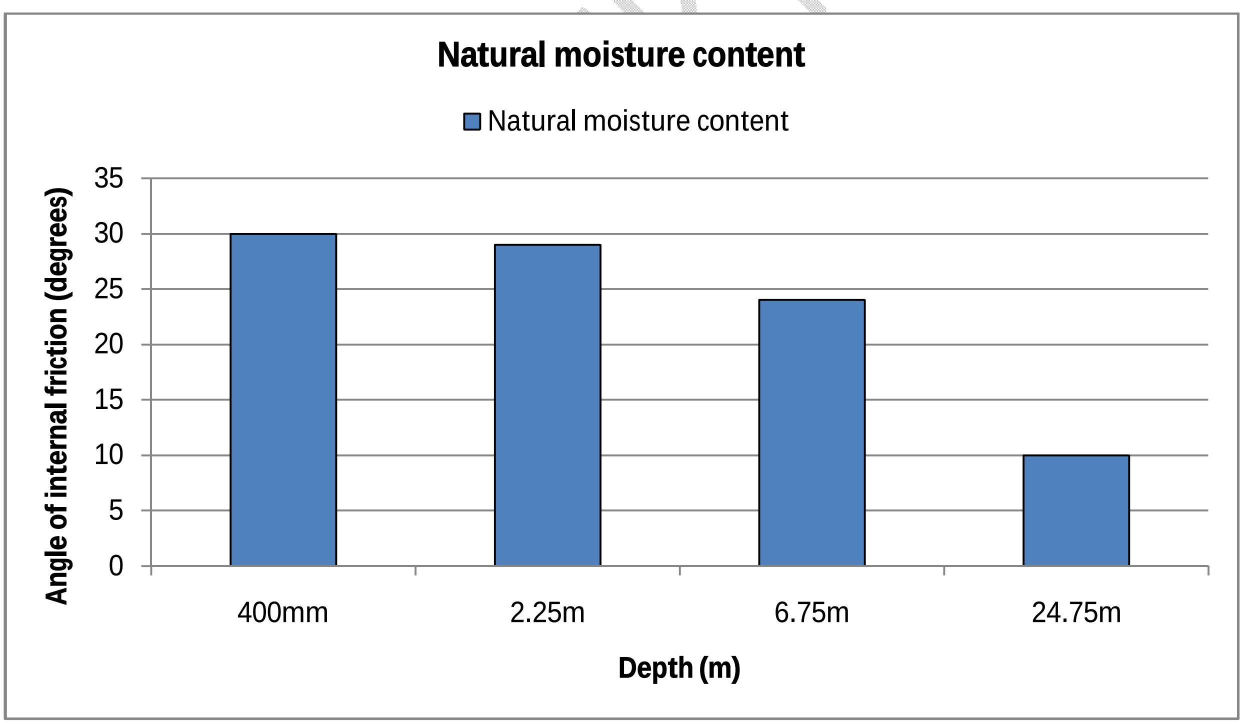


Figure 9.0: Soil angle of internal friction for point 1

At the natural moisture content at different depths below the ground surface, i.e. 0.4, 2.25, 6.75, and 24.75 meters, the angle of internal friction at point 1 increases at 2.25 m, 6.75 m, and 24.75

m depths. These conclusions imply that as soil depth grows, the angle of internal friction decreases and that the soil angle of internal friction increases when moisture content decreases [16].

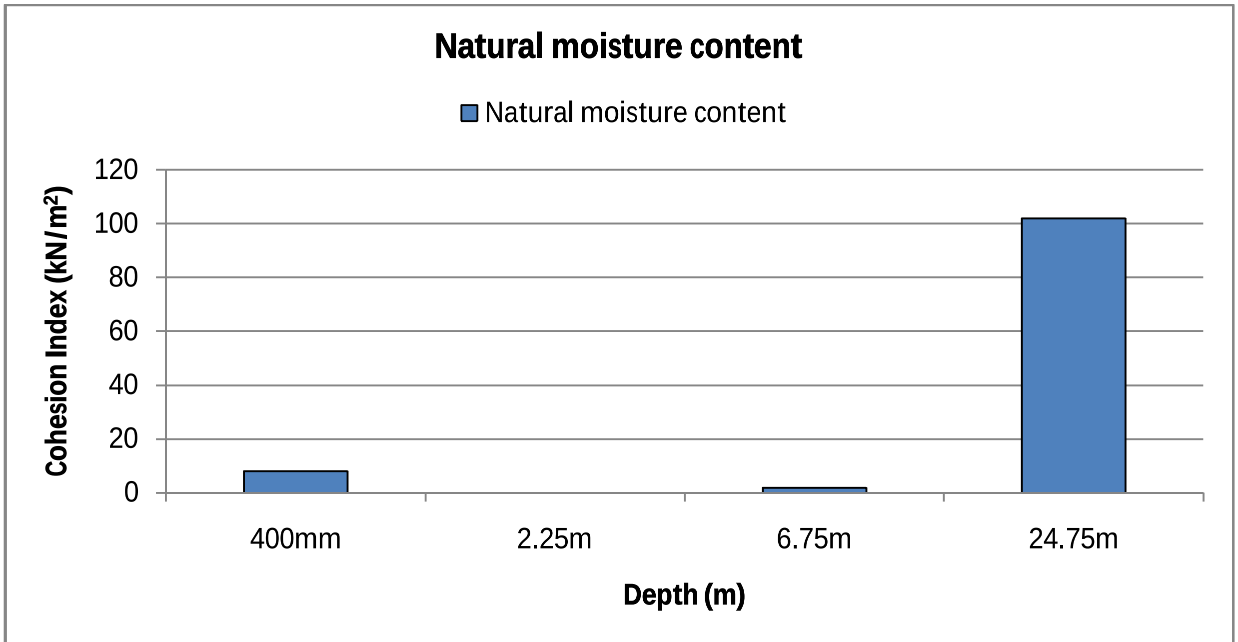


Figure 10.0: Soil Cohesion index for point 1

The soil cohesion index showed an erratic pattern in the result shown in Figure 7.0. The soil's natural moisture content had the highest cohesiveness index at 0.4 meters and 24.75 meters of depth, The soil cohesiveness index was also below 10kN/m2 between 0.4 and 6.75 meters in depth. The soil cohesiveness index, however, was between 80 and 100 kN/m2 at 24.75 n depth and showed a declining trend as moisture content rose.

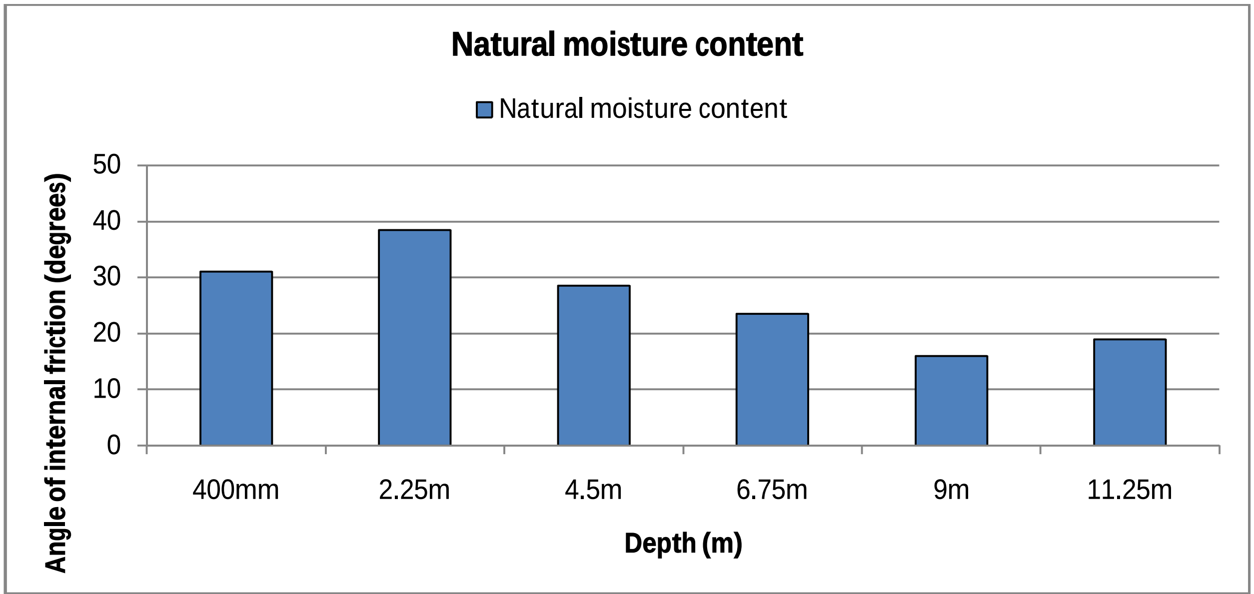


Figure 11.0: Soil angle of internal friction for point 2

Figure 11.0's conclusion demonstrates that, except for 9 meters of soil depth, the soil angle of internal friction decreases as moisture content rises, it happened at 0.4, 2.25, 4.5, and 6.75 meters of depth with the soil's natural wetness.

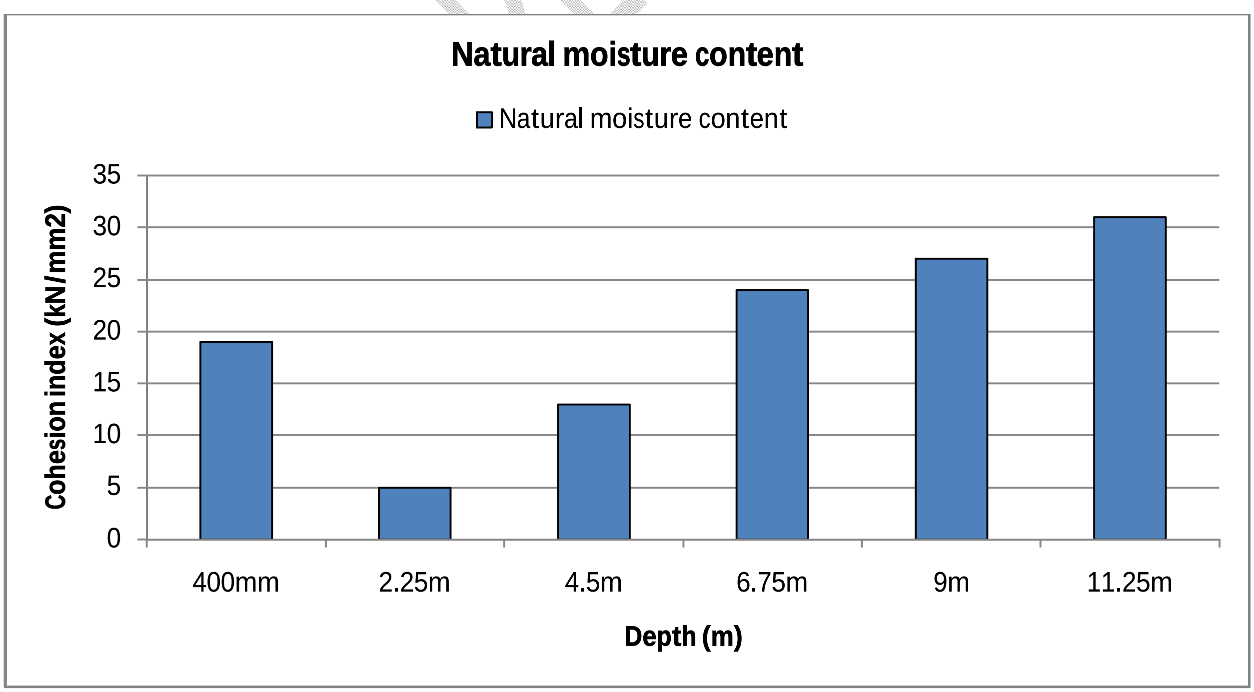


Figure 12.0: Soil Cohesion index for point 2

According to Figure 12.0, the soil cohesiveness index rises as moisture content rises at depths of 0.4, 2.25, 4.5, and 6.5 meters, whereas it falls at depths of 9 and 11.25 meters as moisture content rises. According to Figure 7.0, the maximum cohesiveness index is reached at depths of 0.4 m, 2.25 m, 4.5 m, and 6.5 m with a 4 percent moisture increase, and at depths of 9 m and 11.25 m at the soil's natural moisture content. The conclusion of this study suggests that the optimal cohesion index for this particular soil occurs around 6.75 meters and decreases below that level.

4.0 CONCLUSION

The investigation aimed to ascertain how different moisture contents affected the soil's shear strength characteristics. The soil's specific gravity ranges from 2.47 to 2.90, and the soil plasticity index at point 2 is higher than that at point 1, indicating that it can hold more water without losing its plasticity. According to the soil classification and rating system, the soil is composed of clayey and silty soil, with poor and good subgrade ratings, respectively. The results also show that the angle of internal friction decreases with soil depth and increases with moisture content at point 1, whereas the soil cohesion index showed an uneven pattern at point 1. At point 2, the soil angle of internal friction decreases as moisture content increases at depths of 0.4 m to 6.75 m, with the soil's natural moisture content reaching the maximum value, but increases as moisture content increases at depths of 9 m to 11.25 m, with 4 m of moisture content reaching the maximum value. In contrast, the soil cohesion index increases as moisture content increase from 0.4 m to 6.75 m, with 4 m of moisture content reaching the maximum value, and decreases

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