

Investigation of Shear Strength and Index Properties of disturbed Soil in South-West Nigeria

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Abstract: Sequel to limited data on soil properties in southwestern Nigeria hinders sustainable construction practices. This study addresses this gap by investigating the shear strength and index properties of soils in Ibadan, Oyo State. The research aimed to gain a deeper understanding of local soil behavior, focusing on shear strength and index properties. Soil samples were collected from four locations using core cutters and analyzed in the laboratory. Testing revealed that over 70% of the soil particles are fine-grained, passing a 0.075mm sieve. Shear strength varied significantly, ranging from 135 kN/m² to 285 kN/m² with an average of 243 kN/m². Index properties like liquid limit (23.57% - 43.57%), plastic limit (15.74% - 25.85%), and plasticity index (4.2% - 17.7%) also exhibited variations. Specific gravity ranged from 1.94g to 3.02g. Based on these results, the soil is classified as A-6 in the AASHTO system, indicating high clay content. The triaxial tests suggest relatively high cohesive strength. This comprehensive study provides valuable data on the shear strength and index properties of soils in Ibadan. This information will be instrumental for geotechnical and structural engineers when designing and planning construction projects in the region.

Keywords: Shear strength, geotechnical properties, foundation, CBR, Atterberg limit.

I. INTRODUCTION

The shear strength of soil in Nigeria, like any other country, can vary depending on various factors such as soil type, composition, and geological conditions. The shear strength of soil refers to its resistance to shear stresses and is typically characterized by parameters such as cohesion and angle of internal friction [1]. The internal resistance that the soil mass can provide per unit area to withstand failure and sliding along any plane within it is known as the shear strength of soil. Shear strength can be measured in a laboratory, out in the field, or perhaps both [2]. South West Nigeria is located in a seismically active region, studies have shown that more than half of the seismic events in Nigeria occurred in the South West [3]. Earthquakes can cause ground shaking, liquefaction, and other soil-related effects, which can alter the shear strength and stability of soils. Seismic activities induce shear strains in the soil, causing particle rearrangement and potential sliding along shear planes. The magnitude and duration of seismic shaking can affect the level of shear strain experienced by the soil. It can lead to stress redistribution within the soil mass. This redistribution can alter the effective stress and shear strength of the soil, potentially leading to slope failures and landslides.

Understanding the shear strength and index properties of soil in South West Nigeria is crucial for various geotechnical and civil engineering applications. The region's diverse geological formations and soil types present unique challenges and opportunities for construction projects, foundation design, and soil stabilization. Fugason (2004), stated that the shear resistance of soils is as a result of the angle of internal friction and the interlocking particles that hold or cement the soils particles together [4].

The shear strength of soils also influences the design of retaining walls in South West Nigeria. The shear strength characteristics of residual soils in the region was assessed. The study emphasized the significance of shear strength parameters in the stability analysis and design of retaining structures. Furthermore, the shear strength of soils is essential in the assessment of landslide susceptibility in South-West Nigeria.

The index properties of soil are fundamental to understanding soil structure and are very important in civil engineering. The soil's consistency, resistance, and phase are all determinants of its suitability for constructing buildings and other engineering purposes. Several studies conducted in South-West Nigeria have investigated the importance and application of index properties of soils. For instance, [5] examined the index properties of lateritic soils in the region and emphasized their influence on soil behavior, such as compaction characteristics and moisture content. They found that the plasticity index, a key index property, was closely related to the volumetric strain and shear strength of the soils.

The region of South-West Nigeria, comprising states like Lagos, Ogun, Oyo, Osun, Ekiti, and Ondo, is characterized by a diverse range of soils influenced by geological formations, climate, and vegetation. However, a comprehensive understanding of the shear strength and index properties of soil in this specific area remains limited. Majority of these studies have a limited sample size, which may not provide a representative picture of the entire region. This could lead to biased results and limited generalizability. This knowledge gap poses significant challenges and hinders sustainable development in various engineering construction. This study aims to provide valuable insights into the shear strength and index properties of soil in Southwest Nigeria.

II. MATERIALS AND MATERIALS

Materials

Soil samples were collected from four (4) different Local Government Area in Ibadan, these samples were undisturbed samples collected using the core-cutter apparatus, at depth of about 1m. These samples were canded wax and transported to the Civil Engineering Soil Mechanics Laboratory, River State University, where they are now subjected to laboratory investigations.

Experimental Programs

The method of investigation is in accordance with BS 1377:2022 code of practice. The shear strength and index properties of the soil samples were investigated in the laboratory. Various tests were performed to determine the soil's physical and engineering properties.

Table 1. Experimental Parameters

	Parameters	Standard
Sieve Analysis	Particle Size Distribution	BS 1377-2: 1990
Atterberg Limit Tests	Liquid Limit, Plastic Limit and Plasticity Index	BS 1377-2: 1990
Specific gravity	Dry density and the water content	BS 1377-2: 1990
Triaxial Test	Cohesion, angle of frictional resistance	BS 1377-7:1990

Sieve Analysis

Sieve analysis was performed in order to determine the soil particle size distribution. Representative sample of approximately 300g was used for the test after washing and oven-dried. The samples were washed using the BS 200 sieve and the fraction retained on the sieve was air dried and used for the sieve analysis. The sieving was done by mechanical method using an automatic shaker and a set of sieves.

Atterberg Limit Test

For the determination of liquid limit, the soil sample passing through 425 µm sieve, weighing 30g was mixed with water to form a thick homogeneous paste. The paste was collected inside the Casangrade's apparatus cup with a groove created and the number of blows to close it was Similarly, for plastic limit determination, the soil sample weighing 30g was taken from the material passing the 425 µm test sieve and then mixed with water till it became homogenous and plastic to be shaped to ball. The ball of soil was rolled on a glass plate until the thread cracks at approximately 3 mm diameter. The 3 mm diameter sample was placed in the oven at 105°C to determine the plastic limit.

Specific Gravity

The specific gravity examination was carried out on the clay soils, and the findings were documented. Specific gravity is the ratio of the mass in air of a given volume of soil particle to the mass in air of an equal volume of de-aired distilled water.

Triaxial Test

The triaxial test was used to determine the undrained shear strength of the soil. This test is a method of measuring the strength of a material by applying a confining pressure and an axial load to a cylindrical specimen. The confining pressure is the pressure applied to the sides of the specimen, and the axial load is the pressure applied to the top of the specimen. The triaxial test is commonly used in soil mechanics to measure the shear strength of a soil under various conditions.

III. RESULTS AND DISCUSSION

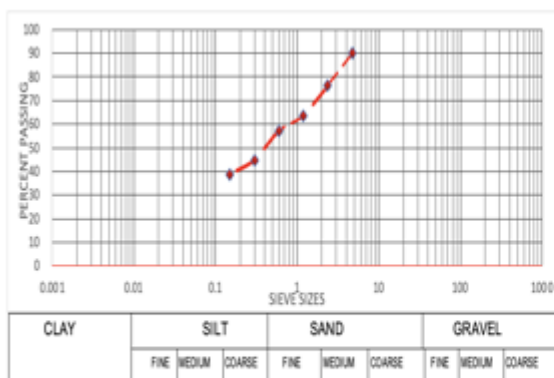
The results obtained from the various laboratory tests are presented and discussed under the relevant subheadings that follow.

Sieve Analysis

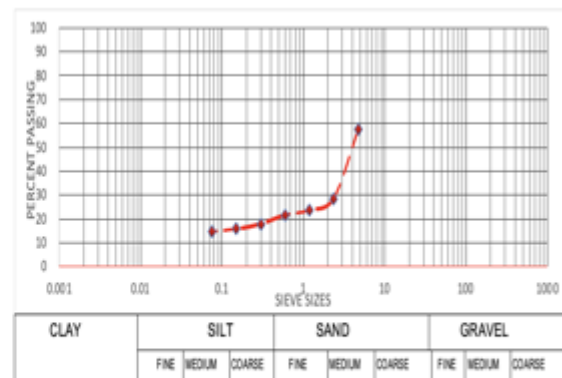
The sieve analysis results and particle size distribution graph of samples and are shown in Table 2 and Figure 1a-d respectively.

Table 2. Sieve Analysis (Awolowo Hall)

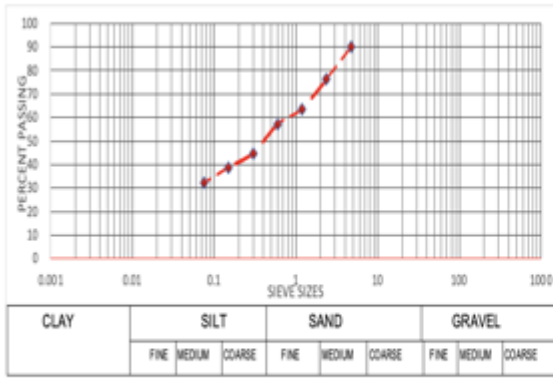
SIEVE (In)	NO. (mm)	MASS RETAINED	PERCENTAGE ON SIEVE	PERCENTAGE RETAINED	PERCENTAGE PASSING
No. 4	4.75	11.2	3.73	3.73	96
No. 8	2.36	23	7.67	11.40	89
No. 10	2.00	-	-	-	-
No. 16	1.18	46.4	15.47	26.87	73
No. 20	0.850	-	-	-	-
No. 30	0.600	24.6	8.20	35.07	65
No. 50	0.300	23.5	7.83	42.90	57
No. 100	0.150	2.1	0.70	43.60	56
No. 200	0.075	1.2	0.40	44.00	56
	PAN	0.5	0.17	44.17	56
TOTAL MASS RETAINED		132.5g	44.17%		



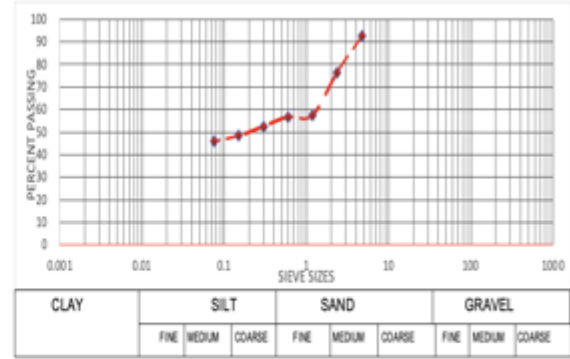
(a) Awolowo Hall



(b) Barracks



(c) Apata Location 1



(d) Apata Location 2

Figures 1(a)-(d). Particle size distribution graphs of some samples

The weights of soil samples from four locations, Awolowo Hall, Barracks, Apata Location 1, and Apata Location 2 after washing were 132.5g, 257.4g, 204.7g, and 162.7g respectively. The soils in the study area are grouped under ML soil group based on Unified Soil Classification systems.

Atterberg Limits

The comprehensive summary result of Atterberg limit test is shown in Table 3.

Table 3. Results of Atterberg Limit Analyses of the Studied Soils

Location	Liquid Limit LL (%)	Plastic Limit PL (%)	Plasticity Index PI (%)
UI Business School	23.33	15.74	7.6
Awolowo Hall	43.57	25.85	17.7
Apata Location 1	26.10	21.81	4.2
Apata Location 2	28.32	18.04	10.3

The Plasticity Index (PI) is a measure of the plasticity of a soil. It is calculated by subtracting the Plastic Limit (PL) from the Liquid Limit (LL). A higher PI indicates a more plastic soil.

The data shows that the Plasticity Index (PI) ranges from 4.2 to 17.7. The location with the highest PI is Awolowo Hall (17.7), and the location with the lowest PI is Apata Location 1 (4.2). The Liquid Limit ranges from 23.33% to 43.57% with an average of 30.4% and Plastic Limit ranges from 15.74% to 25.85% with an average of 20.38% while Plasticity Index ranges from 4.2% to 17.7% having an average of 10%.

Specific Gravity

As defined in ASTM D854-58, specific gravity is the ratio of mass in air of a given volume of soil particle to the mass in air of an equal volume of de-aired distilled water. Table 4 shows the specific gravity of the different soil locations.

Table 4. Specific Gravity of Different Locations

Location	Specific Gravity
UI Business School	2.22
Awolowo Hall	1.94
Barracks	3.02
Apata Location 1	1.96
Apata Location 2	2.82

From Table 4, it is seen that the specific gravity of the sample locations ranges from 1.94 and 3.02.

Moisture Content

Table 5 shows the natural moisture content of the different soil locations.

Table 5. Natural moisture content of the different soil locations

Location	Moisture Content (%)
UI Business School	20.24
Awolowo Hall	19.91
Barracks	5.91
Apata Location 1	9.21
Apata Location 2	10.33

From the proctor compaction tests of all soil samples (Table 5), the moisture content ranges from 5.91% to 20.24%. UI Business School has the highest water content of 20.24% while Barracks has the least water content of 5.91%. The range of values that may be anticipated for optimum moisture content (OMC) may fall between 20-30%.

Triaxial Test

Table 6 shows the triaxial test results of soil samples from locations in South West Nigeria. This test was done in accordance to BS 1377(7):1990 ASTM D4767.

Table 6. Triaxial Test Results of Different Locations in South West Nigeria

Location	Cohesion kN/m ²	Friction Angle	Shear Stress kN/m ²
UI Business School	100	10	282
Awolowo Hall	70	14.80	135
Apata Location 1	105	19.33	285
Apata Location 2	90	19.77	270

From Table 6, Apata Location 1 has the highest cohesion (105 kN/m²) followed by UI Business School (100 kN/m²) and Apata Location 2 (90 kN/m²). The lowest cohesion is observed in Awolowo Hall (70 kN/m²). Apata Location 2 has the highest friction angle (19.77°) followed by Apata Location 1 (19.33°). The lowest friction angle is observed in UI Business School (10°). Apata Location 1 has the highest shear stress (285 kN/m²) followed by UI Business School (282 kN/m²) and Apata Location 2 (270 kN/m²). The lowest shear stress is observed in Awolowo Hall (135 kN/m²).

IV. CONCLUSION

This From the Unconsolidated Undrained (UU) Triaxial test the shear strength vary significantly among the samples, ranging from 135KN/m² to 285 KN/m² with an average of 243 KN/m². Confining pressure appears to influence the frictional angle, with Apata location 2, having the highest angle and UI business school the lowest. The soil samples in the study area are classified as A-6 using AASHTO classification method. The study reveals that the percentage of finer on sieve #200 (0.075mm) is more than 70%, this indicates that the soil in the study area is classified as fine-grained soil. The Liquid Limit ranges from 23.57% to 43.57% with an average of 30.4% and Plastic Limit ranges from 15.74% to 25.85% with an average of 20.38% while Plasticity Index ranges from 4.2% to 17.7% having an average of 10%, from the specific gravity test the average gravity ranges from 1.94g to 3.02g and having an average of 2.39g.

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