

## Geotechnical Characterization of Southern Region Soils for Civil Engineering Applications

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### Abstract

Soil serves as the primary foundation for all types of structures. It makes up the top layer of the Earth's surface and consists of a mixture of minerals, organic substances, water, air, and various living organisms. Beyond its ecological role, soil has immense engineering significance and has been utilized in construction since ancient times. It is used in many ways, including Building materials, where soil is used to make building materials like cement and brick. Bases for structures in which soil is used to create the bases of structures like bridges, highways, dams, culverts, tunnels, and retaining walls. In this project work, two different types of soils, such as Laterite and Black Cotton, are taken, and various basis tests, such as plastic limit, liquid limit, shrinkage limit, sieve analysis, and specific gravity, are carried out to analyze their characteristics. From the test result, it was found that the two types of soil are good in most of the characteristics and show a sunlight variation in all their test value, which is acceptable as per the codal provisions.

**Keywords:** Soil, specific gravity, sieve analysis, plastic limit, liquid limit, shrinkage limit

### INTRODUCTION

Soil is important in construction such as building materials, foundation support, site selection, soil testing, and ground improvement. Soil testing is an important step in the construction process that involves analyzing soil samples to determine their properties and how they will react under various conditions. Soil testing can help to ensure that a structure's foundation is stable and secure to withstand the load [1–3]. Characteristics of soil differ by its color, composition, texture, formation, particle size, hardening, use, etc. When builders test the soil, they look at different features like how strong it is, how much water it can hold, and its density [4, 5]. This information is crucial because it helps determine whether the soil can support a house, bridge, or any other building. Some soils are very soft and can settle over time, which could cause cracks or even structural failure in a building [6, 7].

By testing the soil, the engineers can choose the right type of foundation to prevent these problems. If builders know about hazardous material, high water level issues early, they can take steps to fix or address them, which saves time and money later [8].

Soil tests ensure that construction projects follow safety regulations and building codes. It helps ensure that buildings are safe, strong, and built to last. By understanding the soil before starting a project, builders can avoid problems and create structures that stand the test of time [9]. Due to the change in soil type, bearing capacity, and composition, each soil may act differently when they are imposed to different loads [10, 11]. Due to the change in its characteristics, more groundwater table problems may be faced. Contamination in the soil should be identified before the start of the

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construction activities to avoid the settlement problems [12]. The objective of this study is to address the problem of soil selection by conducting a comprehensive evaluation of the engineering properties. Through standardized testing methods, the study aims.

- Improve soil composition, texture, and relevant geotechnical properties.
- To find out the load-bearing capacity and stability of the soil.

## MATERIALS USED

### Laterite Soil

Laterite soil is a distinct type of soil characterized by its high content of iron and aluminum oxides, which give it a characteristic rusty red to brown color. It generally forms in hot and humid tropical regions due to intense weathering and leaching of parent rock material. Laterite soil is commonly used in construction, particularly for making bricks and blocks after proper treatment. This process removes bases and silica from the primary minerals and increases the proportion of iron and aluminum oxides in the soil. Laterite soil is acidic and has a pebbly crust that forms due to the alternating wet and dry periods. It is also deficient in organic matter, phosphate, nitrogen, and calcium. Laterite soil is suitable for growing tropical crops like rubber, coffee, tea, coconut, areca nut, and cashew. However, it is often poor in fertility, so fertilizers and manure are needed to make it cultivable. Figure 1 shows the laterite soil, which is used for the testing process.



**Figure 1.** Laterite soil.

### Black Cotton Soil

Black cotton soil (BC soil) is a black color clayey soil that varies from clay loamy to clay texture, with high shrink-swell capacity, which causes it to crack during dry periods, low bearing capacity, high swelling and shrinkage, high clay content, high liquid limit, plastic limit, and moisture content. Brick manufacturing: BC soil has high bonding strength and adhesive properties, making it a good material for manufacturing bricks. Road construction: BC soil can be used in road construction. Figure 2 depicts BC soil.



**Figure 2.** BC soil.

## EXPERIMENTAL TESTING

### Sieve Analysis

A soil sample is taken with a weight of 1000 g. Arrange the sieves in descending order of mesh size. The bottom pane is placed to catch all the fines that pass through the smallest sieve. Place the soil sample in the top sieve and secure the sieve stack on a mechanical shaker as shown in Figure 3. Shake the sieves for a specified duration (usually between 10 and 20 minutes), ensuring that all soil particles can move freely through the mesh.



**Figure 3.** Sieve analysis test.

### Specific Gravity

The specific gravity of soil ( $G_s$ ) is the ratio between the mass density of soil solids and the density of water at a reference temperature, commonly taken as 20°C. Being a dimensionless parameter, it is often referred to as the particle density of soil. For most soils, specific gravity values generally lie within the range of 2.55 to 4.0. The pycnometer, as illustrated in Figure 4, is typically employed to determine the specific  $G_s$  samples



**Figure 4.** Pycnometer.

### Plastic Limit

The plastic limit (PL) is the lowest moisture content at which a soil mass starts to show plastic characteristics. Under these conditions, the soil can be molded or deformed without breaking or crumbling, but only within a limited range. When the water content reduces below this point, the soil loses its plasticity and shifts toward a semi-solid state. In practice, the PL is obtained by rolling a soil specimen into thin threads until they reach a diameter of about 3 mm, at which stage the sample begins to crack. When the soil crumbles or breaks apart at a thread diameter of 3.2 mm (1/8 inch), the corresponding water content is taken as the PL. Figure 5 shows PL thread rolling process.



Figure 5. Plastic limit.

### Liquid Limit

The liquid limit (LL) represents the lowest water content at which a soil transitions from a plastic condition to a liquid state. At this stage, the soil exhibits the ability to flow under its own weight. The determination of LL is commonly carried out using the Casagrande apparatus, where a soil paste is placed in a brass cup and a groove of specified dimensions is made in the sample. The cup is then repeatedly dropped from a fixed height, and the LL is defined as the moisture content at which the groove closes over 12 mm after approximately 25 blows. The experimental arrangement is illustrated in Figure 6.



Figure 6. Liquid limit setup.

### Shrinkage Limit

The shrinkage limit (SL) is defined as the highest water content at which a decrease in moisture no longer leads to a reduction in soil volume. At this stage, the available water is just adequate to occupy all the void spaces, keeping the soil fully saturated. When the moisture content drops below this limit, the soil volume remains unchanged despite continued drying. Figure 7 shows the shrinkage test setup.



**Figure 7.** Shrinkage disk setup.

## RESULTS AND DISCUSSION

### Sieve Analysis

The particle size distribution is depicted using the sieve analysis test, and the test results are shown in Tables 1 and 2. Figures 8 and 9 show the variation in the values. The finer value of laterite soil and BC soil is 4 and 5.6.

**Table 1.** Sieve analysis for laterite soil.

IS Sieves	Empty Weight of Sieve (g)	Retained Weight of Sieve (g)	Retained Weight of Soil (g)	Cumulative Weight Retained (g)	Cumulative % Retained(g)	% Finer
4.75 mm	409	539	130	130	13.0	87.0
2.36 mm	413	546	133	263	26.3	73.7
1.70 mm	337	408	71	334	33.4	66.6
1.18 mm	330	444	114	448	44.8	55.2
600 $\mu$	338	403	65	513	51.3	48.7
425 $\mu$	329	440	111	624	62.4	37.6
300 $\mu$	352	532	180	804	80.4	19.6
150 $\mu$	300	441	141	945	94.5	5.5
75 $\mu$	289	322	33	978	97.8	2.2
Pan	304	326	22	1000	100.0	0

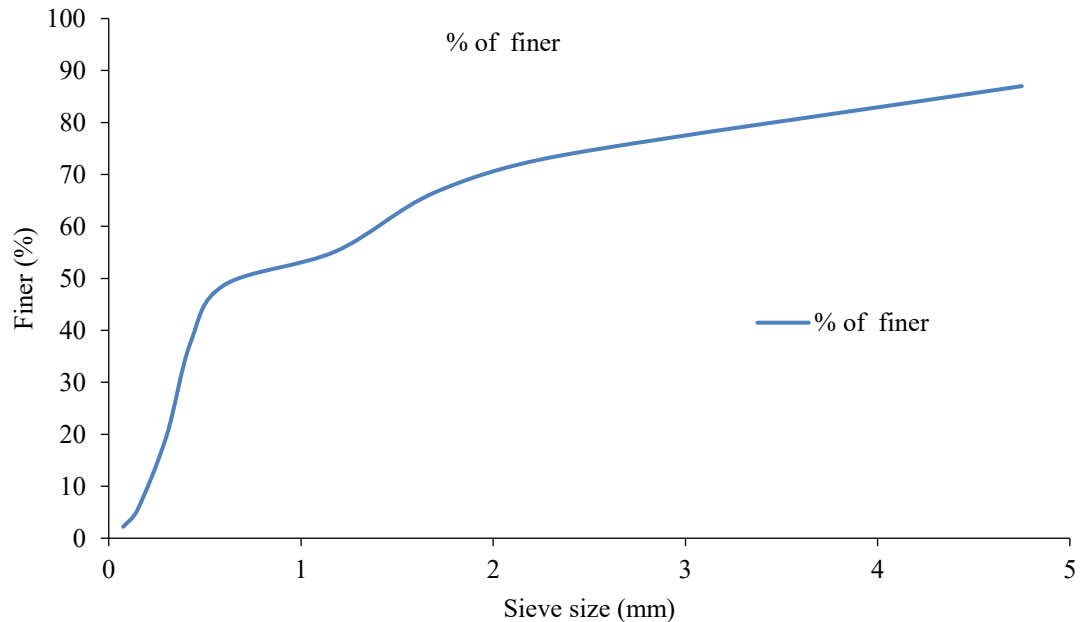
**Table 2.** Sieve analysis for BC soil.

IS Sieves	Empty Weight of Sieve (g)	Retained Weight of Sieve (g)	Retained Weight of Soil (g)	Cumulative Weight Retained (g)	Cumulative % Retained (g)	% Finer
4.75 mm	409	550	141	141	14.1	85.9
2.36 mm	413	484	71	212	21.2	78.8
1.70 mm	337	450	113	325	32.5	67.5
1.18 mm	330	511	181	506	50.6	49.4
600 $\mu$	338	403	68	574	57.4	42.6
425 $\mu$	329	440	129	703	70.3	29.7
300 $\mu$	352	532	113	816	81.6	18.4
150 $\mu$	300	441	132	948	94.8	5.2
75 $\mu$	289	322	33	981	98.1	1.9
Pan	304	326	19	1000	100.0	0

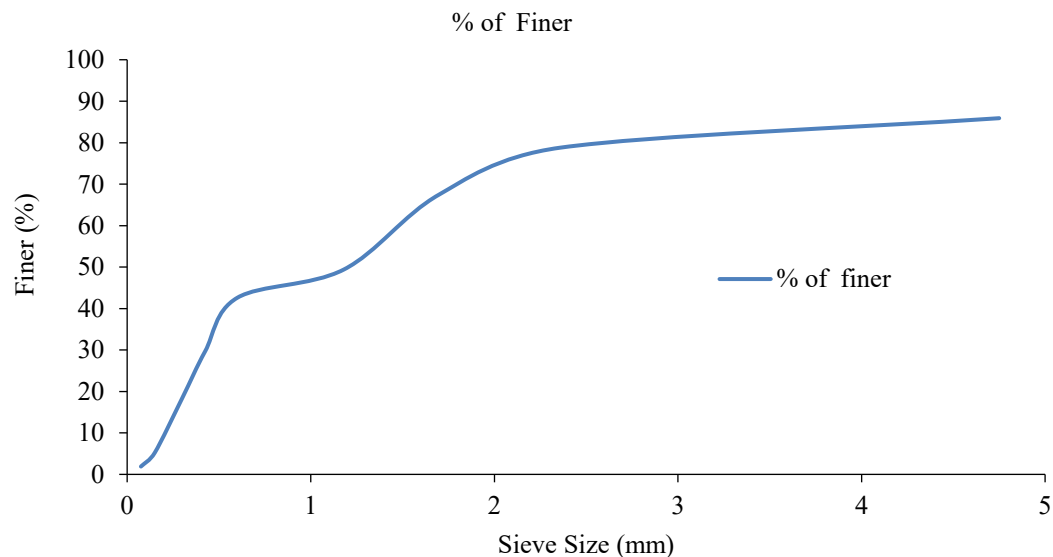
### Specific Gravity

For laterite soil and BC soil, the obtained specific gravity values are 2.28 and 2.13, respectively. This property is essential for calculating parameters such as porosity, void ratio, and the degree of saturation. The specific gravity of BC soil generally falls in the range of 2.5–2.72, while that of lateritic soil usually

lies between 2.55 and 4.6, depending on the mineral composition. The experimental results indicate that the measured values are within the expected limits.



**Figure 8.** Sieve analysis for laterite soil.



**Figure 9.** Sieve analysis for BC soil.

### PL

The PL values determined for laterite soil and BC soil are 28.57% and 37.5%, respectively. The PL of laterite soil can vary considerably, typically ranging between 12% and 48%. The PL refers to the

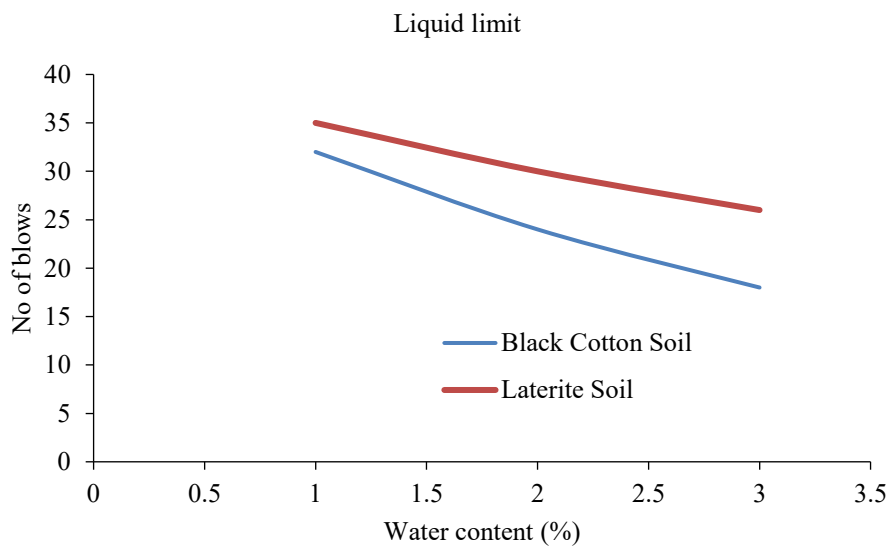
water content at which a fine-grained soil begins to display plasticity. It represents the average moisture content obtained from Atterberg limit testing. At this stage, the soil can be rolled into threads of approximately 3 mm in diameter without disintegration. Once rolled further, cracks appear as moisture is lost, indicating the PL has been reached. For BC soil, the PL generally ranges from 20% to 40%, depending on clay mineralogy and structural characteristics.

### LL

The LL is defined as the water content at which soil transitions from plastic to a liquid state. It is determined using the Casagrande LL apparatus, where the number of blows required to close a groove of 12 mm in a soil paste is recorded. Soils with a high LL are generally more compressible and exhibit greater swelling and shrinkage potential, especially in clay-rich materials. In contrast, the PL is the moisture content at which soil changes from a plastic state to a semi-solid state, determined by rolling the sample into 3 mm threads until cracks develop. The experimental results obtained in this study fall within the standard range, as presented in Table 3 and Figure 10.

**Table 3.** LL test results.

Soil/Trial	1	2	3	Water Content for 25 Blows
Laterite soil	35	30	26	3.0
BC soil	32	24	18	1.8



**Figure 10.** LL test.

### SL

The SL value of laterite soil and BC soil is 6.94% and 6.79%, respectively. The SL of soil is the moisture content at which the soil's volume stops changing when it dries. It is one of the Atterberg limits, which are used to characterize cohesive soils. The linear shrinkage of laterite soil can range from 7.1% to 13.9%. In Nigeria, the regulatory specifications for soils used in road construction state that the linear shrinkage should not be greater than 10%. The SL of BC soil can vary but is typically around 11%–20%.

### CONCLUSIONS

Comprehensive testing and analysis of the engineering properties of soil provide valuable insights into their performance and suitability for various construction applications. Based on the experimental test results, it was observed that:

- The finer percentage of laterite soil is 4 and BC soil is 5.7, which comes under well graded.
- Laterite soil shows a specific gravity of 2.28, and for BC soil, it is 2.13. Both the values are less when compared to the limiting value.
- The PL of laterite soil and BC soil is 28.57% and 37.5% which are within the limiting range. Hence, the moisture content is under control.
- The water content for 25 blows is 3 and 1.8 for laterite and BC soil, which shows the controlled moisture content.
- The SL value of laterite soil is 6.94% and BC soil is 6.79% which is less than the limiting value.

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