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Evaluation of Lateritic Soil along OAU Road 7 – OAUTHC as Pavement Material

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ABSTRACT- Majority of failures in road pavements have been attributed to indiscriminate utilization of laterite soils without fully appreciating their limitations. This has prompted the need for the suitability of laterite soils along road 7 Obafemi Awolowo University (OAU) – Obafemi Awolowo University Teaching Hospital Complex (OAUTHC) road as pavement material. Atterberg limits, moisture-density relationship, and California bearing ratio tests were carried out on the laterite soil sample. This was with a view to examine the various geotechnical paramedics employed in the evaluation of laterite soils as pavement material. Results show that based on AASHTO classification the studied laterite soils belong to group A-2. Also, the soils are cohesive and have high value of compressive strength.

Keywords: lateritic soil, moisture density, compaction, pavement, geotechnical property

1. **Introduction**

In many engineering constructions the engineer will have to perform suitable test to determine the engineering properties of the soil. "The determination of basic geotechnical properties are expensive and often difficult to determine. The index properties, which are simple and cheaper to evaluate may be used as a bases for determining the basic geotechnical properties of soils if there are established relationship between the two i.e the index and basic geotechnical properties (Jimoh and Apampa, 2014; Falade, 1991)
The highway engineers interest in cheap and local materials for road construction, with a view to reduce the cost without sacrificing its effectiveness, has led to the recognition of laterite soils for road construction. This is basically due to its cheapness, abundance and naturally stable with a suitable proportion of clayey materials to act as binders (Agus and Gendut, 2012; Osunnade, 2002.)".
A good understanding of the properties of a given soil is essential for its proper use in pavement construction. Laboratory and field tests are used to set broad limits to the probable behaviour of soils and establish basis for the use of experience and ingenuity in formulating sound engineering solution to design and construction problems involving the use of soils (O'Flaherty, 2002; Falade, 1991; Shuaibu, *et al* 2014.).
Difficult and expensive tests in determining some basic geotechnical properties may be avoided if there is a direct link between the simpler easier tests such as those used in determining the index properties of the soils.

2. Materials and Methods

2.1 Material collection and preparation

Eight different samples were collected along the road linking Obafemi Awolowo University (OAU) road 7 and Obafemi Awolowo University Teaching Hospital Complex (OAUTHC). Soil sample from each location was properly labelled. After collection, each soil sample was put in a sealed bag and quickly transferred to the laboratory. The soil samples were air-dried for a period of about four weeks, during which the soil sample were turned over at regular intervals to enhance an increase in the area of exposure.
Atterberg limit tests

2.1.1 Liquid limit

Approximately 100g of soil sample passing through 425um BS test sieve was obtained. “The soil sample was mixed with water to form a thick paste. The paste of the soil was placed in the circular brass dish of the casagrande’s liquid limit device dish and a groove was made at the center of the dish with the grooving tool. The device was then operated by applying blows to the dish until the groove just closed and the number of blows effected was recorded”. The central portion of the closed groove was sampled for moisture content determination. The liquid limit is the moisture content corresponding to 25 blows on the straight line graph.

2.1.2 Plastic limit

Soil sample under the different conditions of drying were mixed with water to form a uniform paste. Each soil sample was rolled on a glass plate with hand until it was about 3mm in diameter. Rolling continued until signs of crumbling became apparent. Some of the crumbed material was taken for water content determination.

2.1.3 Linear shrinkage test

About 200g of the samples were mixed with water approximately equal to the liquid limit until homogeneity occurs. The mixture was then put inside the mould and air dried until the sample shrinked away from its edges. It was later placed in the oven for 24 hours and the percentage reduction in length was computed and the linear shrinkage was determined.

2.1.4 Specific gravity

Air dried sample was used and about 100g of soil sample was weghed. The soil sample was put in the pycnometer. The pycnometer with its contents was then weighed. After this, the bottle was emptied and cleaned. It was later filled with distilled water and weighed.

2.1.5 Soil compaction test

Approximately 6 kg of the air-dried soil sample passing through a 4.75 mm sieve was mixed with 6% of distilled water. “The soil was mixed thoroughly in the tray and divided into five parts. Each layer was compacted with 27 blows with the rammer. The soil was trimmed. To the top of the mould after the attached collar has been removed. The weight of the mould and the compacted soil was determined and recorded to determine its bulk density after the weight of the empty mould has been recorded previously. The soil was extruded using the extruder, samples were taken from both top and bottom of the compacted soil sample for moisture content determination. The compacted soil was then further mixed with additional 3% water and then compacted. The bulk density of the compacted soil was noted to increase and the water was further increased by 3% and this process was continued until the bulk density of the compacted soil falls”. The dry densities and the corresponding optimum moisture content of the soil were determined by calculation and a graph of dry density was plotted against moisture content. The optimum moisture content (OMC) and the corresponding maximum dry density (MDD) were obtained from the graph.

2.1.6 California Bearing Ratio (CBR) test

Weigh approximately 6kg of soil sample, then mixing it with water quantity equivalent to OMC obtained from compaction test. After thorough mixing, the soil was compacted. The mould contained the specimen with the base plate is positioned but the top face exposed was placed on lower plates of the CBR machine. The plunger was made to penetrate the specimen at a uniform rate, readings of the force was taken at intervals of 0.25mm to a total penetration of 7.5mm, The plunger was raised and the face of the specimen trimmed up by filling the depression left by the plunger and cutting away projecting material with straight edge. “Thereafter, the base plate was removed from the lower end of the mould and fixed on the upper end of the mould and content was inverted. In case of soaked CBR test, the specimen was placed in a water bath and surcharge masses as required placed on the specimen”. The soaking period was 72 hours. Thereafter, the specimen was removed from the bath and allowed to drain for about 15 minutes. The collar and perforated plate was removed and the specimen weighed. It was tested in a similar way with unsoaked CBR test.

3. Results and Discussion

3.1 Soil classification

Table 1 shows the data obtained from the laboratory used in the classification. "An important feature of AASHTO classification is the group index which is based on the service performance of many soils. It permits a more precise prediction of soils behaviour that is possible by soil classification alone and is used by some highway designers to guide in determining the combined thickness of pavement and base over a given soil (Udoeyo *et al*, 2006)". Based on Table 1, all the soil samples were classified as group A-2. Samples 1, 4, 6 and 8 were classified as group A-2-7 with group index of 1, 2, 2, and 2 respectively. Samples 2, 3, 5 and 7 were classified as group A-2-5 with group index of 0. This clearly indicates that the soil samples were good subgrade materials.

Table 1: Data used in AASHTO classification

Sample	% Passing No 40	% Passing No 20	Liquid limit (%)	Plasticity index (%)
1	39.96	1.78	52.30	13.91
2	69.42	6.21	51.80	1.80
3	68.64	5.17	53.50	3.50
4	23.60	2.35	60.80	10.80
5	24.13	3.21	42.30	3.97
6	23.32	0.90	51.50	12.61
7	21.78	0.93	41.80	8.50
8	21.01	1.59	55.80	22.50

3.2 Plasticity Characteristics

The term plasticity describes the ability of a soil to undergo unrecoverable deformation at constant volume without cracking or crumbling. "This is described by the liquid limit, plastic limit and the plasticity index of the soil. Liquid limit indicates the percentage of moisture at which the sample changes with a decrease in moisture from a viscous or liquid state to a plastic one. High liquid limit generally indicates that minerals subject to expansion with increasing moisture are present". The summary of the average values of the plasticity parameters in highlighted in Table 2. For predominantly silty soils, the value of liquid limit ranges between 25% and 50% while the value of predominantly clayey soils range between 40% and 60%.

Therefore, all the eight samples can be said to be clayey soil because of the value of their liquid limits. Plastic limit signifies the percentage of moisture at which the sample changes with decreasing wetness from a plastic to a semi-solid state. At the liquid limit, the moisture will not separate the soil particles but will produce enough surface tension to give contact pressure between the soil grains and thus cause the mass to act as a semi solid. The result of the plastic limit and liquid limit gave the plasticity index of the soil.

Plasticity index measures the fines and shapes of the soil particles, the interplay of the attractive force tending to hold the clay-mineral flakes together, the thickness and lubricating properties of the water film and the quality and electrical charges of the cations (Mengel, 2012). Thus plasticity index is an indirect method of measuring amount of moisture affinities of the clays, colloids and cations in the soil. Soil with high plasticity index such as samples 8 is less durable for subgrade or base course than those having lower indices. Samples 1, 4 and 6 also have high plasticity compared to plasticity of good subgrade and base materials. Samples 2.3.5 and 7 have low plasticity index which are good as subgrade and base course materials.

Table 2: Average value of the Atterberg Limit

Sample	Liquid limit (%)	Plastic limit (%)	Plasticity index (%)
1	52.30	38.89	13.91
2	51.80	50.00	1.80
3	53.50	50.00	3.50
4	60.80	50.00	10.80
5	42.30	33.33	3.97
6	51.50	38.89	12.61
7	41.80	33.33	8.50
8	55.80	33.33	22.50

3.3 Linear shrinkage

Linear shrinkage is a measure of the change in volume and weight that occur as a mixture of soil mortar and water is dried from near the liquid limit to a constant weight at 110^{o}C. The average values of the linear shrinkage are 12.54%, 29.97%, 27.87%, 14.29%, 12.89%, 13.03%, 14.71% and 12.75% for samples 1,2,3,4,5,6,7and 8 respectively. The linear shrinkage value for good lateritic soil varies from 6% to 9% and large values of linear shrinkage for soil samples indicate that the soil would be troublesome as construction material for highways.

3.4 Specific gravity

The average value of the specific gravity of all the lateritic soil samples fall between 2.75 and 2.99, this value falls within the range of 2.6 and 3.4 as stipulated by Das 2006 . This shows that all the soil samples are collusive and contain wide range of particles i.e clay, silt, sand, and so on. The soil with high value of specific gravity indicates high degree of laterization thus the soil samples fall within ferruginous and aluminous laterite.

3.5 Compaction characteristics

Table 3 shows the relationship between moisture contents and dry densities for all the sample. The relationship was obtained from data obtained in the laboratory for the lateritic soils using the West African method of compaction. Compaction is generally the process of increasing the density of soil by parking the particles closer together with a reduction in the volume of air. Compaction is always normally used for soil stabilization. Generally, the higher the degree of compaction, the higher the shear strength and lower the compressibility of the soil. The degree of compaction of a soil is measured in terms of dry density. The moisture content that produces the maximum dry density is known as optimum moisture content. It can be inferred from the results that sample 7 has the highest shear strain and lowest compressibility which indicates a good construction and foundation material in road and highway construction. It is followed by samples 5 and 8. But sample 2 is considered the poorest construction material for road and highway construction because of the higher optimum moisture content and lower maximum dry density which signify a lower shear strength and higher compressibility (Terzaghi, *et al.* 1996).

Table 3: Relationship between moisture content and maximum dry density

Sample	Optimum moisture content (%)	Maximum dry density (kg/m^3)
1	16.80	1765.00
2	24.90	1531.55
3	22.00	1540.87
4	20.02	1678.66
5	22.13	1788.87
6	20.00	1495.00
7	15.98	1992.33
8	14.41	1765.38

3.6 California bearing ratio

The summary of the CBR both soaked and unsoaked results are displayed in Table 4, based on the result obtained from the laboratory. It can be seen that CBR for soaked samples is generally lower than the unsoaked CBR for all the laterite soil samples. This may be due to the fact that after soaked for 3 days in water, the sample absorbed water and swells, thus the internal friction is generally reduced by the absorbed water resulting in which smaller soaked CBR than the unsoaked CBR.

CBR is a measure of the quality of the material in terms of an excellent base course which has a CBR of 100%. Once the CBR for the basement soil and that in order layer is known, the thickness of overlying material to provide a satisfactory pavement can be determined. The result of the CBR test obtained can thus be compared with the typical ratings given in Table 5. It can be observed that all the lateritic soil studied except sample 2 are good base and sub base materials. Comparing the result with the specification for road soil as indicated in Table 6. All the soil sample are suitable for subgrade and sub base material, but will not be an excellent base course material (Terzaghi, *et al.* 1996).

Table 4: CBR result

Sample	Unsoaked (%)	Soaked (%)
1	29	17
2	18	08
3	29	16
4	65	20
5	68	17
6	37	10
7	39	25
8	23	09

Table 5: CBR values and its ratings

CBR Value (%)	General ratings	Uses
0-3	Very poor	Subgrade
3-7	Poor to fail	Subgrade
7-20	Fair	Subgrade
20-50	Good	Base, Subbase
Above 50	Excellent	Base

4. Conclusion

Based on the test conducted in the laboratory, the following conclusion can be drawn. According to AASHTO classification of soils for highway subgrade materials, the studied laterite soils were classified as A-2. Samples 1, 4, 6, and 8 were classified as A-2-7with group index 1, 2, 2, and 2 respectively. Samples 2, 3, 5 and 7 were grouped as A-2-5 with group index 0. This indicates that the soil samples were good subgrade material.

Based on the engineering utilities, the samples show that they all cohesive soils with varying ranges of clay, silt and sand. Some with high plasticity index are less durable for subgrade or base course materials. Also, the large values of linear shrinkage for soil samples indicate that the soil would be troublesome as construction materials.

High maximum dry density and lower optimum moisture contents exhibit by samples except sample 1, show a higher shear strength and lower compressibility which indicates a good construction and foundation material. The CBR of soaked samples are relatively low due to swelling potential. It can also be affirmed that all the samples are very good subgrade materials.

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