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Assessment of the Geotechnical Properties of Lateritic Soil in Some Selected Areas at Owode-Ede in Osun State

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ABSTRACT

This paper assesses the geotechnical properties of selected lateritic soil in Owode-Ede area of Osun State, Nigeria. Three specific locations were considered in the study: Zone 11, Palm Crest Hotel, and Off Olanrewaju. Three samples, labeled as A, B, and C, were collected from each location. Laboratory tests were conducted on the soil samples, including moisture content, Specific gravity, Atterberg limit (liquid limit test, plastic limit test), compaction, California bearing ratio (CBR). The results revealed that the moisture content of the samples obtained from Palm Crest and Off Olanrewaju locations increased with distance, while the opposite was observed for Zone 11. Among the three locations, Off Olanrewaju recorded the highest specific gravity value. The liquid limit values for Zone 11, Palm Crest, and Off Olanrewaju exceeded the 35% limit recommendation of the Federal Ministry of Works and Housing (FMWH). Additionally, the CBR values for these locations were lower than 80% recommended for base course by the FMWH. Lateritic soil from all three locations could be suitable for use in constructing roads with light traffic when stabilized with conventional additives such as cement and lime.

Keywords: Atterberg limits, California bearing ratio, Compaction, Lateritic soil.

1. INTRODUCTION

Lateritic soils are prevalent in many countries as they constitute a common soil type found in various regions. These soils have been extensively utilized in construction, including roads, houses, airfield pavements, and as landfill material for foundations (Bello *et al.*, 2015). Insufficient understanding of soil behaviour can lead to challenges in addressing environmental issues, resulting in significant destruction to engineering applications, particularly in highway pavement construction (Amadi, 2008; Sani *et al.*, 2020). In the construction of highway pavements, it is crucial to carefully consider the foundation layer, known as the subgrade, to accommodate wheel loads. The performance of the pavement depends significantly on this foundation layer, which serves as support for other pavement systems. However, an unsupported subgrade under heavy loading is considered problematic, especially in clay soil that tends to swell upon interaction with water. The primary cause of road accidents has been attributed to poor road conditions, often arising from the improper use of construction materials (Oke *et al*., 2009; Idris *et al.*, 2019).

One of the significant challenges encountered in the engineering profession in Nigeria is the lack of comprehensive, relevant data for preliminary planning, design, and construction, particularly in road pavement projects. In the design and construction processes, a thorough understanding of the bearing capacity of natural soil and other soil parameters that significantly influence the performance of engineering structures needs to be known (Bello and Adegoke, 2010; Ishola *et al.*, 2019). Therefore, the stability and durability of an engineering structure largely depend on the foundation soil. Assessing geotechnical characteristics can be complex, especially due to environmental and soil conditions where certain non-load-related design parameters are overlooked.

In contemporary engineering construction projects, particularly in certain regions of Nigeria, there is a disregard for the behaviour and characteristics of soil tests. This negligence has resulted in the collapse of large structures and significant loss of lives and properties. To prevent such occurrences, it is essential to conduct geotechnical investigations and strength tests on lateritic soils before using them in engineering construction works. Research on the geotechnical and engineering properties of lateritic soils has been conducted in various parts of Nigeria (Agbede and Osuolale, 2005; Bello and Adegoke, 2010). However, reports on the characteristics of lateritic soil in the study area are limited. Therefore, this study aims to investigate the suitability of lateritic soil obtained from three locations: Zone 11, Palm Crest Hotel and Off Olarewaju at Agil Filling Station, all in Owode -Ede, Osun State. This study determines the index properties of the lateritic soil collected from the three locations. Moisture-density relationships and the strength properties of the obtained soil samples through different compactive efforts (namely, British Standard Light) were established. Laboratory test outcomes of the lateritic soil samples were compared with the specifications outlined by the Federal Ministry of Works and Housing (1997).

2. METHODOLOGY

This section provides an analysis of the lateritic soil collected from selected locations in the Owode-Ede area of Osun State. The locations under consideration include Zone 11 (7^0, 44.4712' N, 4^0, 30.546899' E), Palm Crest Hotel (7^0, 43.49907' N, 4^0, 30.27637' E), and Off Olarewaju at Agil Filling Station (7^0, 42.71580' N, 4^0, 29.24880' E). Soil samples were collected at 5-meter intervals from each location, resulting in a total of nine (9) samples. These samples were then taken to the Civil Engineering Laboratory of Osun State University, Osogbo for analysis. The results obtained from the samples were compared with the Federal Ministry of Works and Housing (1997) standard. All tests were conducted in accordance with the procedures outlined in British Standard 1377 (1990).

2.1 Natural Moisture Content

The soil's moisture content was assessed following BS 1377 (1990) Part 2; Test 1(A). Initially, a clean container was weighed and the weight recorded. Subsequently, the sample was placed into the container, and the combined weight was recorded. The container, along with the sample, was then dried in an oven at a temperature range of 105-110ºC for a period of 24 hours. After drying, the container with the sample was weighed again with the same precision. The moisture content was calculated using equation (1). The procedure was repeated three times, from which the average natural moisture content was determined.

$$W = \frac{m_2 - m_3}{m_3 - m_1} \times 100 \quad (1)$$

w = Moisture content in percentage
m_1= Mass of container, (g)
m_2= Mass of container + wet soil, (g)
m_3 = Mass of container + dried soil, (g)

2.2 Specific Gravity

The specific gravity of the soil was determined following BS 1377 (1990) Test (B) designed for fine-grained soils. Initially, the mass of the empty, dry density bottle was measured and recorded as m_1. Subsequently, the bottle was filled with 200 g of the soil sample, which had been air-dried beforehand. The mass of the bottle and the sample together was then measured and recorded as m_2. The bottle was gradually filled with water, and thorough shaking was done to remove any entrapped air in the mixture. The mass m_3 of the bottle, soil, and water was recorded. Finally, the bottle was emptied, washed, and filled to the brim with water, then weighed m_4. All measurements were taken to the nearest 0.01 g. This procedure was repeated for all the lateritic soil samples. The soil's specific gravity Gs was calculated using relationship in equation (2)

$$G_s = \frac{m_2 - m_3}{(m_4 - m_1) - (m_3 - m_1)} \times 100 \quad (2)$$

G_s = specific gravity
m_1= weight of density bottle (g)
m_2 = weight of density bottle + dry soil (g)
m_3 = weight of bottle + soil + water (g)
m_4 = weight of bottle and water (g)

2.3 Atterberg Test

The Atterberg limits test, also referred to as the plasticity test, comprises consistency assessments involving the determination of liquid limits, plastic limits, and plasticity. These tests were carried out following Test 1(A) of BS 1377 (1990) Part 2 for natural soil.

Liquid limit

The liquid limit signifies the minimum moisture content at which the soil begins to flow under its own weight. In this test, 200g of the sample material passing through a sieve with a 425 µm opening was positioned on a clean, flat glass plate. Water was gradually added and mixed with a spatula to create a uniform paste. A portion of the paste was then placed into the Casagrande apparatus, and the surface was leveled using a smooth chopping knife. A 2 mm grooving tool was used to create a groove along the diameter passing through the center of the hinge. The amount of blows needed for the base sections of the groove to come together was recorded while the crank was rotated to raise and lower the cup at a pace of two revolutions per second. The moisture content of a sample was ascertained. From drier to wetter phases, this procedure was repeated for varying degrees of moisture content. The liquid limit was found at the moisture content equivalent to 25 blows of the moisture contents plotted against the corresponding number of blows using semi-logarithmic graph. Every lateritic soil sample that was collected underwent this process again.

Plastic limit

When a lateritic soil particle is wrapped into a thread with a diameter of around 3 mm, the soil will begin to crumble at the minimal water content known as the plastic limit. A part of the dried natural soil that had been sieved with a 425 µm aperture was positioned on a plane glass and combined well enough to form a little ball. The ball was then rolled with the palm of the hand over the glass plate pending it had sufficiently dried. The sample was then separated into approximately four equal halves. After that, each component was made to roll in a thread with a diameter of about 3 mm, or until shearing caused the thread to break. The broken threads were quickly put in a weighing pan to find out how much moisture was in them. This procedure was repeated for all lateritic soil samples obtained.

Plasticity index

The Plasticity Indices of the obtained soil samples were calculated from the previously determined values of LL and PL and are determined using equation (3)

$$k_p = V_L - V_p \qquad (3)$$

Where
k_p = Plasticity Index
V_L = Liquid Limit
V_p= Plastic Limit

2.4 Compaction Test

Compaction tests on the soil samples were conducted following the guidelines outlined in BS 1377 (1990) Part 3, utilizing the British Standard Light (BSL) method. In this test, Maximum dry density and Optimum moisture content were obtained.

Maximum dry density and optimum moisture content

After compaction, the collar was removed, and a straight edge was employed to level the compacted sample at the top of the mold. The starting weight of the mould used in the procedure was then noted to the closest gram (W_1). Subsequently, the leveled sample-containing mould was weighed to the closest gram (W_2). Following the extraction of samples from the compacted soil, a minimum of four sets of samples were collected to determine the moisture content. Equations 4 and 5 were utilized to calculate the bulk density in Mg/m^3 and dry density, respectively, for each compacted layer. The optimum moisture content (OMC) is determined from the plot of dry density against moisture content, where the moisture content at maximum dry density (MDD) corresponds to the OMC.

$$\rho = \frac{W_2 - W_1}{V} \quad (4)$$

$$\rho_d = \frac{\rho}{1+W} \quad (5)$$

Where
ρ= bulk density of the soil (Mg/m^3)
W_1=mass of mould (g)
W_2= mass of mould + compacted soil (g)
V= volume of mould (m^3)
ρ_d= dry density of the soil (Mg/m^3)
ρ=bulk density of the soil (Mg/m^3)
W= moisture content (%).

2.5 California Bearing Ratio (CBR)

The California Bearing Ratio (CBR) test followed the guidelines outlined in BS 1377: Part 4 (1990). Initially, the soil sample underwent air-drying and thorough pulverization to pass through BS sieve No. 4 (4.76 mm). Subsequently, the specimen was compacted within a standard CBR mould featuring a nominal internal diameter of 152 mm±0.5 mm. This mould was equipped with a detachable base plate and a removable extension. The compaction process involved no delays and utilized a 4.5 kg rammer with a circular face diameter of 50mm, falling freely from a height of 450mm. Compaction occurred in three layers, each receiving 62 blows. Following compaction, excess soil projecting from the mould was meticulously trimmed with a straight edge. The sample was then sealed in a polythene bag for 24 hours to ensure moisture homogeneity and prevent moisture loss. Subsequently, the mould, with the base plate containing the sample, was centrally positioned on the lower platen of the testing machine, with the top face of the sample exposed. Annular surcharge discs were appropriately placed on top of the sample. The cylindrical plunger, featuring a nominal cross-section area of 1935 mm^2, along with the force-measuring device assembly, was fitted into place, with the plunger resting on the sample surface. A seating force, dependent on the expected CBR value, was applied to the plunger. The force measuring device was then reset to zero, and the penetration dial gauge was secured and reset to zero as well. The test proceeded as the plunger penetrated the sample, with force gauge readings recorded at 0.1mm penetration intervals, up to a total penetration not exceeding 7.5 mm. This penetration test was duplicated for both the top and bottom faces of the sample to determine the unsoaked CBR values.

3. RESULTS AND DISCUSSION

3.1 Moisture Content

The moisture content of lateritic soil samples from Palm Crest, Zone 11, and Off Olanrewaju, is presented in Table 1. At Zone 11, sample A exhibited the highest moisture content compared to the other two locations, while sample B had the second highest, and sample C had the lowest moisture content. Conversely, at Palm Crest, location C showed the highest moisture content, followed by location B and then location A. Similarly, at Off Olanrewaju, location A had the highest moisture content, followed by location C and then location B. The variation in moisture content may be attributed to differences in pore pressure within the soil.

Table 1: Moisture content of the sample location

Locations	Sample A (%)	Sample B (%)	Sample C (%)
ZONE 11	14.1	13.8	13.5
Palm Crest	10.9	11.2	12.5
Off Olanrewaju	12.5	11.80	12.1

3.2 Specific Gravity

Table 2 presents the specific gravity values of soil samples collected from various locations. At Zone 11, Sample A exhibits the highest specific gravity value of 2.65, followed by Sample B at 2.60, while Sample C records the lowest value of 2.50. At Palm Crest, Sample C demonstrates the highest specific gravity value of 2.53, followed by Sample A at 2.50, and then Sample B at 2.45. At Off Olanrewaju, Sample A shows the highest specific gravity value of 2.7, followed by Sample B at 2.6, and Sample C with the lowest specific gravity value of 2.55. It is noteworthy that a higher specific gravity indicates stronger soil strength.

Table 2: Specific gravity of the sample location

Locations	Sample A	Sample B	Sample C
ZONE 11	2.65	2.60	2.50
Palm Crest	2.50	2.45	2.53
Off Olanrewaju	2.7	2.6	2.55

3.3 Atterberg Limits

Table 3 displays the Atterberg limits, including the liquid limit, plastic limit, and plasticity index, of samples collected from the three locations. At Zone 11, Samples A, B, and C exhibit liquid limit values of 64%, 60%, and 62.4%, respectively, indicating that Sample A has the highest LL value among the three locations. At Palm Crest, Samples A, B, and C show liquid limit values of 44.2%, 43.5%, and 42.4%, respectively, with Sample A having the highest LL value among them. Conversely, Samples A, B, and C of Off Olanrewaju record LL values of 41.4%, 42.6%, and 43.2%, respectively. The liquid limit values obtained for all locations exceed the 35% requirement for road construction specified by Nigeria's general specifications.

The plasticity index of Zone 11, Palm Crest, and Off Olanrewaju is reported for Locations A, B, and C, respectively. At Zone 11, the PI values for the locations are 28.1%, 26.7%, and 28.5%, indicating that Location C has the highest PI value, followed by Location A and then Location B with the lowest PI value. At Palm Crest, the PI values are 27.3%, 21.6%, and 18.3% for Locations A, B, and C, respectively. Here, Location A has the highest PI value, followed by Location B, and then Location C with the lowest PI value. Conversely, at Off Olanrewaju, Location C has the lowest PI value of 17.5%, while Location A has the highest PI value (21.5%) and Location B records a PI value of 18.3%. The plasticity values recorded for all locations exceed the recommended 12% for road material.

Table 3: Atterberg of the sample location

Locations	Sample A (%)			Sample B (%)			Sample C (%)		
	LL	PL	PI	LL	PL	PI	LL	PL	PI
ZONE 11	64.0	35.9	28.1	60.0	33.3	26.7	62.4	33.9	28.5
Palm Crest	44.2	16.9	27.3	43.5	21.9	21.6	42.4	24.1	18.3
Off Olanrewaju	41.4	19.9	21.5	42.6	24.3	18.3	43.2	25.7	17.5

3.4 Compaction characteristic

The maximum dry density of samples from Palm Crest, Zone 11, and Off Olanrewaju is reported in Figure 4. For Zone 11, Location C has the highest value of 1.92 Mg/m³, followed by Location A with a value of 1.62 Mg/m³, and Location B with a value of 1.55 Mg/m³. At Palm Crest, the MDD values are 1.93 Mg/m³, 1.92 Mg/m³, and 2.01 Mg/m³ for Locations A, B, and C, respectively. Conversely, Off Olanrewaju has MDD values of 1.90 Mg/m³, 1.92 Mg/m³, and 2.02 Mg/m³ for Locations A, B, and C, respectively. The variation in MDD values can be attributed to differences in their specific gravity values. Details of the OMC are presented in Figure 5.

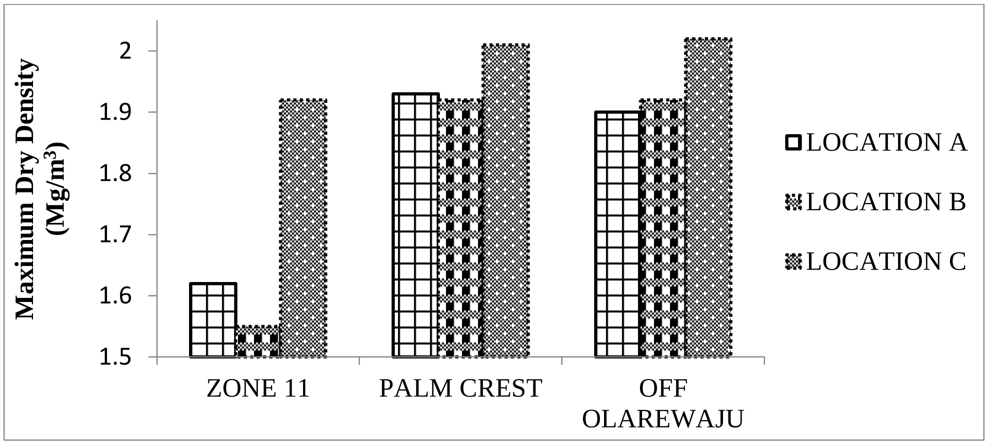

Figure 4: Maximum Dry Density of the location sample

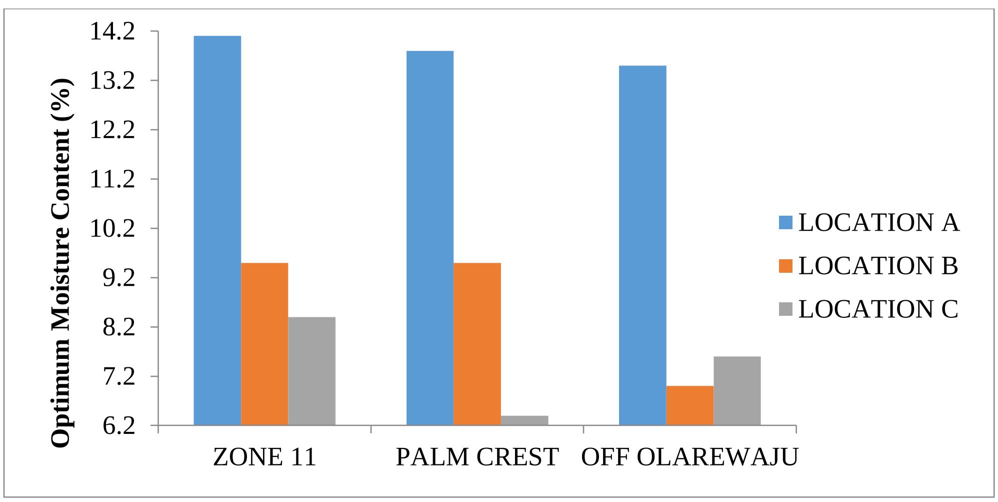

Figure 5: Optimum Moisture Content of the location sample

3.5 Unsoaked California Bearing Ratio

The unsoaked CBR results obtained from three different locations are presented in Table 5. At Zone 11, the CBR values were 13.5%, 13.9%, and 14.0% for Locations A, B, and C, respectively. At Palm Crest, the samples yielded values of 14.2%, 14.9%, and 15%. Similarly, Off Olanrewaju recorded CBR values of 14.9%, 15.2%, and 15.3% for Locations A, B, and C, respectively. All CBR values obtained from the locations were lower than the 80% requirement specified for base course material by the Federal Ministry of Works Standard.

Table 5: Unsoaked California Bearing Ratio of the Sample Location

Locations	Sample A (%)	Sample B (%)	Sample C (%)
ZONE 11	13.5	13.9	14.0
Palm Crest	14.2	14.9	15.0
Off Olanrewaju	14.9	15.2	15.3

4. CONCLUSION

Geotechnical properties and suitability of lateritic soils obtained along Zone 11, Palm Crest Hotel, and Off Olanrewaju were evaluated for use as a pavement construction materials in accordance with the provision outlined in British Standard. Based on the results obtained the following conclusions were drawn:

i. The moisture content increased with distance at Palm Crest and Off Olanrewaju locations, while the opposite trend was observed for Zone 11.
ii. Liquid limit values exceeded the 35% recommended by the Federal Ministry of Works and Housing for the Zone 11, Palm Crest, and Off Olanrewaju locations.
iii. The CBR (unsoaked) values obtained for Zone 11, Palm Crest Hotel, and Off Olanrewaju did not meet the requirement of 80% for the base course material stipulated by the Federal Ministry of Works Standard.
iv. To be utilized as a base material, lateritic soil samples from the three locations need stabilization to align with the specifications outlined by the Federal Ministry of Works.

REFERENCES

Abebawo, Z. (2005). Basic Engineering Properties of Lateritic Soils Found in Nejo – Mendi Road Construction Area. University Press, Welega.

Abubakar, J. B. (2006). Geotechnical Study of Lateritic Soil in Tipper Garage, Katampe Area, Abuja Federal Capital Territory. *Academic Research Sciences, Technology and Engineering*, 2(7):4-34.

Agbede, O. A. and Osuolale, O. M. (2005). Geotechnical Properties of Subgrade Soil in Oriire Local Government Area, Southwestern Nigeria. *Science Focus*, 10(2):137 – 141.

Alexander, L. T and Cady, F. G. (1962). Genesis and Hardening of Laterites in Soils. Techincal Bulletin 1282. US Department of Agriculture, Washington, D.C.

Amadi, A. N., Akande, W. G., Okunlola, I. A., Jimoh, M. O. and Francis, D. G. (2015). Assessment of the Geotechnical Properties of Lateritic Soils in Minna, North Central Nigeria for Road design and Construction. *American Journal of Mining and Metallurgy,* 3(1):15-20.

Bayewu, O. O. Olufemi, S. T. and Adewoye, A. O. (2013). Permeability Characteristic of Some Sub-Grade Soils Along Part of the Sagamu-Ore Highway, Southwestern, Nigeria. *Journal of Emerging Trends in Engineering and Applied Sciences*, 4(4): 581-587.

Bell, F. G. (1993). Engineering Geology. Blackwell Scientific Publication: London. UK.

Bello, A. A. and Adegoke, C. W. (2010). Evaluation of Geotechnical Properties of Ilesha East, Southwestern Nigeria's Lateritic Soil. *The Pacific Journal of Science and Technology*, 11(2): 617-624.

Bello, A. A., Ige, A. and Tajudeen, S. (2007). Geotechnical Characterization of Lateritic Soils in part of Ejigbo Local government Area, Southwestern Nigeria. *LAUTECH Journal of Engineering and Technology*, *4*(2), 34-38.

British Standard Institution, (1990). Methods of Testing Soils for civil Engineering Properties (BS 1377). British standard Institution: London, UK. 143.

British Standard Methods of Test for soils for Civil Engineering Purposes. B.S 1377: Part 2, 1990. Published by the British Standards Institution, pp 8 –200.

Buchanan, C. (1807). Laterite Bauxite. Elsevier Amsterdam, Oxford, New York

Das, B. M. (2002). Soil Mechanics Lab. Manual, Oxford University Press. New York.

Federal Ministry of works and Housing (1997). General Specifications for Roads and Bridges. Volume II. 145 – 284. Federal Highway Department: Lagos, Nigeria.

Gidigasu, M. D. (1976). Laterite Soil Engineering: Pedogenesis and Engineering Principle, Development in Geotechnical Engineering. Elsevier Scientific Publishing Co. 9, 259-272.

Hamitron, R. (1964). Microscopic Studies of Laterite Formation A. Jungerius (Editor). Elsevier. Amsterdam.

Holtz, R. D. and Kovacs, W. D. (1981). An introduction to Geotechnical Engineering Prentice Hall, Englewood Clifies, New Jersey.

Idris, A., Abdulfatah, A. Y., Ahmad, S. S. and Ahmad, S. S. (2019). Compaction Behaviour of Lateritic Soil Modified with Cement and Rice Husk Ash for Road Construction. *Nigerian Journal of Technology,* 38(3), 573-579. https://doi.org/10.4314/njt.v38i3.5

Ishola, K., Olawuyi, O. A., Bello, A. A. and Yohanna, P. (2019). Effect of Plantain Peel Ash on the Strength Properties of Tropical Red Soil. *Nigerian Research Journal of Engineering and Environmental Sciences,* 4(1):447-459

Manjriker G. (2007). The Foundation Engineering Handbook, Taylor & Francis Group press, 2nd Edition pp. 1 – 27

North Carolina Department of Transpiration (2005), Borrow Pit Sampling Manual, Dept. of transportation, Materials and Tests Unit – Soils Laboratory, pp 7 – 10.

Northmore, K. J., Culshaw M. G., Hobbs P. R. N., Hallam J. R. and Entwisle, D. C. (1992). Engineering Geology of Tropical Red Clay Soils. British geological survey, United Kingdom

Nwankwola, H. O. and Warmate T. (2014). Sub-surface Soil Characterisation of a Site for Infrastructural Development Purpose in D/line Port-Harcourt Nigeria. *American International Journal of Contemporary Research,* 4(6): 139-148.

O'Flaherty. A. M. (2002), Highway, 4th Edition, Oxford, Butterworth.

Oke, S. A. and Amadi, A. N., (2008). An Assessment of the Geotechnical Properties of the Subsoil of parts of Federal University of Technology, Minna, Gidan Kwano Campus, for Foundation Design and Construction. *Journal of Science, Education and Technology*, 1 (2):87-102.

Oke, S. A., Okeke, O. E., Amadi, A. N. and Onoduku, U. S., (2009). Geotechnical Properties of the Subsoil for Designing Shallow Foundation in Some Selected Parts of Chanchaga Area, Minna, Nigeria. *Journal of Environmental Science*, 1(1):45-54.

Ola, S. A. (1983). Geotechnical Properties of an Attapulgite Clay Shale in Northwestern Nigeria. *Engineering Geology*, 19: 1 – 13.

Oladeji, O. S. and Raheem, A. A. (2002). Soil Tests for Road Construction. *Journal of Science, Engineering and Technology* 9(2): 3971 – 3981.

Sani, J. E., Yohanna, P. and Chukwujama, I. A. (2020). Effect of Rice Husk Ash Admixed with Treated Sisal Fibre on Properties of Lateritic Soil as a Road Construction Material. *Journal of King Saud University - Engineering Sciences*, 32(1):11–18. https://doi.org/10.1016/j.jksues.2018.11.001

Sergeya, Y. M., Grebowsaka–Oleszawka, B., Osipov, V. I. and Sokotov, V. N. (1978). Types of Microstructure of Clayey Soils. *Proceedings of the III International Congress IAEG.* U.S. Department of Agriculture, Washington, D.C.

Sivakugan, N. (2000). Soil Classification, James Cook, University, Geo-engineering Lecture handout.

Tuncer, E. R. and Lohnes, R. A. (1977). An Engineering Classification for Certain Basalt Derived Lateritic Solis. *Engineering Geology,* 11: 319 – 339.