Geotechnical and Suitability Studies for Subgrade and Sub – Base Construction Materials Around Baba – Ode and Obada Areas Southwestern Nigeria.

IHEME, Kenneth. Obinna.[1], OBARO, Ruben Ibukun.[2], OKOLO, Chukwugozie John[1], IBRAHIM, Oluwatoyin Khadijat[1] , Yusuf, Mumeen Adebayo[1]

1. Department of Geology and Mineral Sciences University of Ilorin, Kwara State
2. Department Of Minerals and Petroleum Resources Engineering Technology, Kwara State Polytechnic, Kwara State

Corresponding author: iheme.ko@unilorin.edu.ng

Abstract
Lateritic soils from Baba – Ode, in Ilorin, Kwara State and Obada in Oyo State, Southwestern Nigeria were investigated with respect to their geotechnical properties and their suitability for subgrade and sub – base construction materials. Four disturbed lateritic soil samples A and B (Baba – ode in Ilorin) and samples C and D (Obada in Oyo state) were selected for grain size analyses, specific gravity tests, atterberg limit tests, compaction, California bearing ratio and shear box tests. Atterberg consistency limit test show that samples from Baba-ode has liquid limit ranges of 27.0 - 30.0%, plastic limit 16.2 - 19.5%, plasticity index 10.5 - 10.8%, shrinkage limit 7.4 - 9.1% while those from Obada has liquid limit ranges of 22.5 - 31.0%, plastic limit of 13.3 - 21.5%, shrinkage limit of 5.5 - 7.4% and plasticity index of 9.2 - 9.5%. They have California Bearing Ratio (CBR) values within 2-3% (mean = 2.75%) and 2% (mean = 2) in Baba-ode while Obada samples are 2-4% (mean = 2.75%) and 1-3% (mean = 1.5%) respectively. Optimum water contents for Baba-ode samples are 15.0% and 13.0 - 14% for standard and modified proctor respectively while those of Obada are 11.0 -15.0% for standard proctor and 10.0 - 14.0% for modified proctor. The cohesion of Baba-ode samples are within 70-90Kpa with mean of 79Kpa and angle of internal friction (ϕ) ranging from 26^0 - 32^0 with mean of 28^0 for standard and modified compaction energies respectively while Obada samples fall within 30- 40Kpa with mean of 35Kpa and the angle of internal friction ranges from 22^o – 28^0. Geotechnical analysis suggest that the soils are good to fair as erosion resistance in canal construction because of its high bearing capacity and can also be used as sub – grade and base course in road construction.

Keywords: Lateritic soil, Construction, Erosional and Geotechnical

1.0. Introduction

Lateritic soils are highly weathered and altered residual soils formed by the in-situ weathering and decomposition of parent rocks under tropical and subtropical climatic conditions. This weathering process primarily involves the continuous chemical alteration of minerals, the release of iron and aluminum oxides, and the removal of bases and silica in the rocks.

According to Rhardjo, *et al*., (2004). Laterite is described as a product of in-situ weathering in igneous, sedimentary, and metamorphic rocks commonly found under unsaturated conditions.

Laterites contribute to the general economy of the tropical and subtropical regions where they are widely utilized in civil engineering works as construction materials. Latertic soil as a road construction material, form the sub-grade of most tropical roads and can also be used as sub base courses for minor roads of unsuitable soil type. Major road failures in most places are attributed to bad construction materials (Adams and Adetoro, 2014).

The state and standard of roads network of a region and a country as a whole play a prominent role in the socioeconomic development of the area. Adequate information on the geotechnical properties of laterite such as strength, grain size distribution, consistency limit, compaction properties, bearing ratio and the shear strength are important in order to make a convenient choice for this basic material as regard the strength and durability of roads depend on these information (Younoussa *et al.,* 2008). The study aims at evaluating the quality of the laterites in both Baba-ode in Ilorin and Obada in Oyo state to determine their applications for industrial purpose and also derive a comparison of both areas.

2.0. Location and Geology of the Study Area

The study areas fall within the Southwestern Nigeria (Fig. 1). Baba-ode area is underlain by granite, granite gneiss and migmatite gneiss. The rocks in this area show contact relationship with one another with the granite rocks intruding the country rocks. The granite rocks comprise of porprytic granites and fine to medium grained granites. The granite gneisses show light and dark band s with respect to their mineralogical composition while the migmatite-gneisses are foliated and have various folds and veins. The mineralogical composition of these rocks comprises plagioclase, quartz, biotite and muscovite. Obada area is underlain by granite gneiss, banded gneiss and migmatite. The granite gneisses are weakly foliated and occur as low lying outcrops. The banded gneisses show bands of dark and light minerals while the migmatites show various metamorphic segregations and is well foliated. Both areas fall within the Precambrian basement complex of Nigeria and visible lateritic soil outcrops were seen in the both areas where the samples were taken. The sampling area in Baba–ode in Ilorin lies between latitude $8^0\ 26^I\ 00^{II}$ - $8^0\ 27^I\ 00^{II}$ N and longitude $4^0\ 33^I\ 00^{II}$ - $4^0\ 33^I\ 54^{II}$ E while the sampling area at Obada in Oyo is of latitude 7° $54^I\ 00^{II}$ - 7° $55^I\ 00^{II}$ N and Longitudes 3° $58^I\ 00^{II}$ - 3° $59^I\ 00^{II}$ E (Fig.1).

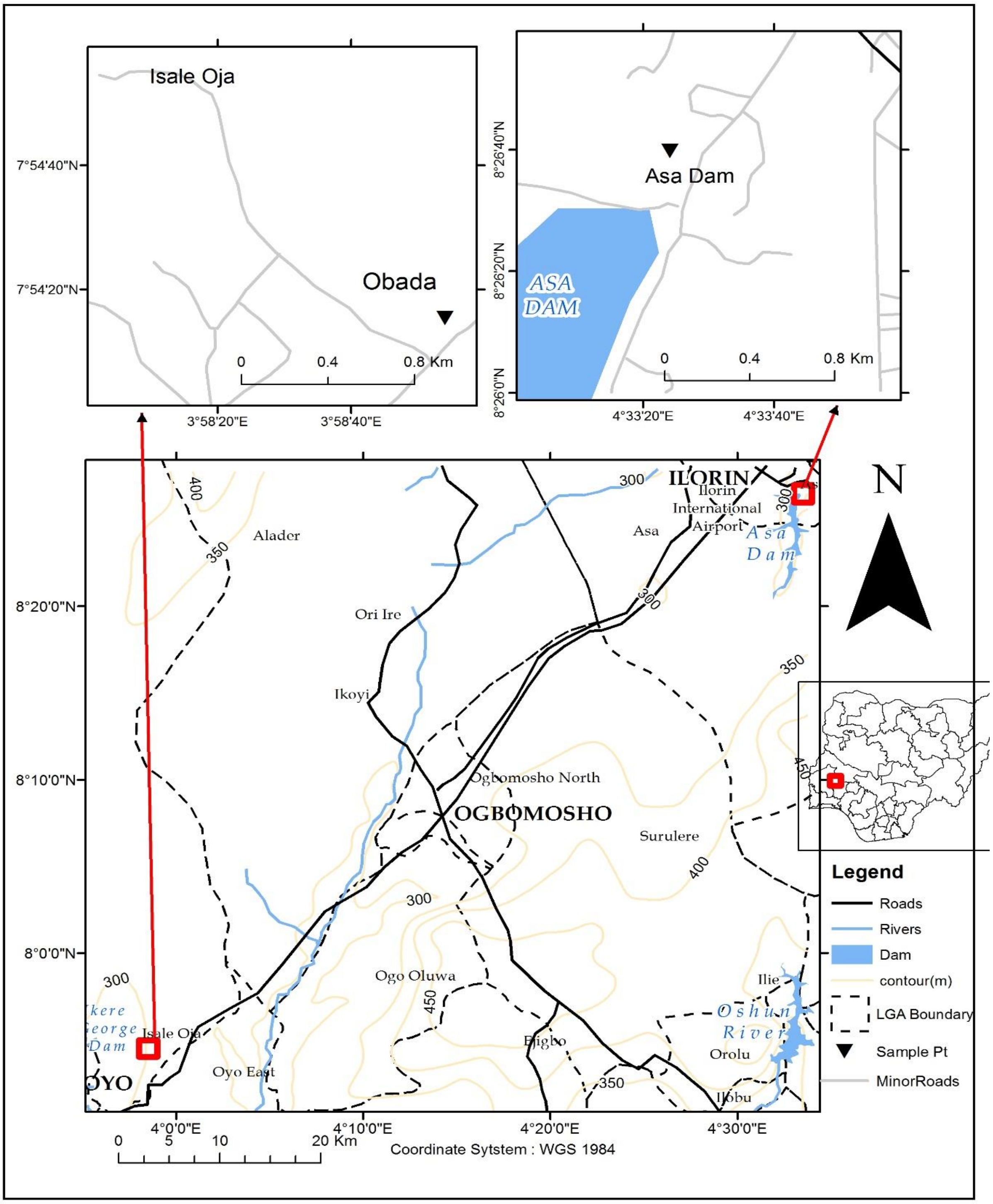

Fig.1: Map showing the areas of study

3.0. MATERIALS AND METHODS

The research work was carried out in two different locations and two major stages. These locations are Baba –ode, Kwara State and Obada, Oyo State. The stages are: Field investigation and laboratory analyses. Field investigation includes sample collection, description and preparation. Bulk samples were collected at the depth of 1 to 3m respectively with aid of digger, hand shovel, head pan and four sacks of bags labelled Sample A, B, C and D from two (2) different trials pits in Baba – ode in Kwara State and Obada in Oyo State. The four samples were air dried differently for three weeks at room temperature before laboratory analyses commenced. The main laboratory tests carried out on different samples were Specific gravity, Grain size distribution which was performed using the coarse sieve and fine sieve methods to determine the percentage distribution of various particle sizes, Atterberg limits, Linear shrinkage, Compaction test which was carried out using standard and modified proctor methods, California bearing ratio and Shear box tests.

4.0. Result and Disscussion

Specific Gravity

The specific gravity is assessing the maturity of lateritic soil and an indication of degree of laterization (Ackroyd, 1963). The higher the specific gravity of a soil, the higher its degree of laterization and the stronger its engineering performances. The specific gravity of 2.73 was obtained for sample A, 2.66 for sample B (Baba-ode) while 2.76 for sample C and 2.65 for sample D (Obada). Comparing these values with typical values for specific gravity (Gs) for some soil types after Lambe and Whiteman, 1969; Bowles, 2012, it is evident that Baba-ode samples are inorganic clay (sample A) and organic clay (sample B) while Obada samples are inorganic clay (sample C) and sandy (sample D).

Textural Analysis

This basically describes the relative abundance of the different grain sizes upon which the physical and engineering attributes of lateritic soils depends. This distribution however influences the capability of soil in engineering construction works. The grain size distribution analysis for Baba-ode samples show that sample A consists of gravelly silt-clayey sand with 32% silt, 32% clay, 51% sand and 17% gravel constituents while sample B could be described as silt-clayey very gravel with 25% silt, 25% clay, 61% sand, and 25% gravel composition. This denotes that both soils can be classified as sandy clay. However, Obada samples can be classified as sandy gravel with percentage gravel of 40%, followed by 32% sand, 20% clay and silt making up 8% for sample C while sample D has high dominance of sand of about 61%, clay 18%, silt 12% and gravel 9%. This can be classified as clayey sand. This shows that the two areas have varied textural characteristics.

Atterberg consistency limit.

According to Ige (2010) the plasticity index of lateritic soil is a crucial index in determining the geotechnical properties of such soil. The atterberg consistency limit test shows that the soil from Baba-ode has liquid limit of 30.0%, plastic limit of 19.5% and linear shrinkage of 9.1% for sample A. It also has a plasticity index of 10.5%, flow index of 20% and toughness index of 0.5%. Sample B has a liquid limit of 27.0% plastic limit of 16.2%, shrinkage limit of 7.4% and plasticity index of 10.8%. The results obtained for sample from Obada show a liquid limit of 31.0%, plastic limit of 21.5%, shrinkage limit of 7.4% and plasticity index of 9.5% for sample C while sample D also has liquid limit of 22.5%, plastic limit of 13.3%, shrinkage limit of 5.5% and plasticity Index of 9.2%.

According to Madedor (1983) as noted in Adewoye *et al.* (2004), shrinkage limit is a parameter that governs the selection of a soil as a good highway subgrade or subbase materials. All the shrinkage limits exhibited by the soil samples A – D suggests that they have very little potential to swell or shrink and they are therefore expected to show minimum shrinkage when dry, thus lowering the risk of the soil failure when used as sub-grade materials in construction. It is important to note that all the soil samples A - D plots are in CL group on the plasticity chart in Fig. 2, from the engineering use chart, this indicates low plasticity. The workability of samples from both area as a construction material is good to fair according to the chart.

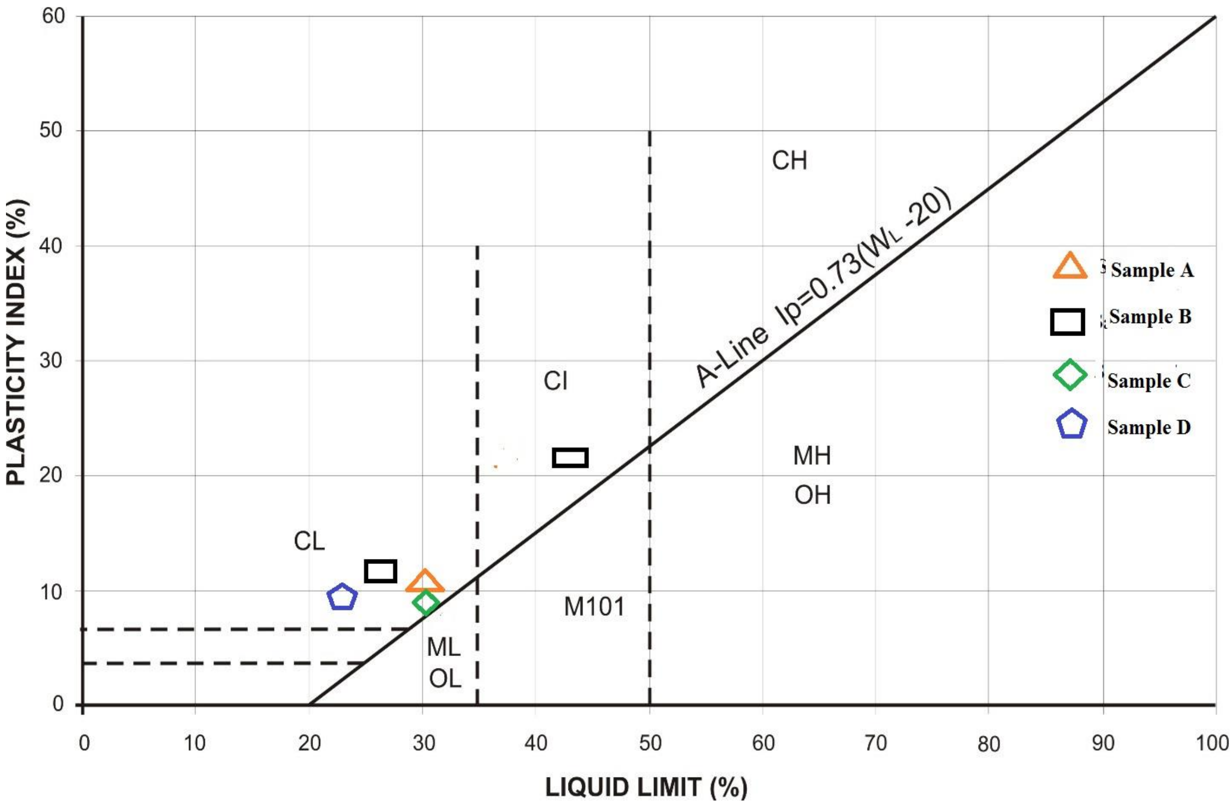

Fig. 2: Casagrande Chart Classification of Studied Lateritic Soil Samples

Compaction tests

The results for the standard proctor and modified proctor test for compaction curves in fig 2 and 3 shows that the dry density increases with increasing moisture content up to the maximum and then decreases. The maximum dry density (MDD) obtained for Baba-ode sample A is 1.80g/cm^3 at standard proctor and 1.90g/cm^3 for modified proctor and Sample B has maximum dry density of 1.7g/cm^3 at standard proctor and 1.78g/cm^2 for modified proctor. The standard proctor for Obada sample C has maximum dry density (MDD) of 1.83 g/cm^3 and 1.88 g/cm^3 for modified proctor while sample D maximum dry density (MDD) is 1.72g/cm^3 for standard proctor and the modified proctor is 1.80 g/cm^3(Fig. 3). This falls within the observed range of 1.3 -2.4g/cm^3 observed by Gidigasu (1972), Madu (1975) and Ogunsawo (1989). There is a minor reduction of maximum dry density down the profile in the study. The optimum water content for Baba-ode sample A is 15.0% at standard proctor and 13.0% at modified proctor and for sample B, the optimum moisture content is 15.2% at standard proctor and 14.0% at modified proctor. Obada Sample C has standard proctor of 11.0% and modified proctor of 10.0% optimum moisture content while the optimum moisture content for sample D is 15.0 % standard proctor and 14.0% for modified proctor. The optimum moisture content is a guide to know the quantity of water to add during construction. The sample with higher fine fraction has higher optimum moisture content while the sample with lower fine fraction or higher coarse fraction has the lower optimum moisture content. This implies that Baba-ode sample A, B and Obada sample D has higher fine fraction and thus, has higher optimum moisture content. This show that samples from both areas can be used as fills and base course in road and liner in landfill.

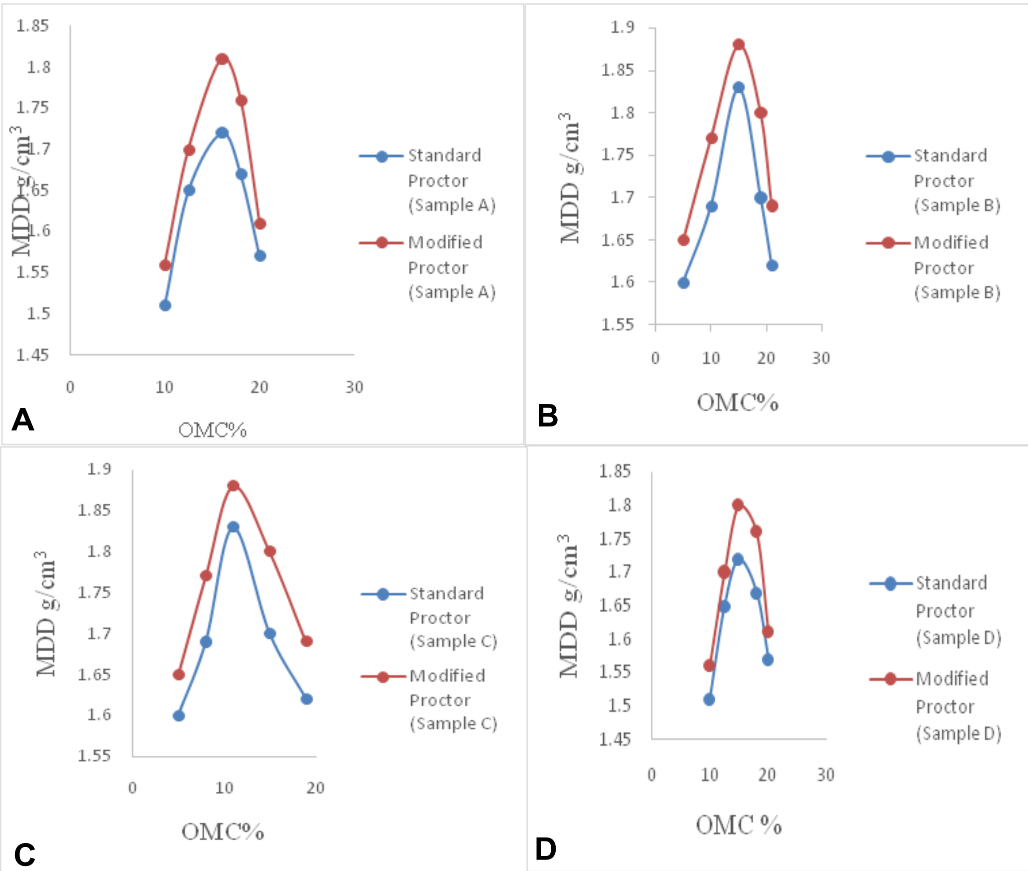

Fig 3: Compaction curve of soil sample standard and modified proctor

California Bearing Ratio (CBR)

The California bearing ratio gives an estimation of the bearing capacity of soils for highway subgrade and sub base uses (Simon *et al.*, 1973; Gidigasu, 1980). Also, Adeyemi (2003) opined that CBR is enhanced by increasing degree of laterization. The CBR values of the samples are stated in Table 1. It shows the general rating of soil materials based on the CBR values of the materials and for use as a sub-grade to base course material for support of flexible pavements. Standard proctor unsoaked and soaked for Baba-ode sample A has 3% and 2% CBR values respectively and sample B also has 2% CBR values for both unsoaked and soaked respectively. The standard proctor of Obada sample C has 4% and 2% values for unsoaked and soaked while the standard proctor for Obada sample D is 3% CBR and 2% CBR values for unsoaked and soaked. Similarly, the modified proctor unsoaked and soaked of Baba-ode sample A has 3% CBR respectively, and sample B has 4% CBR and 3% CBR values respectively while the modified proctor unsoaked and soaked for Obada sample C is 3% CBR values and 2% CBR values and the modified proctor for sample D is 2% CBR values for unsoaked and 1% CBR values for soaked. Based on the values obtained, they fall within CBR value range of 0-3% and 3-7% respectively (Bowles 1990).Consequently, the soils from both areas could be useful for slope stability and as sub-grade materials for road construction.

Table 1. Compaction tests for samples from Baba-ode and Obada

Sample Number		Standard Proctor (%)		Modified Proctor (%)	
		Unsoaked (%)	Soaked (%)	Unsoaked (%)	Soaked (%)
Baba-ode	A	3	2	3	3
	B	2	2	4	3
Obada	C	4	2	3	2
	D	3	2	2	1

Table 2. General Rating of Soil Materials Using CBR Values (After Bowles, 1990)

CBR Value	General	Uses	Classification System
0-3	Very Poor	Sub-grade	OH,CH,MH,OL
3-7	Poor fair	Sub-grade	OH,CH,MH,OL
7-20	Fair	Sub-grade	OL,CL,ML,SC
20-50	Good	Base, Sub-grade	GM,GC,SW,SM,SP,GP
50	Excellent	Base	Gw, GM

Direct Shear Tests

The Shear Strength of a soil describes the maximum internal resistance of a soil to the movement of its particles. It is used to determine the angle of internal friction of soil and the effectiveness of pressure. The shear tests for Baba-ode samples reveals sample A compacted at standard proctor to have cohesion value of 70Kpa and angle of internal friction of 28^0 while modified proctor compacted soil sample A gave cohesion (C) of 90Kpa and has internal friction of 25^0 while Sample B compacted at standard proctor has a cohesion of internal friction of 90Kpa and 31^0 respectively. The modified proctor gave a cohesion (C) and internal friction (ϕ) of 70Kpa and 30^0 respectively. Obada samples C compacted at standard proctor has a cohesion (C) of 40kPa and angle of internal friction of 25° while the modified proctor gave a cohesion

(C) of 30KPa and internal friction (ϕ) of 30° while sample D also gave a cohesion (C) of 30KPa and angle of internal friction of 22° for standard proctor while the cohesion (C) for modified proctor is 40Kpa and the angle of internal friction is 28°. Hence, the shear box test revealed that the soil from both areas has medium bearing capacity having values ranging from 30Kpa to 90Kpa with average of 58Kpa. Similarly, the angle of internal friction ranges from 25^0 to $31^0$with average of 27^0. The tests suggest that the soil is made up of sands and clays. Therefore, Baba-ode samples A and B are good as engineering construction (foundation) materials, support slope stability and also both samples can be used moderately in steep embankment. However, Obada samples C and D revealed that the soil has low to medium bearing capacity which can only be used for support of moderate steep slope to a greater height (Omotoso *et al.*, 2011)

5.0. Conclusion

The tests carried out in this research work were mainly concerned with using basic geotechnical properties of soil with regards to their uses as construction materials. The grain size analyses show that all the samples are clayey sand with silt.

The atterbergs consistency limit for samples A, B, C and D all from Baba-ode and Obada falls on CL- group and indicates that all the samples are clayey sand of low plasticity which are good to fair.

In compaction tests, the maximum dry densities obtained for all the samples indicates that the soils are suitable as base course in road construction materials.

The CBR numbers obtained from the research work indicate that the soil could be useful for slope stability and as sub-grade materials for road construction.

The shear strength suggests that Baba-ode samples A and B are good as engineering construction (foundation) materials, support slope stability and also both samples can be used moderately in steep embankment. However, Obada samples C and D has low to medium bearing capacity which can only be used for filling materials.

References

Ackroyd, L. W. (1963). The Correlation Between Engineering and Pedological Classification System in Western Nigeria and Its Implication. *Reg. Conf. African Soil and Foundation Engineering, 3rd Ed.,* Salisbury, Rhodesia, Vol.1, pp. 115 - 118.

Adams, J. O. and Adetoro, A. E. (2014). Analysis of Road, Pavement Failure Caused by Soil Propertiesalong Ado - Ekiti - Akure Road, Nigeria. *International Journal of Novel Research inEngineering and Applied Sciences*(Ijnreas).;1(1).

Adewoye, A.O. and Adeyemi, G.O. (2004). Geotechnical Properties of Solls Along the Lagos-IbadanExpressway, Nigeria, USEP: Journal of Research in Civil Engineering, Vol. Journal,No.1.

Adewoye, A.O., Adegbola, A.A., Boloji. A.A., and Opebiyi, D.F. 2004. "Engineering Properties Foundational Materials of Oyo – Ogbomoso Road in Southwestern Nigeria". *Science Focus*. 9:42 – 47.

Adeyemi, G. O. (2003). The Influence of Topography on Some Engineering and Geological Characteristics of Two Sand Stone Derived Lateritic Soils from Ishara, South-western, Nigeria. *Journal of Applied Science and Technology,* Vol.3, No 1, pp. 1- 6.

Bowles, J. E. (1990). Physical and Geotechnical Properties of Soil (2nd ed) Mc Graw-hill, Inc. 478p

Bowles, J.E. (2012). Engineering Properties of Soils and their Measurements, 4th edition, McGraw Hill Education (India) Private Limited, New Delhi.

Casagrande. A., (1948). Classification and Identification of Soils. TransactionASCE, Vol. 113, New Yolk.

Gidigasu, M. D. (1972). Mode of Formation and Geotechnical Characteristics of Laterite Materials of Ghana in Relation to Soil Forming Factors. *Engineering Geology, 6,* 79-150. http://dx.doi.org/10.1016/0013-7952(72)90034-8

Gidigasu, M. D. (1980). Geotechnical Evaluation of Residual Gravels in Pavement Construction. *Eng. Geol*.,15, pp. 173-192

Ige O.O. (2010). Assessment of Geotechnical Properties of Migmatite-Gneiss Derived Residual Soil from Ilorin, Southwestern Nigeria, as Barrier in Sanitary landfills. *Continental J. Earth Sciences 5 (1),* pp. 32 – 41.

Lambe, T.N. and Whiteman, R.V. (1969). Soil Mechanics, John Wiley, New York. 553p.

Madedor, A. C. (1983). Pavement Design Guidelines and Practice for Different Geological Areas in Nigeria. In: Ola, S. A. (ed) Tropical Soils of Nigeria in Engineering Practices. AA Balkema, Rotterdam, pp. 291 – 297.

Madu, R. M. (1975). Some Nigerian Residual Lateritic Soil, their Characteristic and Relative Road Building Properties on Group Basis. *Proceedings of 6th Regional Conference for Africa Soil Mechanics and Foundation Engineering Durban, South Africa. International Society for Soil Mechanics and Foundation Engineering*. 1, 121-129.

Olusiji, S. A. (2013). Geology and Structure of the Precambrian Rocks in Iworoko Are and Afao Area, Southwestern, Nigeria. International Research Journal of Natural Sciences Vol.1, No. 1, March, pp.14-29

Ogunsanwo, O. (1989). Some Geotechnical Properties of Two Lateritic Soil Compacted at different *Energies Engineering Geology*, 26, 261-269. http://dx.doi.org/10.1016/0013-7952(89)90013-6

Omotoso, O. A., Mamodu, M. O. and Ojo, O. J. (2011).Evaluation of Geotechnical Properties of Laterite Soils inn Asa – Dam Area, Ilorin, Southwestern, Nigeria. *World Journal of Applied Science and Technology Vol.3. No. 2. Pp. 1 – 9.*

Rahaman, M. A. (1988). Recent advances in the study of the basement complex of Nigeria. In: Geological Survey of Nigeria (Ed) Precambrian Geol. Nigeria, 11–43.

Rhardjo, H., Aung, K.K., Leong, E.C., and Rezam, R.B.(2004). Characteristics of Residual Soils in Singapore as Formed byWeathering. Journal of Engineering Geology, 73:157-169.

Simeon, A.B., Gieseve, J. and Bidlo, G. (1973). Use of Laterite Soils for Road Construction in Northern Dahomey. *Engineering Geology, Amsterdam,* 7: 197-218

Younoussa, M., Karfa, T., Raguilnaba, O., Kalsibiri, K., Philippe, B and Jean, H. (2008). Geotechnical, Mechanical, Chemical and Mineralogical Characterization of a Lateritic Gravels of Sapouy (Burkina Faso) used in road construction. Construction and Building Materials (Elsevier). pp. 70 – 76.